Pizzas: π or Square? Psychophysical Biases in Area Comparisons

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Abstract

Many product categories, from pizzas to real estate, present buyers with purchase decisions involving complex area judgments. Does a square look larger or smaller than a circle? How much smaller does a circle of 8-inch diameter look when compared to one with a 10-inch diameter? In this paper, we propose a psychophysical model of how consumers make area comparison judgments. The model involves consumers making effort-accuracy trade-offs that lead to heuristic processing of area judgments and systematic shape- and size-related biases.

The model is based on four propositions: P1. Consumers make an initial comparison between two figures based on a single dimension; P2. The dimension of initial comparison—the primary dimension—is the one that is most salient to consumers, where salience is figure and context dependent; P3. Consumers insufficiently adjust an initial comparison using a secondary dimension, which we assume to be orthogonal to the primary dimension used for the initial comparison; and P4. The magnitude by which the initial comparison is adjusted is directly related to the relative salience of the secondary dimension versus the primary dimension.

The model predicts that a single linear dimension inappropriately dominates the two-dimensional area comparison task and that contextual factors affect which linear dimension dominates the task. The relative use of the second dimension depends on its relative salience, which can be influenced in a variety of ways. The model extends the area estimation literature in cognitive psychology by exploring new biases in area estimation and is able to resolve controversial effects regarding which shape is perceived to be ''bigger,'' the square or the circle, by incorporating contextual factors into model specifications.

A set of six studies—five laboratory experiments and one field experiment—systematically test model predictions. Study 1 is a process study that shows that when two dimensions are available to make an area comparison judgment, people choose one of those to be the primary dimension, with the other being the secondary dimension. Furthermore, it shows that the choice of the primary dimension is dependent on its relative salience that can be contextually manipulated via manner of visual presentation.

Studies 2 and 3 show how the use of a diagonal versus the side of a square (contextually determined) can affect whether a square is perceived to be smaller or larger than a circle of the same area. Study 3 extends the investigation to the domain of the price people are willing to pay for ''pizzas'' of different shapes, presented differently.

Study 4, a field study, demonstrates external validity by showing that purchase quantities are greater when a circular package is expected to contain less than a rectangular package of the same volume in a domain where consumption goal is constant (cream cheese with a bagel).

Studies 5 and 6 examine ways in which one can increase the salience of the secondary dimension, in a size estimation task, i.e., judging the rate of increase of area. While Study 5 does so via contextual visual cues (incorporating lines that draw one's attention to the underused dimension), Study 6 does the same using semantic cues that direct attention to a single dimension (e.g., diameter) or the total area and comparing these with a visual presentation of the figure.

Overall, results suggest that the manner in which information is presented affects the relative salience of dimensions used to judge areas, and can influence the price consumers are willing to pay. Underlining the external validity of these findings, container shape can significantly affect quantity purchased and overall sales. The paper highlights biases in area comparison judgments as a function of area shape and size. The model is parsimonious, demonstrates good predictive ability, and explains seemingly contradictory results in the cognitive psychology literature. Implications for pricing, product design, packaging, and retailing are suggested.

(*Consumer Behavior; Experiments; Judgment Biases; Package Design; Information Processing*)

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1. Introduction

Consumers make area comparison judgments as part of the purchase decision process: which product to buy, which size pizza to order, or how much to pay for it. There are a number of unanswered questions regarding consumers' area comparison judgments of potential interest to managers. How accurate are these judgments? Does the *shape* of a product or its package affect estimates, e.g., are some shapes perceived to be systematically ''bigger'' than other shapes? Is perceived amount directly related to actual amount irrespective of actual *size,* or are larger package sizes systematically underestimated? Do contextual factors moderate the direction or intensity of these shape- or size-related biases? These questions have important marketing implications for packaging, pricing, and consumer welfare. For example, do consumers' size estimates have consequences for managerially relevant variables including purchase likelihood, purchase quantity, and purchase price? If manufacturers do charge a higher price for the same amount of the product, can consumer education assist in overcoming size and shape estimation biases? This paper is a start in answering some of these questions.

This paper introduces area judgments as a field of study to marketers. We draw on more than a century of research in cognitive psychology, apply it to a consumer domain, and in the process add to the literature on spatial perceptions. Marketers would be specifically interested in the implications of these biases. For example, do consumers' size estimates translate into purchase likelihood with package shapes that seem larger more likely to be purchased? Do they affect purchase quantity? If consumers want an ''ideal'' (or fixed) level of consumption, then consumers should use/purchase a smaller quantity of package shapes that seem larger (e.g., sugar sachets or cream with tea or coffee, or cream cheese with bagels). However, on the other hand, holding price constant, if consumers derive greater utility from greater consumption, then they should purchase a higher quantity for package shapes that seem larger. Understanding how consumers make size judgments is, therefore, key in identifying and exploring the implications of package shape on purchase likelihood and purchase quantity.

Furthermore, marketers are also interested in the maximum price consumers are willing to pay—both for an individual item and for a range of products available in different sizes. Pricing a product line of different sized items is a common managerial task involving an appreciation of the volume discount acceptable to consumers. To the extent consumers underestimate larger sizes of a package, the apparent volume discount required by consumers may be an over statement of what they require (e.g., people may be willing to pay more for a ''large'' pizza, albeit not twice as much, if they appreciate that it is twice the size of a small pizza compared to when they believe it is less than double).

We propose a psychophysical model of how consumers compare areas. The model makes predictions regarding the extent to which the shape and size of a product affect consumers' judgments when comparing areas. The model postulates over reliance on the more salient of two dimensions in a two-dimension judgment, which leads to predictable biases in area comparisons, and predicts how contextual factors affect which linear dimension is overutilized. The model derives from the cognitive process by which consumers perceive and integrate two-dimensional visual information. Our research extends the area estimation literature by providing a single model that parsimoniously explains a number of previously unintegrated effects noted by cognitive psychologists over the last century. The model is also able to resolve a controversy as to which shape is perceived to be ''bigger'': the square or the circle (Anastasi 1936 versus Warren and Pinneau 1955) by incorporating contextual factors into model specifications.

The paper is divided into four sections. Section 2 reviews the literature. Section 3 develops the theoretical model. Section 4 describes the empirical results of model testing based on five laboratory experiments and one field experiment, and Section 5 ends by explicating managerial and theoretical contributions of this research and offering directions for future research.

2. Shape and Size Biases in Area Perceptions

More than a century of research in spatial perceptions documents that size perceptions are a function of the shape and the actual size of objects. While there is agreement that people's estimates of area are systematically biased, there is no consensus as to why these biases occur. Furthermore, there are inconsistent directional findings as to which shapes are perceived to be bigger. In this section, we summarize biases in area comparison judgments based on the shape and the size of a two-dimensional object. We follow this up with a summary of theories proposed to explain these biases.

2.1. Shape Effects

The effect of the shape of an object on estimates of its size has been studied extensively in cognitive and developmental psychology. Regular shapes (e.g., squares, rectangles, pyramids, circles, etc.) are of particular relevance to marketers of frequently purchased consumer products interested in packaging and pricing issues. Findings pertinent to regular shapes include:

2.1.1. Triangle Comparisons. Triangles have been generally found to be perceived to be larger than circles and squares (Anastasi 1936, Fisher and Foster 1968, Hanes 1950, Pfeiffer 1932, Warren and Pinneau 1955 but also see Smets 1970 and Wagner 1931 for exceptions),

2.1.2. Circle-Square Comparisons. There are inconsistent findings regarding the relative size perceptions of circles vs. squares. While studies in the 1930s documented that a square was perceived to be larger than a circle of the same area (Anastasi 1936, Wagner 1931, Pfeiffer 1932), later studies have documented the reverse (Fisher and Foster 1968, Hanes 1950, Mansvelt 1928, Smets 1970), and others yet have found no difference (Croxton and Stein 1932, Warren and Pinneau 1955).

2.1.3. Elongation Effect. Anderson and Cuneo (1978), Holmberg and Holmberg (1969) and Verge and Bogartz (1978) document that the more elongated a figure, the larger it is perceived to be (but see Holmberg and Wahlin 1969 for null results).

2.2. Size Effects

The main findings from prior research that has examined size perceptions of figures of the same shape across different sizes are that:

1. Size increases are underestimated—perceived size increases at a lower rate than actual size (Baird et al. 1970, Ekman 1958, Moyer et al. 1978, Stevens and Guirao 1963, Teghtsoonian 1965).

2. The degree of underestimation increases as the object grows larger. This empirical bias has been modeled as Perceived size = Actual size^e, $e < 1$, by Teghtsoonian (1965) among others.

