Comparison-Induced Distribution-Density Effects on Recall of Values from Memory

Jessica M. Choplin (jchoplin@depaul.edu) and Victoria Bolender
DePaul University Department of Psychology
2219 North Kenmore Avenue
Chicago, IL 60614-3504

Abstract

Choplin's (2004) model of distribution-density effects (see also Choplin & Hummel, 2002) makes the odd prediction that in a skewed distribution the smallest and largest values will often be judged larger when drawn from a negatively skewed distribution than when drawn from a positively skewed distribution. This prediction is contrary to empirical findings reported in the rather large distribution-density effect literature, which has, for the most part, used category ratings as the dependent measure. The experiments reported here investigated this odd prediction using recall of values from memory as the dependent measure. The findings support the predictions of Choplin's model and are not predicted by other models of distribution-density effects.

Density Effects

Evaluations of attribute values such as grades (Wedell, Parducci, & Roman, 1989), taste (Riskey, Parducci, & Beauchamp, 1979), visual velocity (Sokolov, Pavlova, & Ehrenstein, 2000), prices (Niedrich, Sharma, & Wedell, 2001), income (Hagerty, 2000) and so forth often depend upon the density—or frequency—of the distribution from which values are drawn (Krumhansl, 1978; Parducci, 1965, 1995). In particular, evaluation functions are typically concave (downward) for positively skewed distributions and convex (concave upward) for negatively skewed distributions. Values drawn from positively skewed distributions are also judged larger than are values drawn from negatively skewed distributions when category ratings are used as the dependent measure.

Several explanations for these effects have been proposed. Parducci's (1965) Range-Frequency Theory assumes that people are aware of and use percentile rank information to evaluate attribute values. Range-Frequency Theory explains the finding that evaluation functions are often concave for positively skewed distributions, because the density at the lower end of positively skewed distributions gives low values larger percentile rank scores than they would have had otherwise. The slope of the function becomes shallow at the sparse upper end of the distribution where percentile rank scores increase at a slower rate. The reverse pattern of changes in percentile rank scores in negatively skewed distributions explains the finding that evaluation functions are often convex for negatively skewed distributions. Because percentile rank scores remain constant for the smallest (percentile rank = 0.0) and largest (percentile rank = 1.0) values regardless of the skew of the distribution (as do range values), Range-Frequency Theory predicts that judgments of the smallest and largest values ought not to be affected by the skew of the distribution.

Haubensak (1992) suggested an alternative explanation for density effects on evaluations of sequentially presented values. He argued that since people do not know the distribution density and range in advance, they tend to assume that early values are typical or average and they assign them intermediate verbal labels or category ratings. After these initial labels or category ratings have been assigned, people are obliged to use them consistently. Since early values are most likely to come from the dense portion of skewed distributions, the portion of the range at the dense end of these distributions will be smaller than the portion of the range at the sparse end. To cover the entire range of values the remaining verbal labels or category ratings would have to be assigned asymmetrically. This process of assigning category labels to magnitude values almost always produces a pattern of evaluation in which values (including the smallest and largest values) are judged larger when they are drawn from a positively skewed than from a negatively skewed distribution. Occasionally, if an early value is assigned a high or a low value rather than an intermediate value, a high or a low value might be judged larger when drawn from a negatively skewed distribution than from a positively skewed distribution (see Haubensak, 1992, Figure 3 right panel), but both would not be (Haubensak, personal correspondence, January 21, 2006).

Comparison-Induced Distortion Theory

Choplin and Hummel (2002) and Choplin (2004) proposed that their Comparison-Induced Distortion Theory of attribute-value evaluation might explain some density effects (see also Choplin & Hummel, 2005). Comparison-Induced Distortion Theory (CID Theory, Choplin, 2004; Choplin & Hummel, 2002, 2005) is a theory of attribute-value evaluation in which verbal magnitude comparisons (e.g., "This portion is larger than that portion," "Hamburger A is more fattening than Hamburger B," and so forth) systematically bias how people perceive, conceptualize, judge, and recall attribute values. Such magnitude comparisons are very common in everyday conversation; and verbal magnitude comparisons that people articulate to themselves subvocally appear to be ubiquitous (Choplin & Hummel, 2005).

