Graph Framing Effects in Decision Making

Abstract

This study manipulated the graphical representation of options by framing the physical characters in figures and found that preferences could be affected even when the words and numbers of the problem were constant. Based on attribute substitution theory and an equate-to-differentiate approach, we proposed a two-process model of graph framing effects. In the first mental process, the graph editing process, the physical features (e.g., distance, size) represented in the graph are visually edited and the perceived numerical difference between the options is judged based on its physical features. The second mental process, the preferential choice process, occurs by an equate-to-differentiate approach. People seek to equate the difference between options on the dimension on which the difference is smaller, thus leaving the greater other-dimensional difference to be the determinant of the final choice. Four experiments tested graph framing effects. Experiment 1 found a graph framing effect in coordinate graphs resting on the (de)compression of the scales employed in figures. Experiment 2 revealed additional graph framing effects in other question scenarios and showed that preference changes were mediated by perceived numerical distances. Experiment 3 further confirmed graph framing effects in sector graphs rather than in coordinate ones. Experiment 4 suggested that such graph framing effects were eliminated when encouraging logical processing (e.g., introducing a mathematical operation before a choice task). This paper discusses related research and a possible substrate basis for graph framing effects.

Keywords: decision making, framing effect, graph, attribute substitution

Introduction

Graphs often help to clarify communication. However, the graphical format per se can sometimes shape our preferences. This study investigated a newly identified decision making bias: graph framing effects that can be caused by graph manipulation.

As an introduction to the study itself, we begin by discussing traditional framing effects in decision making. We then review spatial framing studies that have not been previously recognized as being related to decision framing effects. Next, we introduce the concept of graph framing and propose a mental process model of graph framing effects: the Graph-edited Equate-to-differentiate Model. Finally, we review previous research on framing effects involving graphic displays of choice outcomes and present a summary of the four experiments in this study.

Framing effects in decision making

One of the axioms of normative economic theory, the description invariance principle, requires that equivalent descriptions of a problem yield the same preference ordering. However, a number of studies have revealed that people often violate the invariance principle in real-world decision making. This is called preference framing effects in decision making.

In their seminal work on framing, Tversky and Kahneman (1981) reported that a preference could be shifted if a problem was described in different frames. That is, when the outcomes of risky choice options were described in terms of gains, decision makers were risk averse; but when outcomes were described in terms of losses, decision makers were risk-seeking, even when outcomes and probabilities were the same. Various researchers have found converging evidence that such framing effects can be replicated in decisions (Fagley & Miller, 1997; Kühberger & Tanner, 2010; Marteau, 1989; McElroy & Seta, 2003; McGettigan, Sly, Connell, Hill & Henry, 1999; Schneider, 1992; Wang, Simons & Bredart, 2001). The available evidence shows that framing effects for risky-choice type problems are small to moderate in strength (for reviews see Kühberger, 1998; Levin, Schneider, & Gaeth, 1998).

In addition to risky-choice problems, there are numerous framing effects that do not involve risk. For example, Levin (1987) and Levin and Gaeth (1988) evaluated the associative effects of various ways of framing consumer information and found that consumers' evaluations were more favorable toward beef labeled "75% lean" than toward packages labeled "25% fat." In addition, alternative rating scales in questionnaires might affect people's self-reports. For instance, when asked how successful they have been in life, 34% of responders reported high success when the numeric values of the rating scale ranged from -5 to 5; whereas only 13% did so when the ranged from 0 to 10 (Schwarz, Knäuper, Hippler, Noelle-Neumann, & Clark, 1991).

Framing in spatial judgment

Interestingly, researchers have also discovered that the framing of a spatial attribute can affect spatial judgment When children made volume judgments, Piaget (1968) found that they often reported that the volume had been reduced if a liquid was poured into an equi-volume wider glass. They perceived the volume as having changed simply because a taller container had been replaced by a shorter and wider one. Raghubir and Krishna (1999) even found similar results with adults. They found that participants tended to think that a tall-thin glass contained more ice cream than an equi-volume short-fat glass. In keeping with this spatial framing view, in an area comparison between a square and a highly elongated rectangle of the same area, Krider, Raghubir, and Krishna (2001) found that the rectangle was judged to be larger because the longer dimension of a rectangle appears more prominent than the dimensions of the square.