3. The degree of underestimation has not been found to be contingent on the shape of the figure, with the value of *e* around 0.8 across a number of two-dimensional figures (e.g., Circles: Ekman 1958 = 0.86; Squares: Stevens and Guirao 1963 = 0.70, Across shapes: Baird et al. 1970 = 0.80).

2.3. Theories Proposed to Explain Shape and Size Biases

The theories that have been developed to explain the above biases are broadly categorized into those that propose that the bias is due to (i) *Information Selection*, people using incorrect information (e.g., ignoring or underestimating one of the dimensions)—see Dembo and Hanfmann (1933), Teghtsoonian (1965), Verge and Bogartz (1978)—or (ii) *Information Integration,* an incorrect combinatorial rule to integrate available information (e.g., adding dimensions rather than multiplying them)—see Anastasi (1936), Anderson and Cuneo (1978), Smets (1970), Martinez and Dawson (1973), and Warren and Pinneau (1955).

The information selection models, although useful, are unable to explain why in certain situations squares are perceived to be larger than circles whereas in others the reverse holds. Furthermore, the models appear atheoretic with no behavioral theory behind why one source of data is used at the expense of another. No single information integration or information selection theory appears to satisfactorily explain both the shape and size biases reviewed earlier. To be useful such a theory must be based on a behavioral process, be parsimonious but still have high explanatory power, and be able to incorporate variables used in these models but at a deeper explanatory construct level. In the next section we formulate such a psychophysical model of area judgments.

3. Theoretical Framework

3.1. Psychophysical Model of Area Judgment

We propose a parsimonious psychophysical model of area comparisons involving an information integration process that incorporates information selection. The model (i) rests on strong behavioral foundations in terms of the *process* people go through while making judgments, (ii) predicts results consistent with major previous findings on area judgments, (iii) explains contradictory shape effects, and (iv) predicts a new bias in area comparison judgments.

3.1.1. Area Judgments. The basic behavioral foundation that the model rests on is that consumers simplify a difficult cognitive task by utilizing simplifying heuristics, such as using a single piece of information as a proxy for a more complex analysis (e.g., Einhorn and Hogarth 1981). In fact, there is strong evidence from the literature on judgment and decision making that in many complex judgment situations, people use the simplifying process of anchoring on a single piece of information and insufficiently adjusting for remaining information (for a review see Kahneman 1992). Analogously, the *prominence* effect shows that people tend to overweight information that they believe is most important in a task (for a review see Tversky et al. 1988). Recent work on this prominence effect has shown that it may be task dependent, with the prominent attribute receiving more weight when the experimental task is to differentiate (versus equate) options (Fischer et al. 1999), as is the case in an area comparison procedure where the output is to identify which figure is smaller or larger.

We propose that the processing strategy of area comparisons involves an overreliance on the prominent information source—the primary linear dimension—at the cost of alternate information sources, the secondary linear dimension. This is because of the perceptual salience of one of the dimensions in a two-dimensional task. Perceptual salience effects have been shown in the context of spatial judgments of distance where the direct distance between endpoints of a map was overutilized as a source of information to make judgments about the distance of the route (Raghubir and Krishna 1996) and volume, where the elongation of a container systematically affected perceptions of volume of that container (Raghubir and Krishna 1999). Furthermore, research has shown that the difference in salience of the dimensions enhances the use of the more salient dimension, which is then used as the primary dimension, encouraging the disregard of other secondary dimensions (Krishna and Raghubir 1997, Lauer 1929, Seashore and Williams 1902).

This suggests a model of area comparisons where the primary comparison between figures is made on the basis of a single comparable dimension chosen due to its perceptual salience (e.g., width), with an adjustment of the results of this initial comparison based on a secondary comparison using the remaining orthogonal dimension (e.g., length). The use of the secondary comparison in the judgment is inadequate, as would be argued by both traditional anchor-adjustment theories as well as the prominence literature.

Our model of area comparison is based on the following monadic area judgment:

$$\text{Perceived Area} = \text{Primary dimension} * \text{Secondary dimension}^{\alpha}. \quad (1)$$

We do not claim that monadic judgments of area will be made per Equation (1) but that relative area judgments (area comparisons) will be consistent with this monadic judgment. We now develop a model for area comparisons. A two-dimensional figure has two defining dimensions, which are typically orthogonal. These are often labeled ''width'' and ''height'' and may be analogous to the sides of a square, to the diagonals of a square, to the base and altitude of a triangle, or to two orthogonal diameters of a circle. Consider two two-dimensional figures, F_1 and F_2, which are to be compared, each with a most salient dimension of length L_i (i = 1, 2) and a secondary dimension, less salient and orthogonal, of width w_i. That is, L_i and w_i are defined by [salience of L_i] > [salience of w_i]. An initial judgment as to which figure is larger is made by comparing the length of the most salient dimensions. Define the initial comparison based on the most salient dimensions as $I_{1,2}$, = L_1/L_2. Here $I_{1,2}$ anchors the comparison of F_1 and F_2, with F_1 initially judged as larger than F_2 if $I_{1,2} > 1$.

This comparison is then adjusted by a secondary comparison of the less salient dimensions. Define the secondary comparison as $A_{1,2} = w_1/w_2$.

Let the final *criterion ratio,* $R_{1,2}$ be defined as[1]

$$R_{1,2} = I_{1,2}*(A_{1,2})^{\alpha} = (L_1/L_2)*(w_1/w_2)^{\alpha}, \qquad 0 < \alpha < 1, \qquad (2)$$

where $\alpha > 0$ implies that the initial comparison *is* adjusted, and $\alpha < 1$ implies that the adjustment is insufficient. The area of F_1 is finally judged larger than the area of F_2 if $R_{1,2}$ is greater than one.

The model is consistent with the underlying behavioral process, which can be summarized as:

PROPOSITION P1. *Consumers make an initial comparison between two figures based on a single dimension.*

PROPOSITION P2. *The dimension of initial comparison—the primary dimension—is the one that is most salient to consumers, where salience is figure and context dependent.*

"Salience" refers to the properties of a dimension that cause a consumer to pay more or less attention to it. These may be properties of the figure itself. In a comparison between a square and highly elongated rectangle of the same area, for example, the longest dimension of the rectangle is more "attention-getting" than the shorter dimension and will, therefore, be the dimension chosen for the initial comparison

[1]The criterion ratio could have been operationalized as either $R_{CS} = I_{CS}\cdot\alpha\cdot(A_{CS})$ or $R_{CS} = I_{CS}\cdot(A_{CS} - \alpha)$. We chose the power function formulation to be consistent with prior literature. Note also that the criterion ratio, $R_{1,2} = (L_1/L_2)*(w_1/w_2)^{\alpha}$, can be derived through a comparison based on two monadic tasks with $A_1 = L_1^{*}W_1^{\alpha}$ and $A_2 = L_2^{*}W_2^{\alpha}$.

Figure 1 Example of the Most Salient Dimension (Used for the Initial Comparision)

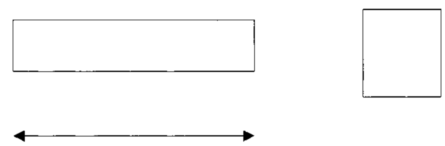


Figure 2 Example of a Contextual Cue (the Arrangement of Shapes to Be Compared) for the Most Salient Dimension

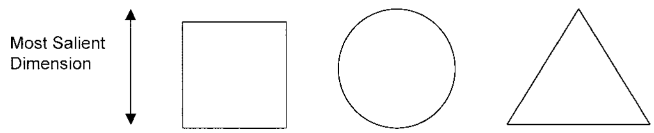
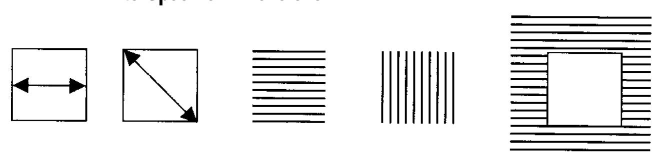


Figure 3 Examples of Graphical Highlighting Used to Draw Attention to Specific Dimensions



with a side of the square. Hence, the "elongation effect" (see §2.1)—because the long dimension of the rectangle is longer than the side of the square of the same area, the rectangle is judged larger (Figure 1). Contextual cues, for example, the direction in which two or more figures to be compared are lined up, may also determine relative salience of two dimensions. This would be particularly likely in the case where the figures are symmetric and there is no "long dimension" that stands out. In the example (Figure 2), the dimension perpendicular to the row of figures is the most obvious one on which to make initial comparisons. This particular contextual manipulation is used in several of the studies that follow. Graphical highlighting can also draw attention to specific dimensions and encourage their use. Examples include, but are not limited to, individual lines, arrows, or sets of lines, either inside or outside of the figures to be compared (Figure 3).