CID Theory starts with the observation that because people use verbal comparisons in their daily lives to refer to specific quantitative values and differences, verbal comparisons become associated with these particular quantitative values and differences (Rusiecki, 1985). To illustrate the principle that comparisons are associated with values and differences, Choplin and Motyka (2006) showed a group of pretest participants a portion of "mashed potatoes" that was approximately 2.8cm in diameter on a photograph of a plate that was approximately 9.0cm in diameter as shown in the top of Figure 1. The experimenters then asked these participants to imagine and draw a larger portion size on an empty plate like the one shown in the bottom of Figure 1. The median portion size participants drew was approximately 5.2cm in diameter. We will call imagined sizes like this 5.2 cm diameter size *comparison-suggested sizes*, because they are the sizes that are suggested by comparisons. Of importance to the current discussion, the difference between the portion size that participants viewed and the portion size they drew was approximately 2.4 cm diameter on average (5.2cm minus 2.8cm). We call imagined differences such as this 2.4cm difference *comparison-suggested differences*, because they are the differences that are suggested by comparisons. Notice that this difference is defined empirically as the mean or median of the differences imagined by a control group. While Comparison-Induced Distortion Theory relies upon this quantitative notion of a comparison-suggested difference, this quantity is not a free parameter of the model. It is fixed *a priori* by the responses of a control group.

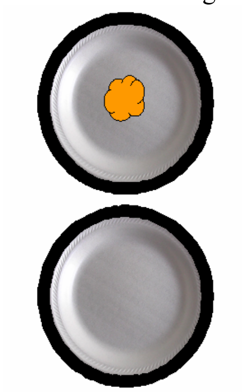


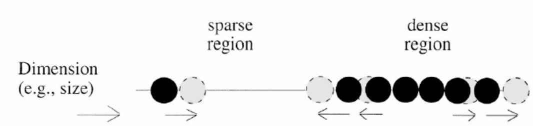
Figure 1. Stimuli used to measure a comparison-suggested difference in portions of "mashed potatoes."

The basic idea underlying CID Theory is that when people's eyes tell them one thing and the sizes suggested by verbal comparisons tell them something different, people will combine the two sources of information by taking a weighted average of the visual and the comparison-suggested sizes. For example, if the actual difference between two compared portion sizes was only 0.6cm diameter (i.e., less than the comparison-suggested difference of 2.4cm diameter), then averaging the two sources of information would bias judgments of the sizes apart toward the 2.4cm diameter comparison-suggested difference. The smaller portion would be judged smaller and the larger portion would be judged larger than they would have been judged otherwise. Likewise, if the actual difference between two compared portion sizes were 3.6cm diameter (i.e., more than the comparison-suggested difference of 2.4 cm diameter), then averaging the two sources of information would bias judgments of the sizes together toward the 2.4 cm diameter comparison-suggested difference. The smaller portion would be judged larger and the larger portion size would be judged smaller. Note that we use the term "judgment" to refer to any measure by which participants might assess magnitude values including category or line ratings, magnitude estimation, judgments on a correlated dimension, or—in the case of the experiments reported below—recall of values from memory.

To demonstrate this principle, Choplin and Motyka (2006) asked participants to view two portion sizes. One group viewed pictures of two portion sizes (2.7cm and 3.3cm in diameter), one presented after the other, that differed by a small amount (a difference of 0.6 cm diameter). A second group viewed two pictures of portion sizes (2.7cm and 7.3cm in diameter) that differed by a large amount (a difference of 4.6cm diameter). Participants later redrew the sizes from memory. The group that had seen the sizes that differed by a small amount redrew sizes such that the average difference between the diameters of the two sizes was 1.6cm, a difference that was reliably larger than the actual difference of 0.6cm, $t(38)=6.53$, $p<.05$. The group that had seen the sizes that differed by a large amount redrew sizes such that the average difference between the diameters of the two sizes was 3.6cm, a difference that was reliably smaller than the actual difference of 4.6cm, $t(38)=9.33$, $p<.05$. This basic pattern of comparison-induced bias was originally reported by Choplin and Hummel (2002) and has been replicated in scores of unpublished experiments.