Graph framing effects

Since spatial judgment can be biased by the framing of a spatial attribute, as reviewed above, we conjectured that framing effects would also appear in decision making problems involving graphs if we manipulated the graphical representations instead of the words or numbers. In order to appreciate the significance of this manipulation, see the MP3 problem in Figures 1 and 2.

> *Consider this task: Imagine that you will buy an MP3. There are two brands (A, B). The brands were scored on two dimensions (repair rate and storage capability). Obviously, you would be glad if you could get an MP3*

with a low repair rate and a high capability. On the basis of the following scores, please indicate your strength of satisfaction for each brand.

Insert Figures 1 and 2 about here

In this MP3 problem, the same numerical and verbal information is provided in each figure, but the prominence of the spatial representation differs as a function of the scale employed in each of the graphs. That is, the storage capability dimension appears to be relatively prominent in Figure 1, whereas the repair rate dimension appears to be relatively prominent in Figure 2. We call this type of framing *graph framing*, which means that the relative prominence of dimensions is manipulated by graphical representations instead of the words or numbers. We predicted that the evaluation of the two brands would be affected by the graph employed. Specifically, the strength of satisfaction with brand A would be higher in participants who saw Figure 2 than in those who saw Figure 1, but the reverse would be true for brand B.

Such a graph manipulation effect shares some common characteristics with traditional framing effects in decision making. For example, the general principle of framing is the passive acceptance of the formulation given in the sense of information process. This principle applies equally to graph framing effects. However, graph framing effects proposed here differ from traditional framing effects in the perceptual process. Note that "perceptual process" in this article literally means the visual perception processes related to the physical features of an object (e.g., size, distance). Graph framing effects suggest that a perceptual process about the physical aspects of the graph could affect preferences. This seems likely because we only manipulated the physical aspects of the actual graphs. The wording of the question and provided numbers were constant. If adjustments in the physical aspects of the graphs were irrelevant to the participants' evaluations, then no significant difference should appear in the participants' preference between the two versions of the graph. In contrast, traditional framing effects usually result from changing the wording of the question a/o related numbers.

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The point, then, is to outline the way that the visual perception of physical features of an option that is graphically represented might affect a preference evaluation. We argue that it might be mediated by the perceived numerical distance. Specifically, in graphs, physical distances between options on a dimension may affect the perceived numerical distance on the same dimension, which in turn might determine the final preference. For example, compared to Figure 2 (i.e., the repair-rate prominent version), the longer physical distance between two brands on the capability dimension in Figure 1 (i.e., the capability-prominent version) could lead decision makers to perceive that the numerical distance on this dimension is greater, and thus that brand B is clearly better than brand A on the capability dimension. Conversely, the shorter physical distance between the two brands on the repair rate dimension in Figure 1 could lead decision makers to perceive that the numerical distance on this dimension is smaller, and thus that brand A is slightly better than brand B on the repair rate dimension. This idea is consistent with the framework of attribute substitution. Kahneman and Frederick (2002) proposed a theory of the heuristic process that is based on attribute substitution. That is, in assessing an attribute (the target attribute, e.g., probability) that is less readily assessed than a related property (the heuristic attribute, e.g., representativeness), people unwittingly substitute the simpler assessment of the heuristic attribute for the assessment of the target attribute. According to Kahneman and Frederick, perceptual salience often drives people to use physical properties as heuristic attributes. In our cases, it is not easy to assess the numerical difference (i.e., a target attribute) between two brands on a dimension, so people might use its physical distance (i.e., a heuristic attribute) as a proxy for these judgments.