The third and fourth propositions relate to a secondary comparison based on the remaining information—the secondary dimension.

PROPOSITION P3. *Consumers insufficiently adjust an initial comparison based on a second comparison using the secondary dimensions, which we assume to be orthogonal to the primary dimension used for the initial comparison.*

Proposition P3 states that consumers know that comparing areas strictly on the basis of one dimension is not correct, and they therefore adjust this judgment. The adjustment, however, is not sufficient to reach the normatively correct comparison because of the overutilization of the prominent primary dimension. The model captures the insufficient adjustment with the exponent, $\alpha < 1$.[2] The first three propositions provide a parsimonious unifying basis for a wide range of area comparison biases reported in the literature. These are discussed below.

We offer a fourth proposition that states that the degree of over- and underutilization of the primary and secondary dimensions, respectively, will be endogenously determined by their relative salience. This follows from the argument that a dimension is chosen to be the primary or secondary dimension by virtue of its perceptual salience. In this sense, any factor that will increase the salience of the second dimension (visual cues, semantic cues, priming cues, etc.) will increase the likelihood of a complete adjustment. Specifically:

PROPOSITION P4. *The magnitude by which the initial comparison is adjusted is directly related to the relative salience of the secondary dimension to the primary dimension.*

In terms of our model, this implies that α is a monotonically increasing function of the relative salience of the secondary dimension compared to the primary dimension.

In summary, the choice of the primary dimension is a categorical outcome of the determination of the "most salient" dimension. The degree of adjustment based on the secondary dimension is a continuous outcome, based on the relative salience of the two defining (nominally orthogonal) dimensions of a two-dimensional object. The salience of a dimension depends on characteristics of the figure and can be affected by contextual factors.

[2]The power function formulation is a mere operationalization of Proposition 3, rather than a principle in itself. We thank a reviewer for pointing this out.

3.2. Consistency of Model with Prior Empirical Findings

This model has many desirable properties. Using examples, we illustrate the intuition behind the model, and how it can explain the earlier reviewed (i) Size and (ii) Shape effects.

3.2.1. Size Effects. When comparing many figures of the same shape, e.g., squares, rectangles, circles, etc., setting $\alpha = 1$ (i.e., adequate adjustment based on the secondary dimension) *gives a normatively correct perceived ratio,* $R_{1,2}$. Thus, when comparing squares of sides 2 cm and 4 cm, the computed $R_{1,2} = (4/2)(4/2) = 4$ equals the true area ratio. On the other hand, if $\alpha < 1$, $R_{larger\text{-}smaller} = (4/2)*(4/2)^{\alpha} = 2^{1+\alpha} < 2^2$; the larger square is underestimated relative to the smaller square.

This is the well-known "size effect" (Teghtsoonian 1965), where the increase in size of similar objects is underestimated. Our model suggests that the relative salience of the primary and secondary dimensions determines perceived area ratio and that these ratios do not depend on shape. This implies that perception of increased area does not depend on whether squares or circles are being compared and is consistent with prior empirical findings. Equation (2) also predicts that *the degree of underestimation of larger sizes of the same shape is a function of the relative difference in size of the object.* This is a consequence of the power law formulation with $\alpha < 1$.

The extent of underestimation, $U_{Cvs.S} = (L_C/L_S)*(w_C/w_S) - (L_C/L_S)*(w_C/w_S)^{\alpha}$, which is >0, *iff* $\alpha < 1$. Thus, for a given α, a small square of side n, and a larger square of side n + m, the underestimation of area increases with m. That is, as $(n + m)^2 - (n + m)^{1+\alpha}$ increases more than proportionately with m. The larger the square, the more it will be underestimated. A simple numerical illustration amplifies this for squares with $\alpha = 0.8$ and $n = 2, 4, 8$:

	Alpha	Actual Area	Perceived *Area*	*U*	*U*nderestimation as % Normative Area (%)
Side = 2	0.8	4	3.48	0.52	12.9449
Side = 4	0.8	16	12.13	3.87	24.2142
Side = 8	0.8	64	42.22	21.78	34.0246

Thus, the formulation presented predicts (i) the correct formula when there is complete adjustment; (ii) that larger sizes of the same shape are underestimated; (iii) that size effects are not contingent on shape (provided there is no explicit manipulation of the relative salience of primary and secondary dimensions); and (iv) that underestimation increases as the size of the object increases.

3.2.2. Shape Effects. Consider first the *elongation effect.* Compare a square of side 4 cm with a rectangle of 2 × 8 cm, both of area 16 cm^2. In our formulation, taking the most salient dimension as the longest dimension, the above formula gives: $R_{Rect\text{-}Sq} = (8/4)*(2/4)^{\alpha}$. If $\alpha = 1$ (no bias), $R_{Rect\text{-}Sq} = 1$. However, if $\alpha < 1$, $R_{Rect\text{-}Sq} > 1$, or, the rectangle will be judged larger than the square: the "elongation effect."

Consider next *across-shape judgments* of triangles, circles and squares of the same true area, where prior literature has shown that there is no clear agreement on whether squares appear smaller or bigger than circles, although triangles have been found to appear bigger than both. The model formulation is able to demonstrate how each of these findings is explainable.

Equilateral Triangle vs. Circle or Square: The side and the height of an equilateral triangle are longer than the side or diagonal of a square or the diameter of a circle of the same area. Thus, our model predicts that triangles will be judged larger than circles and squares, as has been documented (Anastasi 1936, Fisher and Foster 1968, Hanes 1950, Pfeiffer 1932, Warren and Pinneau 1955).

Square vs. Circle: An interesting area comparison is between circles and squares. This is because while the circle has an unambiguous linear dimension (its *diameter*) the square can be defined either in terms of its *sides,* or in terms of its *diagonals.* If consumers' estimates of area are based on the length of a single dimension, then the outcome of the initial comparison ($I_{C\text{-}S}$, Equation (1)) between a circle and a square of the *same true area* depends on whether the diagonal or side of the square is used as the primary dimension. For a square and circle of the same area, the ratio of the side-of-square to the circle diameter is 0.88, while the ratio of the diagonal of square to the circle diameter is 1.25. Thus, if the diagonal is most salient, $R_{Sq\text{-}Cir} = (1.25)*(1.25)^{\alpha}$, which is >1 for all $\alpha > 0$, implying squares will be judged as larger than circles in this case. On the other hand, if the side of the square is most salient, $R_{Sq\text{-}Cir} = (0.88)*(0.88)^{\alpha}$, which is <1 for all $\alpha > 0$, implying that circles will be judged as larger than squares in this case. Note that $R_{Sq\text{-}Cir}$ is greater when diagonals are salient, implying different effect sizes for circle-square comparisons. (In other words, it will be easier to find circle-square differences when diagonals are salient and the square is judged larger than the reverse, as 1.25 is 25% greater than 1, whereas 0.88 is only 12% less than 1. We test this proposed resolution of reported circle-square inconsistencies below.

In conclusion, the model meets our first criterion of unifying a number of previously unintegrated and contradictory biases reported in the literature.

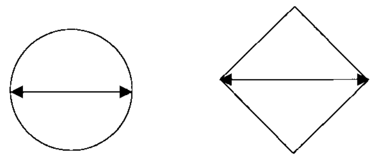
4. Empirical Tests of the Model

A set of six studies—five laboratory experiments and one field experiment—systematically tests model predictions.

Subjects for all laboratory experiments were drawn from undergraduate subject pools at three different universities in three different countries. No subject participated in more than one study. The pools were drawn from students of introductory marketing classes who participated in the experiments for partial course credit.

In Section 4.1, we present a process study that suggests that a primary and a secondary dimension are used in comparing area, and that relative salience can be manipulated to influence the choice of a primary dimension. In Section 4.2 we present two laboratory studies to challenge Propositions P1 and P2, and at the same time demonstrate the validity of our pro-

Figure 4 Example of Stimuli Used for Study 1



Note. The circle and square have equal areas.

posed resolution of the circle-square controversy (see §2.1). A field study (Study 4) demonstrates external validity. The last two studies in this section also examine economic implications of the bias. Section 4.3 then focuses on the use of the secondary mechanism, as outlined in Propositions P3 and P4, and on associated economic implications.

4.1. Study 1: Process-Based Evidence for Propositions P1–P4

This study explicitly examines the underlying process used to make area comparisons, using squares and circles as stimuli. Because squares and circles are 90° rotationally symmetric, there are no elongation cues (i.e., long dimensions) to base the initial comparison on. Comparisons are, therefore, likely to be based on contextual cues such as arrangement. We used contextual graphics by drawing double-headed arrows either horizontally or diagonally (relative to the sides of the paper) in both the square and the circle in an attempt to increase the salience of the associated dimension. Figure 4 shows an example for a square and circle of equal area.