Comparisons Might Create Density Effects

Comparison-induced biases like those just described might produce distribution-density effects. To intuitively understand how comparisons could create distribution-density effects, consider the negatively skewed distribution presented in Figure 2 (black circles represent presented values; gray circles represent comparison-biased values).



from Choplin and Hummel (2002)

Figure 2: Comparison-induced biases in a negatively skewed distribution.

Values in dense regions will be more likely to differ from each other by less than a comparison-suggested difference than will values in sparse regions. Or if they differ from each other by more than a comparison-suggested difference, the degree to which these differences exceed the comparison-suggested difference will be less than the degree to which values in sparse regions exceed this difference. Comparisons between values in dense regions will, therefore, either be more likely to bias judgments apart or be less likely to bias judgments together than will comparisons between values in sparse regions.

By contrast, values in sparse regions will be more likely to differ from each other by more than a comparison-suggested difference than will values in dense regions. Or if they differ from each other by less than a comparison-suggested difference, the degree to which these differences subceed the comparison-suggested difference will be less than the degree to which values in dense regions subceed this difference. Comparisons between values in sparse regions will, therefore, either be more likely to bias judgments together or be less likely to bias judgments apart than will comparisons between values in dense regions.

The overall effect of these comparison-induced biases would be a pattern of evaluation in which values are biased away from dense regions and toward sparse regions. Values on the boundary between dense and sparse regions, such as the second value from the left in Figure 2, would be biased toward sparse regions (downward in the case of the negatively skewed distribution shown in Figure 2). Values at the tail of a skewed distribution (the sparse region) will either be more likely to be biased toward the values to which they are compared or be less likely to be biased away from these values than will values at the head of a skewed distribution (the dense region).

Small values placed at the tail of a negatively skewed distribution, for example, would either be more likely to be biased upward toward the values to which they would be compared or be less likely to be biased downward away from these values than they would have been had they been placed at the head of a positively skewed distribution. Small values should, therefore, be judged (recalled in the experiments reported below) larger when placed within a negatively skewed distribution than when placed within a positively skewed distribution. Likewise, values placed at the head of a negatively skewed distribution (i.e., large values), would either be more likely to be biased upward away from the values to which they would be compared or be less likely to be biased downward toward these values than they would be had they been placed at the tail of a positively skewed distribution. Large values should, therefore, also be judged (recalled) larger when placed within a negatively skewed distribution than when placed within a positively skewed distribution. To see the mathematical model and simulations demonstrating how this prediction is a necessary consequence of Comparison-Induced Distortion Theory please refer to Choplin (2004).

No previous model of distribution-density effects (Haubensak, 1992; Krumhansl, 1978; Parducci, 1965, 1995) predicts the pattern of biases that is predicted by Comparison-Induced Distortion Theory. In fact, the predictions of Comparison-Induced Distortion Theory are contrary to virtually all previous empirical findings. The literature on distribution-density effects has consistently found that values drawn from positively skewed distributions are judged larger than values drawn from negatively skewed distributions. However, these empirical studies have primarily used category ratings as the dependent measure, although they have occasionally also used line analog or similarity ratings as the dependent measure. Category and line analog ratings might be inadequate to test these predictions, because they might be rescaled to reflect the range of values (Choplin, 2004; Volkmann, 1951). Similarity ratings are also inadequate to test these predictions because they involve only pairwise judgments. Choplin and Hummel (2002) argued that recall of values from memory might be used to investigate how people conceptualize values (see also Huttenlocher, Hedges, & Vevea, 2000).

The goal of the research reported here was to investigate whether empirical support for the predictions of Comparison-Induced Distortion Theory could be found using recall of values from memory as the dependent measure. Note that Figure 2 was published in 2002, the mathematical model of the theory was published in 2004, and the empirical tests of the theory reported here were run in the spring of 2005. The experiments reported here, therefore, tested a strong *a priori* prediction of the model. It was a necessary consequence of the model that at the time had no empirical support and, in fact, seemed contrary to reported empirical findings.