If such a substitution process actually occurs, the next question is how the difference in the perceived numerical distance between options on each dimension will affect the final preference. We argue that this process must involve a trade-off between the two dimensions. For example, in the MP3 question above, because neither option dominates the other, the comparison between them involves an evaluation of differences along the repair rate and storage capability axes. Many choice models have been proposed to describe decision making processes that involve a trade-off between dimensions. For example, Li (2003, 2004) demonstrated that human decision making may be explained by an "equate-to-differentiate" approach. This approach addresses pairwise choice situations, in which each alternative is better than the other on one of two dimensions. It models much human choice behavior as a process in which people seek to equate the difference between alternatives on the dimension on which the difference is smaller, thus leaving the greater other-dimensional difference to be the determinant of the final choice. Take the MP3 problem as an example. When the participants were asked to choose between brands A and B, the two options on the "repair rate" dimension were paired as "2%" vs. "6%"; whereas the two options on the "capability" dimension were paired as "1G" vs. "2G". If the subject thinks that one of the two pairs, e.g. 2% vs. 6% or 1G vs. 2Gs, is "more nearly equivalent" according to his or her preconceptions, he or she will choose the option with the better outcome in the "more different" pair. Thus, according to the equate-to-differentiate approach, if the "most different" pair was changed from the "capability" dimension to the "repair rate" dimension in different figures, then a graph framing effect would occur.

Thus, based on the attribute substitution theory and an equate-to-differentiate approach, we propose a two-process model of graph framing effects: Graph-edited Equate-to-differentiate Model. Please see Figure 3. In the first mental process, the graph editing process, the physical features (e.g., distance, size) represented in graph are visually edited and the perceived numerical difference between options is judged based on its physical features. The second mental process, the preferential choice process, occurs by the equate-to-differentiate approach.

Insert Figure 3 about here

Previous research on framing effects also used graphical displays of choice outcomes. For example, in a life-death problem adapted from the Asian disease problem, Wang (2004) found that when a pie-slice chart emphasized only survival outcomes, participants were more risk taking under positive hedonic frames whereas when the whole-pie chart depicted both survival and mortality outcomes, they became risk averse under positive frames. In addition, graphical information perception may be moderated by individual differences. Indeed, when presented an ambiguous Asian disease problem with a whole-pie chart, McElroy, Seta and Waring (2007) found that low self-esteem participants had a relatively greater tendency to perceive the task more negatively. However, the present study differs from these works. In this study we investigated a new framing effect that was caused by graph manipulation. Thus, we kept all the factors except for the graph constant between question versions, rather than changing the wording of outcomes as is done in the Asian disease problem. In contrast, Wang (2004) and McElroy, Seta, and Waring (2007) investigated traditional framing effects within the paradigm of the Asian disease problem. Their primary aim was to explore how decision makers spontaneously encode and frame a choice problem when using pie charts as ambiguous stimuli.

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Summary of Experiments 1–4

In this study we designed four experiments to test graph framing effects; these specifically focused on the Graph-edited Equate-to-differentiate Model we proposed. In Experiment 1, we tried to confirm a graph framing effect using the MP3 problem mentioned above. We expected that the evaluation of the two brands would change as a function of the graph version. In Experiment 2, we created three additional hypothetical scenarios that were similar to the MP3 problem to determine whether the effect of the graph manipulation was reliable across situations. More importantly, using the equate-to-differentiate approach, we tested whether the greater perceived numerical distance determined the final preference. Experiment 3 was designed to detect whether a graph framing effect similar to that found in coordinate graphs (e.g., Figure 1 and Figure 2) in Experiments 1 and 2 could also be identified in sector graphs (see the figures in Appendix 2). Furthermore, in Experiment 4, we explored whether attribute substitution (e.g., using physical distance as a proxy to judge numerical distance) could serve as a conceptual underpinning of graph framing effects during perceptual processing. We expected that graph framing effects would be eliminated or reduced if attribute substitution was inhibited (e.g., introducing a mathematical operation before a choice task).