Method. Each of 33 subjects saw two pairs of circles and squares of equal area (42.25 cm^2) on letter size (8½ × 11) paper, with the circle beside the square and one circle-square pair above the other. The four figures are thus arranged in a rectangular pattern congruent with the sides of the paper. For half the subjects the squares were on their base, and for the other half on their corner (with left-right circle-square order counterbalanced between subjects). We refer to the corner orientation as a "kite." One circle-square (or circle-kite) pair had a horizontal double-headed arrow through the center of the pair of figures. The other pair had a diagonal double-headed arrow through the figures.[3] The pair presented on top was counterbalanced between subjects. Subjects ($n = 33$) were told to compare the circles to the squares. Subjects were then asked to allocate 100 points between the two dimensions (side or corner-to-corner diagonal) to reflect the extent to which each dimension played a role in their size comparison. They could also indicate if they had used any other method for the area comparison.

Subjects were then asked how they thought they made their size comparison. They were given eight choices.[4] Four of these were based on the comparison of a single dimension with adjustments (e.g., "I basically compared the side of the square with the diameter of the circle but made some adjustments for the difference in shape"). Four were based on comparing squared dimensions (e.g., "I compared the (side of the square)^2 with the (radius of the circle)^2 but made some adjustments for the difference in shape"). Among the eight given choices, four were based on diagonals of the square and four on the side of the square. They also had a ninth choice for any other method they may have used. The order of presentation of the eight choices was also counterbalanced between subjects.

Results. Vertical order of presentation of the choice figures had no effect on the allocation of points between the use of the horizontal and diagonal dimension and is not discussed further ($p > 0.80$). When the square was presented on its side, the mean point allocation was 61.76 (versus 38.24) for the side (versus corner-to-corner diagonal) dimension, whereas it was

[3]To test whether consumers use the side or diagonal dimension of the square in making area comparisons, we need to use the horizontal (or vertical) and diagonal dimensions. Taking all three horizontal, vertical and diagonal dimensions would bias the results in favor of the side (vertical/horizontal) dimension merely by allowing two options for side versus one option for diagonal.

[4]The eight choices were constructed through a pre-test ($n = 32$), where four choices, plus an "other" choice were provided. The eight choices were constructed from the answers subjects gave in this pretest, taking into account balancing of the number of linear/square options and side/diameter options to minimize bias resulting from inferences as to what the appropriate response was based on the number of options available on any given type of process.

37.50 when the square was presented on its vertex like a kite ($F(1,31) = 5.38$, $p < 0.05$, $\eta^2 = 0.148$).

Furthermore, 21 of 33 subjects believed they had used one of the four single-dimension-with-adjustment strategies. Eight of 33 subjects felt they had used squared-dimensions-with-adjustment strategies (binomial $p < 0.01$). The remaining four subjects used a visual strategy of trying the place the circle (square) inside the square (circle).

Results strongly indicate that people commonly use one of the dimensions of a two-dimensional figure as a primary comparison point, and then subsequent adjust this to incorporate the second dimension. Further, results show that the choice of the primary dimension can be influenced by contextually manipulating dimension salience.[5] In the remaining studies we investigate detailed predictions of Propositions 1–4.

4.2. Propositions P1 and P2: Initial Comparison Based on the Most Salient Dimension

In this section we present three studies. The first two (Studies 2 and 3) are laboratory studies that provide support for Propositions P1 and P2 and simultaneously demonstrate the validity of our proposed resolution of the circle-square controversy. A field study provides external validity. The second and third studies also examine economic implications of the bias.

4.2.1. Study 2. The Primary Use of the Salient Dimension for the Initial Comparison. Following Study 1, we manipulate the salience of alternate linear dimensions of the square—the diagonal or the side—presented alongside a circle of equal area. The relative salience of the side versus the diagonal of a square should influence which dimension is used for the initial comparison and, hence, whether the circle or square is judged larger. Thus, it follows:

Hypothesis 1. *A square where the diagonal (versus the side) is salient is more likely to be judged as larger than a circle of equivalent area.*

Method.

(a) *Design.* The design manipulated the salience of the diagonal versus the side of the square similar to Study 1. In the *diagonal salient* condition, the squares were presented on their corners (like a kite). In the *side salient* condition, the squares were presented on their sides.

(b) *Procedure and Measures.* In each condition the experimenter gave the subject a white cutout circle as a standard and explained that the task was to place the circle beside one of six white squares that was closest in area to the standard circle. The six squares (or kites) of different sizes were aligned vertically on a gray background. The six squares were generated by enlarging or reducing a square of area equal to the standard circle, by factors of 0.90, 0.94, 0.98, 1.02, 1.06, and 1.10. The subject was allowed to move the circle around but could not place the circle on top of the squares. Matching a circle with a larger square indicates that circles are perceived to be larger than squares of the same area, whereas matching it with a smaller square indicates that squares are perceived to be larger than circles of the same area. Note that this is a strong test of the prominence effect because more important attributes have been shown to have a greater influence in choices than in matching judgments (Hawkins 1994).

Subjects ($n = 38$) were told that the experiment was designed to study judgments under time pressure and that the task was to be completed in 10 seconds. There was a trial session prior to the experimental task to familiarize subjects with the unfamiliar task. After completing the task, the subjects filled out a questionnaire that included gender and handedness, knowledge of the formula for the area of a circle, and an open-ended question on what they believed the purpose of the study was.

[5]We also conducted a second study, not reported in detail here, which indirectly supports the hypothesized single-dimension anchoring mechanism. When asked to *draw* squares and circles of the same given area, subjects produced squares and circles that had sides and diameters closer in length than the true sides and diameters would be for figures of equal area (the drawn circles had smaller area than the drawn square). In a control condition, subjects were also given the true side and diameter dimensions associated with the equal-area figures and were then able to reproduce the figures much more accurately.

Results. We expected that when the diagonal was salient (kite orientation) the circle would be (i) judged smaller than the kite of the same area and (ii) matched with a smaller square and that the reverse would happen when the side of the square was salient.

(a) *Choice.* As predicted, in the side-salient condition, 74% of the subjects matched the circle with a larger square, indicating that the area of the circle was perceived to be larger than the area of the square. In the diagonal-salient condition, 63% matched the circle with a smaller square, indicating that in this condition the square was perceived to be larger than the circle (Overall $\chi^2_{(1)} = 5.2$, $p < 0.05$).

(b) *Mean Subjective Equivalence (MSE).* As a measure of the magnitude of the bias, for each condition we calculated the mean (across subjects) size of the squares that were chosen as equivalent to the circle—i.e., its MSE (cf. Fisher and Foster 1968). In the side-salient condition the MSE was 1.057 (i.e., linear magnification = 1.028 × and area = 1.057 × standard circle area), which is significantly higher than the MSE of 0.964 in the diagonal-salient condition ($t_{36} = 2.25$, $p < 0.05$, $\eta^2 = 0.123$). Area comparisons were biased by approximately 5% in either direction, depending on whether the side or diagonal of the square was salient.

Discussion. We found that relative judgments of a circle versus a square were contingent on the context-influenced salience of the different linear dimensions of the figures—in this case, the side or the diagonal of the square. Given a square and a circle of equal area, the square was judged *larger* when its diagonal was salient and *smaller* when its side was salient. Hypothesis 1 is supported. These results are consistent with the first two parts of the proposition—that people base area comparison judgments on a single dimension, and the choice of the dimension is a function of its salience.

In the next study we examine the robustness of the effect using a different experimental method with a simpler judgment and examine whether the bias translates into the price consumers are willing to pay.

4.2.2. Study 3: Salience-Contingent Choice of Primary Dimensions and Reservation Price. Firenze's,[6] an Italian restaurant, caters to the "eat-in" pizza segment. It needed to decide whether to make round pizzas or square pizzas. Preliminary cost calculations had shown that the two shapes did not significantly vary on overall cost. Firenze's wondered whether customers would care.

Consumers' reservation price should be directly related to perceived size, or:

Hypothesis 2. *Consumers will be willing to pay less (more) for a circular package versus a square one when the square package is presented on its corner (side).*

Method. The product chosen was pizza, a common two-dimensional consumer product. The design was a 2 (shape: circle/square) × 2 (salience of diagonal: low/high) mixed design, with the first factor administered within subjects and the second between subjects. The salience of the diagonal of the square was manipulated as in section 4.2.1. Each subject saw both a circular and a square "pizza" presented side by side. Both figures were of the same area (256 cm^2, side of square = 16 cm < circle diameter = 18.1 cm < diagonal of the square = 22.6 cm). Note the methodological difference between Studies 2 and 3—instead of matching a circle to a series of squares of different areas, in this study subjects are shown figures of the same area.