Note also that in modeling work not reported here, we fit the mathematical model of Comparison-Induced Distortion Theory to the results presented below. To do so, we empirically measured the differences suggested by hamburger-calorie comparisons and investigated a number of possible comparison strategies that would determine which values get compared to which (e.g., all pairwise comparisons, random subset of pairwise comparisons, comparisons to the most recent values, comparisons to similar values, etc.). This modeling work will not be reported here, but note that the qualitative predictions described above hold regardless of the exact differences suggested by hamburger-calorie comparisons or which values are compared to which.

Experiment 1

The purpose of Experiment 1 was to investigate patterns of bias in recall of values from memory. Comparison-Induced Distortion Theory predicts that recall will be biased away from dense regions and towards sparse regions. Therefore, the smallest and largest values of a skewed distribution will often be recalled larger when placed in a negatively skewed distribution than when placed in a positively skewed distribution.

Method

Participants. One hundred people volunteered to participate after being approached by the experimenter on the DePaul University campus or in the surrounding community (50 in the positively skewed condition and 50 in the negatively skewed condition).

Materials and Procedure. Participants viewed seven hamburgers and their respective caloric values presented in either an ascending or a descending order. The hamburgers and their associated caloric values were placed within either a negatively skewed or a positively skewed distribution as shown in Table 1. We were primarily interested in recall of three values: the ¼ lb. Burger, ½ lb. Big Double Burger, and

⅔ lb. Monster Double Burger. To create a positively skewed distribution of values, four hamburgers with caloric values between the caloric values of the ¼ lb. Burger and the ½ lb. Big Double Burger were included in the distribution of values. To create a negatively skewed distribution of values, four hamburgers with caloric values between the caloric values of the ½ lb. Big Double Burger and the ⅔ lb. Monster Double Burger were included in the distribution of values. To ensure that participants spent some time processing the seven values, they were asked whether they were surprised by the number of calories in the distribution of hamburgers. Participants were then given a distracter task followed by a surprise recall task in which they recalled the number of calories in each of the seven hamburgers. Participants were instructed to estimate values, if they could not recall exact values.

Table 1. Presented distributions of calories associated with hamburgers.

Positively Skewed Distribution	
Hamburger	Calories
1/4 lb. Burger	**564.0**
1/3 lb. Cheeseburger	599.9
1/3 lb. Bacon Cheeseburger	635.8
1/3 lb. Deluxe Burger	671.7
1/3 lb. Double Burger	707.6
1/2 lb. Big Double Burger	**743.5**
2/3 lb. Monster Double Burger	**923.0**
Negatively Skewed Distribution	
Hamburger	Calories
1/4 lb. Burger	**564.0**
1/2 lb. Big Double Burger	**743.5**
2/3 lb. Big Bacon Double Burger	779.4
2/3 lb. Big Bacon Double Deluxe Burger	815.3
2/3 lb. Super Bacon Double Burger	851.2
2/3 lb. Super Big Bacon Double Deluxe Burger	887.1
2/3 lb. Monster Double Burger	**923.0**