Experiment 1: Testing a graph framing effect in coordinate displays

Method

Participants

The initial participant pool consisted of 195 undergraduate student volunteers who were recruited by poster and all of whom provided oral consent. The participants were tested in small groups ranging in size from 6 to 8. After the experiment, the participants were debriefed and were given a small gift to thank them for their participation. Two incomplete questionnaires were excluded from the analysis.

Materials and Procedure

The MP3 problem, along with several unrelated problems, was presented in questionnaire form in two versions (i.e., a capability-prominent version and a reliability-prominent version). The numerical and verbal information provided in the two versions was the same. The two versions differed only in the scale employed in the figure. That is, Figure 1 was used in the capability-prominent version; whereas Figure 2 was used in the repair rate-prominent version. The participants, who were randomly assigned to one of the two versions, were asked to rate the preference strength for each brand on a 9-point scale ranging from 1 (not at all) to 9 (extremely) for each brand. In the end, 99 participants responded to the capability-prominent version, and the other 94 participants responded to the repair rate-prominent version. Thus, this was a 2 (brand type: *superior capability brand* (i.e., brand B) vs. *superior reliability brand* (i.e., brand A)) × 2 (graph version: *the capability-prominent version* vs. *the reliability-prominent version*) mixed experimental design, with the graph version as the between-subjects factor and the brand type as the within-subjects factor. The dependent variable was the preference strength for an MP3 player.

Manipulation Check

In order to check the effect of graph manipulation on spatial perception, we removed the numbers and labels from Figures 1 and 2. We presented an additional 19 participants with these blank figures and asked them to rate "the difference in the distance between A and B along the abscissa/ordinate" on a 9-point scale ranging from 1 (very small) to 9 (very large) for each figure. The results showed that the rating score was higher for the abscissa ($M = 6.32$) than for the ordinate ($M = 4.26$) for Figure 1 ($t(18) = 4.44$, $p < .01$); whereas the rating score was lower for the abscissa ($M = 3.53$) than for the ordinate ($M = 6.84$) for Figure 2 ($t(18) = -8.19$, $p < .01$). This significant finding indicated that our graph manipulation was strong enough to affect the spatial perception. That is, with respect to the physical distance per se, the difference between A and B along the abscissa was relatively prominent in Figure 1; whereas the reverse was true in Figure 2.

Results and Discussion

A 2×2 ANOVA on the preference strength revealed that the main effect was significant for brand type ($F(1, 191) = 27.13$, $p < .01$). Specifically, the superior reliability brand ($M = 6.16$, $N=99$) was preferred over the superior capability brand ($M = 5.69$, $N=99$) in the capability-prominent version. Also, the superior reliability brand ($M = 6.51$, $N=94$) was preferred over the superior capability brand ($M = 5.18$, $N=94$) in the reliability-prominent version.

More relevant to this study is that the ANOVA also showed a significant interaction between brand type and graph version, $F(1, 191) = 6.09$, $p < .05$, indicating that the effect of the brand type on preference strength was mediated by the graph version. As we predicted, although superior reliability was preferred over superior capability in both graph versions, the size of the preference differed between the two versions. The score difference between two brands was smaller (M_{A-B}=.48, N=99) in the capability-prominent version; whereas the difference was larger (M_{A-B}=1.33, N=94) in the reliability-prominent version. A t-test on the score difference revealed a significant difference between the two versions ($t (191) = 2.47$, $p < .05$). These results indicated a stronger preference toward the superior reliability brand in people shown the reliability-prominent version, compared with those shown the capability-prominent version.

Experiment 1 preliminarily confirmed that a graph framing effect exists in coordinate graphs. That is, simply compressing a scale may have influenced the relevant evaluation when the information was presented in a coordinate graphical format. Contrary to the principle of descriptive invariance, the result of our Experiment 1 indicated that framing the scale in a graph can yield systematic fluctuations in the relevant evaluation, even if the information presented is the same. In addition, it could be argued that the manipulation in spatial prominence might have been confounded by scale resolution. This sounds plausible from an experimental perspective, but the evidence showed that scale resolution did not affect graph framing effects (Sun, Li, & Bonini, 2010).