Subjects ($n = 90$) were told that there was a new pizzeria opening on campus and asked to (i) judge which figure was smaller and (ii) estimate the maximum price they were willing to pay, i.e., their reservation price (RP) for the two "pizzas."

Results.
(a) *Choice.* As in Study 2, when the diagonal of the square was salient, the majority (71.8%) judged the square larger than the circle, whereas when the side of the square was salient, a larger proportion of subjects (56%) estimated the circle as larger ($\chi^2_{(1)} = 6.88$, $p < 0.01$). Thus, Hypothesis 1 is again supported.

(b) *Reservation Price.* The format and presentation

[6]Examples are based on actual situations. Names may have been disguised to maintain anonymity.

of the square pizza also affected the maximum price a subject was willing to pay (Reservation Price, RP). A within-subjects analysis of variance (ANOVA) on RP for the circular and square pizza across the two salience conditions revealed a significant shape by salience interaction ($F(1,88) = 4.20$, $p < 0.05$; $\eta^2 = 0.05$): When the diagonal was salient, the maximum price subjects were willing to pay was significantly lower for circles vs. squares (Means = HK$43.39 vs. HK $46.56; Ratio of Means = 1.07; contrast $F(1,88) = 6.13$, $p < 0.05$; $\eta^2 = 0.065$). However, shape exerted no effect when the diagonal was not salient (Means = $40.25 vs. $39.86 for circle and square, respectively, ratio of means = 0.99; contrast $F < 1$). This is not surprising because of the small effect size in this study (half of that in Study 1). In sum, Hypothesis 2 as partially supported—size estimates translate into the reservation price of consumers, but the effect is stronger when the diagonal is salient.

Discussion. This study provides further support for Propositions P1 and P2, that while making an area comparison judgment, people overly reply on the more prominent dimension, with the prominence of the dimension determined contextually in part. Additionally, the study shows that this can affect the price they are willing to pay for a product. Thus, our study suggests that Firenze's should make square pizzas and display them in a diamond pattern.

While the shape biases reported to this point are consistent and robust, all have been found in the context of controlled laboratory experiments. We conducted a field study to address whether the biases have an economic impact in a real-world setting.

4.2.3. Study 4: External Validity for Propositions P1 and P2. This study examines whether container shape affects perceived size and, in turn, affects purchase quantity.

Stimuli. A popular cafeteria of an undergraduate college on the East Coast carries only one type of (plain) cream cheese every day. There are two types of cream cheese tubs—rectangular and round. Both contain ¾ oz. of plain cream cheese. The rectangular tub has a smaller surface area but is taller compared to the round tub. Both tubs are priced at 25 cents, but prices are not marked on the tubs. Consumers see only the total price of ''bagel and cream cheese'' on the cash register. In the first part of the study, the pretest, we examine whether one container is perceived to be smaller or larger than the other. In the follow-up main study, we examine whether purchase quantity per bagel purchased is affected by container shape.

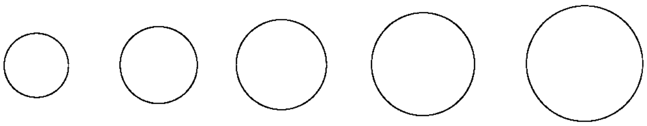
Pretest. Two cream cheese containers were covered with white paper. Cafeteria patrons were used as subjects ($n = 19$). They were asked which of the two containers was bigger. Two subjects correctly estimated that the two containers were the same size. Thirteen judged the rectangular container as bigger than the round one, significantly greater than the four subjects who judged the reverse (76.47% versus 23.53%, $p < 0.05$). This is consistent with our expectations that the longest dimension of a rectangle is the most salient and is used as the primary comparison with the circle's diameter.

According to the cafeteria manager, most consumers buy either one or two containers of cream cheese. If a round container is perceived to be smaller than a rectangular container of cream cheese, then more containers of the round container should be purchased if a fixed amount of cream cheese is desired. That is, the purchase likelihood of buying multiple units should be greater for the round versus the rectangular container. The main field study examines whether container shape affects purchase quantity.

Field Study. In the field study, the cafeteria carried a ¾-oz. round tub of cream cheese on two days and a ¾-oz. rectangular tub on two other days. Cashiers were instructed to note the number of cream cheese tubs picked up by each person purchasing cream cheese on these 4 days from 8:00 a.m. (opening time) to 12 noon.

The results were in the expected direction. Whereas 18 of 41 (43.90%) consumers purchased 2 tubs of the round cream cheese (others bought 1 tub), only 7 of 34 (20.59%) bought 2 tubs of the rectangular cream cheese ($\chi^2_{(1)} = 4.55$, $p < 0.05$). This pattern is consistent with the results of the previous study that showed that the round cream cheese container is perceived to be smaller than its rectangular counterpart. This pattern

Figure 5 Stimulus for Study 5: Five Circles of Increasing Area to Elicit Area Ratio Judgments



also led to the mean quantity purchased being higher for the round tub (mean = 1.44) versus the rectangular tub (mean = 1.21, $F(1,73) = 4.71$, $p < 0.05$).

This study provides external validity to our results in Studies 1–3 that support Propositions P1 and P2. We now turn to testing propositions P3 and P4.

4.3. Propositions P3 and P4: Use of Secondary Dimension

We have proposed that consumers will compare secondary (less salient) dimensions to adjust the initial area comparison; and that the exponent α, which lies between 0 (no adjustment) and 1 (full normative adjustment), depends on the relative salience of the primary and the secondary dimensions. In Study 5, we estimate α in the two ''salience'' conditions, using simple contextual graphics to manipulate salience of the adjusting dimension and to show support for the propositions. In Study 6, we use a more realistic salience manipulation to show that the salience-dependent adjustment can have a strong effect on consumers' reservation prices.

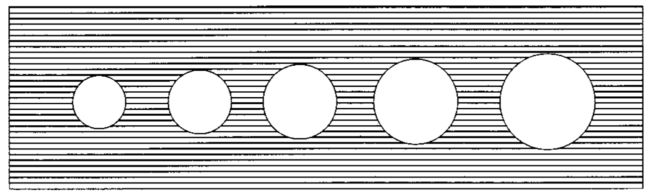
4.3.1. Study 5: Salience Dependence of the Exponent. The literature is consistent in reporting the size effect—when figures of the same shape but different sizes are compared, perceived size increases at a lower rate than actual size, with perceived to actual ratios following a power law. (Croxton and Stein 1932, Ekman 1958, Stevens and Guirao 1963, Teghtsoonian 1965). Given, for example, five circles of increasing area, as in Figure 5, the judged area ratios $R_{L,S(judged)}$ of any of the larger circles to the smallest can be expressed in terms of the true area ratios $R_{L,S(true)}$.

$$R_{L,S(judged)} = R_{L,S(true)}^{(\alpha+1)/2}, \quad \text{or} \tag{3}$$

$$\ln[R_{L,S(judged)}] = (\alpha + 1)/2 \ln[R_{L,S(true)}]. \tag{4}$$

The five circles can be used to provide four sets of true and judged ratios, from which α can be estimated by regression. Noting that $L_i = w_i$ for a circle and thus $R_{L,S(true)} = (L_L/L_S)^2$, this is consistent with our equation (2), $R_{1,2} = I_{1,2}*(A_{1,2})^\alpha$, with $L = 1$, and $S = 2$, and our theory provides more insight into the underlying mechanism. Specifically, the arrangement of the circles in a row encourages the initial comparison $I_{L,S}$ to be made on the dimension perpendicular to the row. The secondary $A_{L,S}$ is then based on the dimension parallel to the row, and the magnitude of the adjusting exponent α depends on the salience of that dimension relative to the primary dimension. This implies that if we modify the figure to draw more attention to the dimension parallel to the row, we should increase α. Such an effect would provide strong support for our theory. A simple way to increase the salience of the secondary (underused) dimension is to provide contextual cues that draw attention to the dimension, e.g., one or more lines parallel to it (see Figure 6).

Figure 6 Contextual Graphics Added to Figure 5 to Increase the Salience of the Secondary or Adjusting Dimension



HYPOTHESIS 3. *The value of the exponent in the "size effect" is greater when the context increases the salience of a secondary dimension.*

Method. Figures 5 and 6 were used as stimuli, with the addition of ''100%'' written beneath the smallest circle. Subjects ($n = 84$) were shown one of the two figures and asked to give the area of the larger figures relative to the smallest, with the smallest assigned 100%.

Results. Equation (4) was estimated for each condition by OLS. In the low salience condition, α was estimated as 0.62 (s.e. = 0.02, $R^2 = 0.89$), and in the high salience condition, as 0.86 (s.e. = 0.02, $R^2 = 0.90$). This provides strong support for Hypothesis 3.