Results

Because we were interested in participants' recall of the distribution of values and not in whether participants could correctly associate the number of calories with each hamburger, each participant's list of recalled calories was sorted from smallest to largest. The smallest recalled value was associated with the ¼ lb. Burger. The second recalled value in the negatively skewed distribution and the sixth recalled value in the positively skewed distribution were associated with the ½ lb. Big Double Burger. Finally, the largest recalled value was associated with the ⅔ lb. Monster Double Burger. The results are presented in Table 2. Consistent with the predictions of Comparison-Induced Distortion Theory and inconsistent with other models of distribution-density effects, the smallest and largest values were recalled significantly larger when they were placed within the negatively skewed distribution than when they were placed within the positively skewed distribution. That is, participants recalled more calories in the ¼ lb. Burger when it was placed in a negatively skewed distribution of values (527.9 calories) than when it was placed in a positively skewed distribution of values (433.7 calories; actual number 564 calories), $t(98)=3.44$, $p < .01$. Participants also recalled more calories in the ⅔ lb. Monster Double Burger when it was placed in a negatively skewed distribution of values (974.2 calories) than when it was placed in a positively skewed distribution of values (903.4 calories; actual number 923 calories), $t(98)=2.46$, $p < .05$. Also as predicted by Comparison-Induced Distortion Theory (see Figure 1) and analogous to the predictions of other models of distribution-density effects, participants recalled more calories in the ½ lb. Big Double Burger when it was placed in a positively skewed distribution of values (793.4 calories) than when it was placed in a negatively skewed distribution of values (637.4 calories; actual number 743.5 calories), $t(98)=6.43$, $p < .01$. This result is particularly problematic for Huttenlocher and her colleagues' category adjustment model (Huttenlocher et al., 2000), as the recalled number of calories was systematically biased away from the central tendency of the category.

Table 2. Recalled number of calories in Experiment 1. As predicted, recall of the smallest and largest values was generally biased away from the tail of the distribution and in the direction of the head. The value on the borderline between the sparse and the dense regions of the distribution was biased away from the dense regions.

Hamburger	Positive skew	Negative Skew
¼ lb. Burger	433.7	527.9
½ lb. Big Double Burger	793.4	637.4
⅔ lb. Monster Double Burger	903.4	974.2

Experiment 2

The results of Experiment 1 supported the predictions of Comparison-Induced Distortion Theory. However, the sequences in which values were presented might have made this pattern of results particularly likely. In particular, caloric values were presented simultaneously in either an ascending or a descending order in Experiment 1. This format might have constrained participants to make primarily pairwise comparisons among adjacent values. However, the qualitative predictions of Comparison-Induced Distortion Theory do not depend upon values being compared in any particular order (although quantitative predictions might differ somewhat, Choplin, 2004; Choplin & Hummel, 2005). Rather, Comparison-Induced Distortion Theory makes the same qualitative predictions across a variety of comparison strategies (strategies that determine which values get compared to which). The purpose of Experiment 2, therefore, was to investigate whether the effects observed in Experiment 1 generalize to random sequences of values and to sequential presentation of values. Half of the participants viewed hamburgers and their associated caloric values presented simultaneously and the other half viewed them presented sequentially.

Method

Participants. Two hundred volunteers participated after being approached by the experimenter on the DePaul University campus. There were fifty participants in the negatively skewed condition and fifty participants in the positively skewed condition in each of the simultaneous-presentation and sequential-presentation conditions.

Materials and Procedure. Fifty random sequences were created for each of the positively and negatively skewed distributions of values presented in Figure 1. Participants in the simultaneous-presentation condition viewed these seven values presented in order from top to bottom on the same page. Participants in the sequential-presentation condition saw the exact same sequences as did the participants in the simultaneous-presentation condition, but each of the seven values was presented on a separate page. To ensure that participants spent some time processing these values, they judged whether the numbers of calories in the hamburgers were surprising. Participants then completed a distracter task and recalled the number of calories in the seven hamburgers they had viewed in any order. Participants were instructed to estimate, if they could not recall exact values.

Results and Discussion

Each participant's list of recalled caloric values was sorted from smallest to largest. The smallest recalled value was associated with the ¼ lb. Burger. The second recalled value in the negatively skewed distribution and the sixth recalled value in the positively skewed distribution were associated with the ½ lb. Big Double Burger. Finally, the largest recalled value was associated with the ⅔ lb. Monster Double Burger. The results are presented in Table 3.

Table 3. Recalled number of calories in Experiment 2. Replicating Experiment 1, recall of the smallest and largest values was generally biased away from the tail of the distribution and in the direction of the head. The value on the borderline between the sparse and the dense regions of the distribution was biased away from the dense regions.