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Experiment 2: Perceived numerical distances as a mediator of graph framing effects

Experiment 1 confirmed our hypothesis that the evaluation of two brands could be affected by the scale employed in the graphs. However, it yielded no information about the cognitive process involved in this graph framing effect. In addition, some researchers have argued that findings on judgment and decision making are sensitive to the problem scenarios used (Schneider, 1992). It therefore seemed prudent to attempt a replication of our findings in another scenario before making any strong theoretical claims.

The goal of Experiment 2 was thus two-fold. The first was to explore the process of graph framing effects by focusing on the Graph-edited Equate-to-differentiate Model to see whether the preference change was mediated by the perceived numerical distances. The second was to examine whether graph framing effects would also be found in different scenarios.

Method

Participants

The initial participant pool consisted of 200 undergraduate student volunteers who were recruited by poster and all of whom provided oral consent. The participants were tested in small groups ranging in size from 5 to 8. After the experiment, the participants were debriefed and were given a small gift to thank them for their participation. Five incomplete questionnaires were excluded from the analysis.

Materials and Procedure

We employed the same MP3 problem used in Experiment 1 in the second experiment. Following the pattern of the MP3 problem, we also developed three additional, parallel problems involving employee selection, scholarship application and vaccine selection. In each problem scenario, participants needed to judge two options according to two dimensions presented in coordinate graphical displays. Neither option dominated the other, so the comparison between them involved an evaluation of differences along two dimensions. Table 1 outlines the essential features of each of the four problems. For the graphs used in the problems, please see Appendix 1.

As in Experiment 1, this questionnaire consisted of two versions (i.e., an abscissa-prominent version and an ordinate-prominent version). Each version consisted of four problems and was identical except that each contained one of the two different figures for each problem. We randomly assigned the participants to one of the two versions. 99 participants responded to the abscissa-prominent version, while the remaining 96 participants responded to the ordinate-prominent version.

Please note that participants in Experiment 2 were not asked to rate their preference strength for each option, as the participants did in Experiment 1. Instead we asked them to choose a preferred option for each problem and then to evaluate the degree of numerical distance difference between the two options for each dimension. In the employee selection problem, for example, the participants first needed to indicate their preference between two employee candidates. After that, they evaluated the degree to which the two candidates differed on a 9-point scale ranging from 1 (very little) to 9 (extreme) for both a technical knowledge dimension and a human relations dimension.

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Manipulation Check

Similarly to what we did after Experiment 1, we removed the numbers and labels from the figures in the questionnaires to check the effect of graph manipulation. We presented an additional 25 participants with these eight blank figures and asked them to rate "the difference in distance between A and B on the abscissa/ordinate" on a 9-point scale ranging from 1 (very small) to 9 (very large) for each figure. Consequently, the rating scores were higher on the abscissa than on the ordinate for abscissa-prominent figures, and the reverse was true for ordinate-prominent figures. In a result similar to that found in Experiment 1, the differences of the rating scores between the abscissa and the ordinate were significant for all eight figures (all *ps* < .01), indicating that our graph manipulations were strong enough to affect the *spatial perception.*

In addition, to understand whether vertical and horizontal line segment differences are treated similarly, we regressed the rating scores of abscissa on horizontal line segment differences, and the regression coefficient was significant (b=0.69, $p < .01$); then we regressed the rating scores of ordinate on vertical line segment differences and found that the regression coefficient was also significant (b=0.72, $p < .01$). However, the difference between the regression coefficients was not significant, meaning that the manipulation check participants treated vertical and horizontal line segment differences similarly.