However, because each subject provided several data points the independence assumption of OLS was violated, leading to a possible underestimation of variance. A somewhat ad hoc method to determine group parameters would be to estimate individual coefficients for each subject and average them across subjects to produce group coefficient means.[7] A more formal approach to estimating the mean rate of change in each group, used in the econometric analysis of panel data, where there are typically many subjects but few data points for each subject, is a random coefficient model (Hsiao 1992, Judge et al. 1985). The slope is treated as a random variables across subjects, and we estimate its mean and variance using two-stage EGLS.[8]

With this model, the estimated mean α for the low salience condition was 0.602 (s.e. = 0.043) and for the high salience condition 0.832 (s.e. = 0.046). While the estimated errors have increased over the OLS errors as expected, the Wald statistic for testing coefficient equality is $W = 3.36$ ($p < 0.07$), consistent with Hypothesis 3.

Discussion. A normatively correct judgment is indicated by $\alpha = 1$. We observe the usual "size effect" bias in area comparison judgment, with the magnitude of the bias in the low-salience condition comparable to that reported in the literature. When the relative salience of the secondary dimension is increased contextually, the bias is reduced, in accordance with Propositions P3 and P4.

In the final study, we investigate the implications of the salience-based adjustment for consumers' reservation prices in a more complex managerial setting and challenge the theory further with another manipulation.[9]

[7]It is interesting to note that for individuals, the model fits very well. Only 7 of 84 subjects had R^2 values less than 0.97 when Equation (4) was fit to each subject's data individually. The interpretation is that the majority of the variance in the pooled OLS regression is a result of differences in the coefficients between subjects, rather than of the errors within subjects.

[8]We also allow for heteroscedasticity across individuals, which a priori seems reasonable, and subsequent specification tests confirm.

[9]We also replicated the effect of this study directionally in a matching task. Subjects were asked to match a square to the series of circles. In one condition the square was blank, and in another it was filled with parallel lines to increase the salience of the adjustment dimension.

4.3.2. Study 6: Salience-based Adjustment—Does Description of Sizes Affect Prices? Pepperoni's, a neighborhood pizzeria had to decide how to label their "small," "medium," and "large" sizes on their menu, and how to price the different sizes. Should sizes be given as diameter dimension (e.g., 8 inches, 10 inches) as per the prevailing practice? Should they depart from convention and provide actual pizza areas, or perhaps display sample pizzas? How would the different presentations affect customers' reservation prices?

Pepperoni's is prepared to encourage customers to purchase larger sizes by giving them a quantity discount. The implication of the established size effect bias for Pepperoni's, however, is that customers will not fully appreciate how much extra they are getting in the medium and large pizzas compared to the small pizza and thus underestimate the value of any quantity discount. A menu that states only the diameters is providing information on only one dimension, cuing the sole use of that dimension to make a two-dimensional judgment (size of the pizza). Because there is nothing in the stimulus to draw attention to a second dimension, the relative salience of the orthogonal secondary dimension is low—specifically, lower than when an actual pizza is presented. This implies less adjustment, a larger size-effect bias, and a smaller perceived quantity discount for a given price.

Salience in this study is manipulated via the manner in which information on the three sizes of pizza is presented: using information on one linear dimension (e.g., "8-inch diameter") or graphic information (a figure of diameter 8 inches displayed). Formally, α, which captures the salience and relative use of the second dimension, should be greater in the graphic case than in the linear dimension case. Propositions P3 and P4 imply

$$\alpha_{\text{linear}} < \alpha_{\text{graphic}} \tag{5}$$

Given this pattern of α, it follows that:

HYPOTHESIS 4. *The rate of increase of Reservation Price with pizza size when Graphic Information is provided will be greater than when Linear Dimension Information is provided.*

In contrast to the previous study, where contextual graphics were used to increase the salience of the adjusting dimension and hence reduce the bias, in this study we use numeric diameter information to reduce the salience of the adjusting dimension and predict this will increase the bias. Because our dependent variable is reservation price, and the relation between *perceived* area and reservation price may include an expected quantity discount, we include a third condition where we present true area information (e.g., ''50 square inches''). Providing true area information eliminates the judgment bias so that any expected quantity discounts can be observed directly. In terms of the model, the salience of the secondary dimension is effectively high—in fact, it is the same as the salience of the primary dimension. Propositions P3 and P4 imply:

$$\alpha_{\text{graphic}} < \alpha_{\text{area}} = 1. \tag{6}$$

Given this pattern of α, it follows that:

HYPOTHESIS 5. *The rate of increase of Reservation Price with pizza size when Area Information is provided will be greater than when Graphic Information is provided.*

Method. Subjects ($n = 136$) were informed that there was a new pizzeria that was opening on campus. They were told that the pizzeria was deciding on its product offerings, and was interested in assessing consumers' reactions, including the price they were willing to pay for various pizzas.

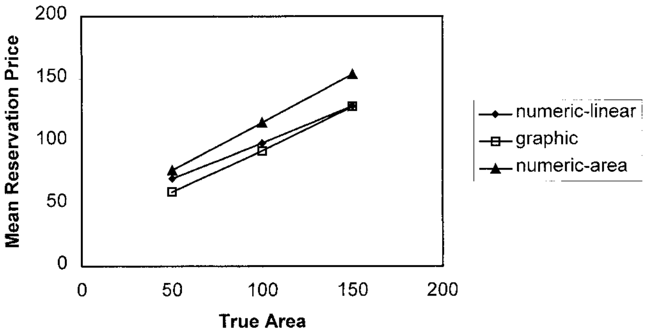
We used a 2 (shape—circle, square) × 3 (Salience of Adjusting Dimension—*Low* Linear Dimension Information, *Medium* Graphic Presentation, and *High* Area Information) × 3 (Size: 50, 100, 150 sq. inches) mixed design with the first two factors administered between subjects and the last within subjects. Thus, each subject made three price judgments: one each for the small, medium, and large pizzas, with the order of elicitation counterbalanced (ascending or descending). In the linear dimension information condition, the diameter of the pizza was provided (8 inches, 11.25 inches, and 13.75 inches). On the other hand, in the high salience area information condition, the dimensions were not provided, and only the area of the ''pizza'' was given (50, 100, and 150 sq. inches). In the graphic information condition, a white sheet of cardboard represented each pizza, and no dimension or area information was provided. Here, ''Pizzas'' were placed in a row, in order of size, in the center of a rectangular table. Subjects, sitting all around the table, estimated the maximum price they were willing to pay for each of the three pizzas. There were a number of other questions to increase the credibility of the cover story used and also questions on demographics, motivation level, and knowledge of measures. The task took approximately 20 minutes, after which subjects were debriefed and dismissed.

Results. A majority of the subjects were aware of the correct formula for calculating the area of a square ($n = 125$, or 92%) and circle ($n = 114$, or 84%). Knowing the correct formula did not affect price estimates (all ps > 0.50). Handedness ($n = 128$, or 94%, reported being right-handed) and gender (females = 111, or 82%) also did not affect price estimates. Reported motivation and interest levels were acceptable (means = 4.49 and 4.57, respectively, on a seven-point scale).

(a) *Impact of Pizza Description on Reservation Price for Different Sizes.* Figures 7 and 8 depict the mean RPs of the six conditions.[10] The graphic condition is consistently lower than the two numeric conditions, suggesting that numeric information generally biases reservation prices upwards, although the variable of interest—the rate of change of reservation price with size in the graphic condition—is between the rate of change in the two numeric conditions. Interestingly, the mean reservation prices in each condition are very nearly linear with size and have positive intercepts. The pattern is as if subjects are expecting a quantity discount that is implemented as a fixed fee and a constant marginal price. Appendix A describes how we use this observation and our psychophysical model to derive a relation between the true area and the reservation price, and how to use this relation to test the hypotheses.

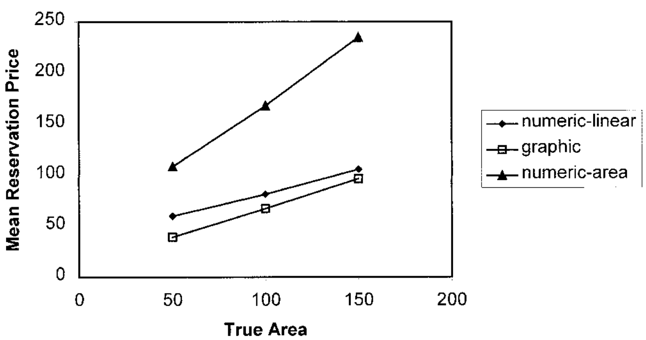
[10]Note, however, that the different description conditions (numeric linear dimension, graphic, numeric area dimension) may introduce systematically different area judgments for reasons other than the process under investigation, and that the relation between perceived area and reservation price may further distort the effect.