Simultaneous Presentation	Positive skew	Negative skew
¼ lb. Burger	521.3	576.6
½ lb. Big Double Burger	778.4	664.9
⅔ lb. Monster Double Burger	868.6	898.6
Sequential Presentation		
¼ lb. Burger	506.3	551.2
½ lb. Big Double Burger	748.6	664.2
⅔ lb. Monster Double Burger	876.3	914.8

Consistent with the predictions of Comparison-Induced Distortion Theory and inconsistent with other models of distribution-density effects, the smallest and largest values were recalled significantly larger when they were drawn from the negatively skewed distribution than when they were drawn from the positively skewed distribution. That is, for the ¼ lb. Burger there was a main effect of the type of distribution in which it was placed such that participants recalled more calories in the ¼ lb. Burger when it was placed in a negatively skewed distribution of values (563.9 calories) than when it was placed in a positively skewed distribution of values (513.8 calories; actual number 564 calories), $F(1,196)= 14.66$, $p < .01$. There was no main effect of the type of presentation, $F(1,196)=2.38$, $p>.05$, nor an interaction, $F(1,196)= 0.16$, $p>.05$. There was also a main effect of the type of distribution in which the ⅔ lb. Monster Double Burger was placed such that participants recalled more calories when it was placed in a negatively skewed distribution of values (906.7 calories) than when it was placed in a positively skewed distribution of values (872.45 calories; actual number 923 calories), $F(1,196)= 9.58$, $p<.01$. There was no main effect of the type of presentation, $F(1,196)= 1.16$, $p>.05$, nor an interaction, $F(1,196)= 0.14$, $p>.05$.

Finally, as predicted by Comparison-Induced Distortion Theory (see Figure 1) and analogous to the predictions of other models of distribution-density effects, participants recalled more calories in the ½ lb. Big Double Burger when it was placed in a positively skewed distribution (763.5 calories) than when it was placed in a negatively skewed distribution (664.55 calories; actual number 743.5 calories), $F(1,196)=71.56$, $p<.01$. This result is particularly problematic for Huttenlocher and her colleagues' category adjustment model (Huttenlocher et al., 2000), as the recalled number of calories was systematically biased away from the central tendency of the category. Again, there was no main effect of the type of presentation, $F(1,196)=1.70$, $p>.05$, nor an interaction, $F(1,196)=1.54$, $p>.05$.

General Discussion

Comparison-Induced Distortion Theory (Choplin, 2004; Choplin & Hummel, 2002, 2005) makes the unique prediction among theories of distribution-density effects that the smallest and largest values in a skewed distribution should often be judged larger when drawn from a negatively skewed distribution than when drawn from a positively skewed distribution. Two experiments found evidence for such a pattern using recall of values from memory as the dependent measure. In Experiment 1, hamburgers and their associated caloric values were presented simultaneously in either an ascending or a descending order. In Experiment 2, hamburgers and their associated caloric values were presented in random orders wherein the seven hamburgers were presented either simultaneously on the same page or sequentially on seven separate pages. The results supported the predictions of Comparison-Induced Distortion Theory across all orders and types of presentation.

Category ratings are often used to measure people's evaluations of magnitude. The dissociation between the effects of distribution density on category ratings and the effects of distribution density on recall of values from memory raises the concern that researchers might be relying too heavily upon category ratings to measure human magnitude evaluation. Category ratings might be particularly susceptible to biases such as primacy effects (Haubensak, 1992) and rescaling to reflect the psychological range of values (Volkmann, 1951), which might vary even if the presented range is held constant (Choplin, 2004).

We do not think that recall of values from memory is necessarily a better measure of magnitude evaluation than category ratings. Recall of values from memory is susceptible to its own biases. Rather, we think that researchers should try to measure human magnitude evaluation by seeking converging evidence across a variety of dependent measures. Each measure will undoubtedly have its own biases, but together these measures will provide a more thorough, multifaceted picture of human magnitude evaluation.

Conclusions

The experiments reported here suggest that some density effects are likely created by verbal comparison-induced biases. Verbal comparisons between values in dense regions will tend to bias values away from each other (or, at least, will be less likely to bias values toward each other). Verbal comparisons between values in sparse regions will tend to bias values toward each other (or, at least, will be less likely to bias values away from each other). These biases produce distribution-density effects.

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