Results and Discussion

Results of Choices

With respect to the presentation of the four problems considered in Experiment 2, one option had a comparative advantage on the abscissa dimension and the other had a comparative advantage on the ordinate dimension. In Experiment 2 we predicted that the participants would choose the option that had a comparative advantage in the ordinate dimension more frequently when these problems were presented with the ordinate-prominent versions than when they received the abscissa-prominent versions. The proportions of the choices in the different conditions are summarized in Table 1.

As predicted, compared to the ordinate-prominent version, the proportions of the choices in favor of the superior-Y-dimension option in the abscissa-prominent version decreased for all the four problems. The differences between graph versions were all significant ($ps < .05$). These data support a generalization of graph framing effects.

Insert Table 1 about here

Mediational Analysis

The purpose of the mediational analysis was to see whether a graph framing effect was mediated by the perceived numerical distance on each dimension and thus the equate-to-differentiate approach would be able to model the underlying process of the trade-off between dimensions. In the following analysis (cf. Baron & Kenny, 1986), we tested whether the effect of version condition on choice preference was mediated by rating the score differences between the ordinate dimension and the abscissa dimension ($SCORE_{Y\text{-}X}$). A higher $SCORE_{Y\text{-}X}$ would indicate that the numerical distance difference in the ordinate dimension between options A and B was perceived as larger than the difference of the abscissa dimension. The version condition and the choice preference, as categorical variables, were recoded as dummy variables. As a result, abscissa-prominent/ordinate-prominent versions were recoded as 1and 0, respectively, and the participants' choice of A/B in the decision making process was recoded as 1and 0, respectively.

Take the employee selection problem in Table 2 as an example. First of all, a regression analysis revealed a significant regression weight for the version condition predicting the choice preference, β_1 = -.16, t = -2.30, p < .05. Second, the version condition also significantly predicted the expected mediator 'score difference between dimensions', β_2= -.18, t = -2.48, p < .05. Finally, both 'version condition' and 'score difference between dimensions' were used as predictors for the choice preference. The score difference between dimensions received a significant regression weight, β_3 = .42, t = 6.37, p <.01, whereas the regression weight for the version condition decreased to β_4 = -.09 and was no longer significant, t = -1.37, p > .05. The regression weights for the mediation analysis for all four of the problems are provided in Table 2. The mediation analysis revealed that the effect of version condition on choice preference was fully or partially mediated by $SCORE_{Y\text{-}X}$. This finding suggests that the equate-to-differentiate approach is able to model the decision making process for the observed choice changes across the four problems.

Insert Table 2 about here

Discussion

Consistent with Experiment 1, the choice results in the four questions confirmed that a (de)compression of scale can influence preference when choices are presented graphically. In fact, we found similar effects of graph manipulation of the figures on the participants' preferences in these two experiments. These results thus implied that graph framing effects are both common and robust, representing the rule rather than the exception in choice behavior.

The fact that the effect of scale manipulation in the figures on the choice preference is mediated by the $SCORE_{Y\text{-}X}$, which expresses the perceived difference in the numerical distance between the ordinate dimension and the abscissa dimension, led us to conclude that the observed effect in Experiment 2 can be accounted for by the Graph-edited Equate-to-differentiate Model.

Experiment 3: Confirming graph framing effects in sector displays

Our Experiments 1 and 2 provided converging evidence for graph framing effects. We demonstrated that preferences were reliably influenced by stretching (or shrinking) the physical distance between points to accentuate (or diminish) the salience of the dimension represented on that axis. However, Experiments 1 and 2 both presented graphs in a coordinate context; thus whether such a graph manipulation effect also exists in other graphical displays is unclear. The purpose of Experiment 3 was to extend the graph manipulation effect to other types of graphical displays. Specifically, we attempted to detect a similar graph framing effect in a sector context, rather than a coordinate one.

Method

Participants

The initial participant pool consisted of 107 undergraduate student volunteers who were recruited by poster and all of whom provided oral consent. The participants were tested in small groups ranging in size from 9 to 12. After the experiment, the participants were debriefed and were given a small gift to thank them for their participation. Two incomplete questionnaires were excluded from the analysis.