Figure 7 Mean Reservation Prices for Small, Medium, and Large Circular Pizzas



Note. The mean reservation price across the three information conditions suggest that consumer price expectations can be captured with a linear model of true area.

Figure 8 Reservation Price Patterns for Square Pizzas Are Similar to Those of the Circular Pizzas Shown in Figure 7



(b) *Estimation.* As in Study 5, we use two-stage EGLS in a random coefficient framework to estimate the mean value of the coefficients given in Equation (4) across subjects, in each of the information and shape conditions, and for circles and squares together. We then test for the ordering that the salience of the adjusting dimension should impose on the marginal RP.

One question of interest is how well a linear model captures the relation between reservation price and true area for *individuals.* While R^2 cannot be interpreted as a measure of variance explained in the random coefficient model, the question can be addressed by calculating a separate regression for each individual, and then calculating a total R^2 using the resulting residuals. In each of the three information conditions, this gives an R^2 value of 0.99. For all but four of the 136 individuals in the study, R^2 is greater than 0.96, indicating the sequence of reservation prices for most individuals is very nearly linear. The linearity, of course, carries through to the means across individuals, as can be seen in Figures 7 and 8. We also estimated the relation (17) including a quadratic term. For four of the six conditions the quadratic term was nonsignificant ($p > 0.5$). For two of the conditions the quadratic term was significant at $p < 0.05$. The maximum effect size of the significant quadratic terms over our data range was 12% of the effect of the linear term in one case and only 8% in the second. Thus, we take the linear model with nonzero intercept as the most appropriate structure for the relation between true dimensions and perceived price, and derive how α should enter into the model, in Appendix B. Estimated coefficients and their standard errors (which indicate that all coefficients are strongly significant) are given in Table 1.

(c) *Only Linear Dimensions.* As argued, the slopes in the Linear Numeric and Graphic conditions (Table 1) show that for both shapes, subjects were on aver-

Table 1 Results of Study 6

Info Condition	Linear Numeric (e.g., Diameter 8″)		Graphic (Figure)		Areal Numeric (e.g., 50 sq. in.)	
Mean Coefficients	Intercept (s.e.)	Slope (*b*) (s.e.)	Intercept (s.e.)	Slope (*b*) (s.e.)	Intercept (s.e.)	Slope (*b*) (s.e.)
Circles	14.9 (2.41)	27.7 (2.33)	8.9 (2.08)	32.3 (3.03)	13.0 (2.56)	31.7 (3.92)
Squares	17.9 (4.07)	22.1 (2.13)	3.73 (3.05)	28.4 (3.58)	14.3 (3.58)	47.1 (4.85)
Circles + Squares	16.3 (2.21)	25.3 (1.63)	6.6 (1.81)	30.5 (2.31)	13.6 (2.16)	39.2 (3.26)

age prepared to pay more for a ''marginal square inch'' of pizza when they saw the actual pizza than when they were given linear dimensions. A Wald test of the differences for circles or squares does not, however, achieve significance. For the combined circle and square data, the mean slope in the numeric case (25.3) is significantly less than in graphic case (30.5). The overall Wald statistic testing for equal coefficients is W = 14.45 (distributed $\chi^2_{(2)}$; see Green, p. 215), a strong rejection. For the slope coefficient alone, W = 3.33 ($p < 0.08$), supporting Hypothesis 4. The magnitude of the effect is striking: consumers are willing to pay 20% more per unit of pizza if they can see the sizes as compared to when they are given only the diameters on a menu.

The two conditions in which subjects were given the true area in square inches (eliminating the perceptual bias and hence attempting to tease out the expected quantity discount) produced unusual results (see Figures 7 and 8 and Table 1). When subjects were told that the pizzas were circular, the marginal price was the same as for the graphic condition, a rejection of Hypothesis 5. However, when subjects were told that the pizzas were square, both the reservation prices and the marginal prices were much higher, supporting Hypothesis 5.

Discussion. Not surprisingly, subjects expect a quantity discount as size increases. However, when presented with only the linear dimensions, as in most pizza parlors, customers will apparently expect a greater quantity discount than when they can see the actual pizzas, as would be expected given Propositions P3 and P4, and the relatively lower salience of the second dimension when only information on one dimension is presented.[11]

One point to note is that for all sizes, the largest reservation price is obtained when the area of the pizza is provided—a practice followed by very few, if any, pizzerias. These results apply equally to bakeries, which sell cake ''sheets'' by giving linear dimension info or by showing sample sheets but seldom by providing the actual area. Our results also suggest that Pepperoni's should present pizza information in area terms and that they would get greater sales from two small pizzas versus a larger one of the same area.[12]

5. Conclusions

This paper examined how people simplify an area judgment task. We proposed that a single linear dimension, chosen by virtue of its salience, would be overweighted in an area comparison judgment. Furthermore, we argued that the extent of use of the secondary dimension relative to the primary dimension depends on the relative salience of the secondary dimension to the initially used primary dimension. This relative salience was contextually manipulated: using visual cues that enhanced its being noticed (lines within and outside the figure), and semantic descriptors that reduced or increased its usage (e.g., diameter information versus area information). This simple and parsimonious account of how people judge areas was demonstrated across contexts, experimental procedures, and tasks and was used to reconcile contradictory effects noted in the visual perception literature.

Specifically, we developed a psychophysical model of area estimation and tested it across five experiments and a field study. The model proposed that consumers simplify the complex area estimation and comparison task by making an initial comparison based on the most salient dimension between two figures and adjust this comparison by incorporating the less salient secondary dimension, with the degree of adjustment dependent on the relative salience of the dimensions. This relative salience was manipulated differently using visual and verbal cues. Across stud-

[11]When the true area was presented in square inches to get an indication of the expected quantity discount without perceptual biasing, reservation prices were much higher for squares. The anomalous effects between circles and squares may be occurring because when told the pizzas were square, some subjects interpreted ''100 sq. inches'' as ''100 inches square.'' The support for Hypothesis 5 is thus questionable, and we leave further investigation of this anomaly to future research.

[12]In another study (not reported), 33 of 43 subjects did prefer two small pizzas over one large one of the same area.

ies, we found support for all four propositions of the model.

Study 1 used process measures to determine that consumers can commonly recognize their area comparison strategy as overly relying on a primary dimension and that they can report relative usage of linear dimensions that are consistent with salience manipulations. Studies 2 and 3 used different methods and measures to test Propositions P1 and P2. Next, in a field experiment (Study 4), we showed external validity for Studies 1–3. Studies 5 and 6 tested Propositions P3 and P4 by manipulating relative salience of the secondary dimension in different ways.

The main contributions of this article are to (i) develop a single model based on behavioral assumptions that can explain size and shape effects; (ii) make a contribution to the cognitive psychology literature, by not only reconciling conflicting results (specifically the square-circle controversy) but also predicting new effects (e.g., that presentation format influences the size-effect bias); (iii) showing that salience of dimensions can be manipulated through the shape of the figure, and also through orientation and description of the shape; (iv) show context (orientation of shape) related and information presentation (description of shape) related influences on shape and size judgment biases; (v) demonstrate economic implications of the judgment biases on two important managerial variables: prices people are willing to pay, and purchase quantity; and (vi) add to the marketing literature that tests behavioral theories with experimental data using mathematical models.

5.1. Managerial Relevance and Areas for Future Research

This research has implications for package design, pricing, communication, and shelf space. We showed that the shape of a container affects estimated size and through this affects purchase quantity. This has direct implications for package design.

Specifically, perceived area implications may apply to the surface area of packages as seen on retail shelves. If consumers want to buy the "biggest" box of detergent within a price range and do not peruse the unit price information (Dickson and Sawyer 1986), then the shelf facing that is perceived to have the largest surface area will be chosen. Thus, tall rectangular boxes have two advantages over square ones of equal volume: more fit on a shelf facing and greater perceived volume. The variation in shapes of cereal boxes suggests that this is not conventional wisdom in the packaging industry.

The experiments showing the difference in perceptions of area of a square as a function of the salience of the diagonal versus side suggest that displays using such shapes would benefit from an arrangement where the box is placed on its corner rather than on its side. We also have strong evidence for other managerially relevant effects of area perception. Contextual presentation can be used as a managerially actionable tool. Clever graphics can lead to a perception of a larger package. If certain dimensions of a package are larger than others (rectangular cartons), these dimensions could be made salient with the use of graphics like double sided arrows or lines through the longest dimension. Or, their manner of presentation in a store layout, advertisement, or Web layout, could be managed appropriately. For example, in a pizzeria, where visual information about the sizes of different pizzas is presented, it is clear that simply showing the "larger" pizza is inadequate for consumers to appreciate the increase in size between a small, medium, and large pizza. Additional information about the size of the larger pizzas should allow pizzerias to charge a higher price for their larger pizzas (i.e., offer a smaller volume discount).

Aside from deciding on what package shape and graphics to have, it is also important how package information is communicated to consumers. Not enough companies are focusing attention on this. Again, a simple example of this is fast-food pizza parlors where some parlors give size dimensions in diameter, whereas others paste up a picture of the different sized pizzas. Our research suggests that consumers understand the size increase more readily when presented with pictures of the various sizes versus when merely presented with the diameters. The best strategy, however, is to give the actual area numerically where consumers are willing to pay more than under linear dimension or graphic descriptions. This should be particularly relevant for those businesses that rely on takeout or order-in using menus. Such pizzerias should not rely on providing mere diameter or side information about sizes, because consumers are unable to apply these accurately to compute overall size.

Our results also suggest that offering a discount on two small pizzas may be perceived as more favorable than a discount on one large pizza of the same total area, which may go some way to explaining the success of 2-for-1 pizza outlets. This may also suggest that ''2-for-1'' or ''buy 1, get 1'' promotions may be particularly effective, compared to economically equivalent discounts on larger packages.

However, we need to exercise caution before applying these findings directly to the field. The tasks here were all done in a within-subjects domain, and the model proposed is a model of *comparisons.* It is unclear whether the model will translate into contexts where consumers do not make choices between different container sizes/shapes, but decide on a buy/no buy decision (i.e., make a monadic purchase decision for a single product).

Future research could examine whether there are systematic differences in the quantity that consumers purchase as a function of the shape of the product packaging: e.g., ''Are there differences in purchase quantity of bottles versus cans versus tetra-packs used to market drinks?'' One may expect that when people are trying to limit consumption or when consumption level is expected to be fixed, then there would be an inverse relationship between perceived size and purchase quantity, but when utility is monotonically related to amount consumed, then the relationship would be direct. For example, in the product category of beer, bottles are more elongated than cans. Does this suggest that fewer bottles compared to cans will be purchased per purchase occasion in certain situations and the reverse in other situations?

Furthermore, future research could examine the total volume that is purchased when people buy many small-sized packages (e.g., single serving packs of chips, cans of soda) versus single larger-sized packages (party-sized bags or large soda bottles)? If larger sizes are underestimated, this suggests that controlling for desired consumption level, a larger absolute quantity would be purchased when larger containers are purchased as compared to smaller containers.

Furthermore, the results in this paper have implications for the amount people are willing to pay as a function of the elongation of a package. Do more elongated packages charge a higher price? Are national brand names more likely to be in more elongated packages, compared to package shapes that minimize package wastage? Furthermore, this raises the issue of how package shape and size affect likelihood of purchase. Based on these studies, one would expect that controlling for price, more elongated shapes would be perceived as better value for money.

Another issue that is raised by our studies is whether there are ancillary effects of package aesthetics, i.e., are some shapes and ratios more pleasing to the eye than others? There is plenty of anecdotal evidence that the ratio of ϕ ($\phi \approx 1.618$) was used from pre-Pythagorean times and common during the time of Euclid, with continuing use by Fibonacci (Herz-Fischler 1987). Its almost mystical properties have gained it the name of the ''divine proportion,'' or the ''Golden ratio,'' and it is believed to have special esthetic properties, with famous paintings and architectural monuments (e.g., the Parthenon) based on such a ratio (Ghyka 1977). An interesting application of the perceived-size effects noted in this paper would be to assess whether an elongation proportion of ϕ brought with it additional attitudinal benefits. As such, this would extend the perceptual distortion literature into an affective domain.

Will the effects noted in the paper translate from aerial views to frontal views? If they do, they may have implications for store layout and and be a starting point for those interested in examining route choice. Future research could also examine the role of individual factors in moderating area perception biases. Do area perception biases reduce for people who have a high need for cognition? Or may they increase? How do individual differences in visual versus verbal ability affect the manner in which people use visual cues? Are those with a high visual imagery ability less or more likely to be prone to the shape and size biases? If so, would the effects be moderated by cross-cultural factors as countries differ in the visual/semantic aspect of their script (e.g., Chinese versus English)? Further research on contextual factors can also investigate the effect of ''framing'' on area perception. Does a circle framed in a square look smaller or larger than the other way round?

How do people make such judgments? Theoretically, the limits to the effects noted in this paper need to be established. Can biases in perception of size be reduced through adequately motivating consumers? What about biases in perceptions of shape? Our work leads us to suspect that if there is a simple algorithm available for making area comparisons from linear judgments, high motivation can remove the bias; otherwise, the bias remains. These are important issues from the point of consumer welfare, as they inform whether these biases can be reduced through appropriate incentives. Can consumer education help in this regard, or must regulators insist on more prominent displays of quantity information on packages?

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Appendix 1

The reservation price is modeled as a linear function of *perceived* area, which in turn is a power function of *true* area. Because our measures are of reservation price and *true* area, and our hypothesis is on the rate of increase of reservation price with true area, we take a first order approximation of the combined function, which is both convenient and adequate for our purposes. First, we derive the relation between the true area and the estimated area from our proposition. For ease of exposition, we assume $L = w$

$$\text{Let } A_t == \text{true area} == KL^2$$

where K is a geometric constant dependent on shape.[13]

$$\text{Let } A_e == \text{perceived area.}$$

Let R_{ms} be the criteria ratio (see Equation (2)) between the medium and small sizes. We interpret this ratio as being the ratio between estimated areas, that is,

$$A_e(\text{medium}) = R_{ms}A_e(\text{small}) = (L_m/L_s)^{1+\alpha}A_e(\text{small}), \quad (1)$$

$$\frac{A_e(\text{medium})}{L_m^{1+\alpha}} = \frac{A_e(\text{small})}{L_s^{1+\alpha}}. \quad (2)$$

The true area $A_t(\text{med}) = KL_m^2$, implying

$$[A_t(\text{med})/K]^{(1+\alpha)/2} = (L_m^2)^{(1+\alpha)/2}. \quad (3)$$

Substituting into the denominator of Equation (4):

$$\frac{A_e(\text{medium})}{[A_t(\text{med})/K]^{(1+\alpha)/2}} = \frac{A_e(\text{small})}{[A_t(\text{small})/K]^{(1+\alpha)/2}}. \quad (4)$$

This ratio is constant for *all* sizes for any one individual, but of course varies across individuals i. Define this individual ratio constant as C_i, which captures individual differences in converting eyeballed graphic sizes to numbers. Substituting C_i for the LHS of Equation (4) and rearranging, we write

$$A_e(\text{small}) = C_i[A_t(\text{small})/K]^{(1+\alpha)/2}. \quad (5)$$

Define: $\beta = (1 + \alpha)/2$. Then

$$A_e(\text{small}) = C_iK^{-\beta}[A_t(\text{small})]^{\beta}. \quad (6)$$

And, in fact, for any size, we have the following relation between true and perceived areas.

$$A_e = C_iK^{-\beta}A_t^{\beta}. \quad (7)$$

Next, assume customers will pay a fixed price, f, and a per-*perceived*-square-inch price, m, for pizza:

$$RP = f + mA_e. \quad (8)$$

Or in terms of true area,

$$RP = f + mC_iK^{-\beta}A_t^{\beta}. \quad (9)$$

A Taylor expansion of $RP = g(A_t)$ to first order

$$RP = a + b*A_t \quad (10)$$

gives a marginal fee per *true* square inch

$$b = \beta mC_iK^{-\beta}A_0^{\beta-1}, \quad (11)$$

where A_0 is the true area value about which the function is expanded. Unless A_0 is chosen very large, b is increasing in β, and

[13]For a square when the linear dimension is the side, the value of K is one. For other figures and linear dimensions, K is typically somewhat less than one. For a circle when the linear dimension is diameter, for example, K is π/4.

hence in the adjustment exponent α. This suggests that if the exponent varies across information conditions, we can detect it in the empirical relation between reservation price and true area by running regressions for each of the information conditions

$$RP_{info} = a_{info} + b_{info}A_t, \tag{12}$$

and measuring slopes. The intercept reflects that the expected fixed fee may be different for pizzas displayed in the three different information presentation conditions (real prices of different size pizzas show a nonzero intercept, consistent with a fixed fee plus constant marginal price structure). The parameter of interest, b_{info}, includes the perceptual bias in judging size increases, and any quantity discount consumers expect. In summary, Hypotheses 4 and 5 imply, respectively,

$$b_{linear} < b_{graphic}, \tag{13}$$

$$b_{graphic} < b_{area}. \tag{14}$$

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