Materials and Procedure

To test graph framing effects in a sector context, we developed a scenario in which participants had to choose a lucky wheel for a hypothetical game (see Appendix 2). The question consisted of two versions (i.e., a money-prominent version and a probability-prominent version). We randomly assigned the participants to one of the two versions. Note that, unlike the probability-prominent version, the sizes of the wheels were enlarged proportionally and the reward areas were also divided into four parts in the money-prominent version. As a result, the radius length dimension appeared to be relatively prominent in the money-prominent version, whereas the angle value dimension appeared to be relatively prominent in the probability-prominent version. Based on the graph framing effects that we found in Experiments 1 and 2, we conjectured that such irrelevant manipulations in physical aspects would affect the preference. That is, we predicted that the strength of preference for Wheel 1 would be higher in participants who saw the probability-prominent version than in those who saw the money-prominent version, but the reverse would be true for Wheel 2.

Manipulation Check

Since the reward areas were evenly divided into four parts in the money-prominent version, we assumed that the participants would focus on one of the four parts rather than on the entire reward area in the decision making process. A query after the formal question confirmed our conjecture. After the participants in the money-prominent version indicated their preference for the wheels, they were asked a query as follows:

According to your decision making process, please indicate which description is true for you.

a) I incorporated the four reward areas into a whole picture in my mind.

b) I simply focused on one of four reward areas in my mind.

As we expected, most participants (92%) thought the second description was consistent with their decision making process (binomial test $p < .01$).

Results and Discussion

Consistent with our prediction, thirty-three out of fifty-two participants in the probability-prominent version (63%) preferred Wheel 1 to Wheel 2, whereas only twenty-two out of fifty-three participants in the money-prominent version (42%) preferred Wheel 1 to Wheel 2. The difference between two versions was significant (χ^2 (1, N=105) = 5.07, $p < .05$), indicating that the preference was indeed affected by the physical aspects in the sector graphical context. Thus we can say that there is a graph framing effect not only for coordinate displays but also for sector displays.

Experiment 4: Testing graph framing effects when attribute substitution is inhibited (e.g., introducing a mathematical operation before a choice task)

The purpose of Experiment 4 was to determine whether attribute substitution can serve as a conceptual underpinning of the graph framing effect in the perceptual process. Our Experiment 2 suggested that the equate-to-differentiate approach, as a specific decision making model, may possibly be useful for modeling the underlying process of the trade-off between dimensions. In Experiment 4, furthermore, we explored the broader conceptual underpinnings (i.e., attribute substitution) for the graph framing effect at the perceptual level. Kahneman (2003) argued that attribute substitution will be reduced or eliminated when logical processing is encouraged. Hamilton, Hong, and Chernev (2007) confirmed that a mathematical operation can effectively prime logical processing in a choice task. Logically, if the graph framing effect occurs only due to the attribute substitution, then it should be inhibited by such a mathematical operation. To test this conjecture, Experiment 3 was repeated exactly, except that a mathematical operation was introduced before the wheel choice task. We predicted that the graph framing effect, which had appeared in Experiment 3, would disappear in Experiment 4.

Method

Participants

The initial participant pool consisted of 115 undergraduate students attending a lecture, and all provided oral consent. After the experiment, participants were debriefed and were given a small gift to thank them for their participation. Four incomplete questionnaires were excluded from the analysis.

Materials and Procedure

All participants were given an initial task with five arithmetic problems that consisted of adding together two three-digit numbers, a task conceptually similar to those used in prior research (Hamilton, Hong , & Chernev, 2007). Using any electronic tool (e.g., a mobile telephone) was not allowed for the arithmetic task, though these numbers could be calculated on a sheet of paper.

After that, the same wheel problem employed in Experiment 3 was presented. Participants were randomly assigned to one of the two question versions.

Manipulation Check

The same check query was also asked in the money-prominent version. Similar to the results in the Experiment 3, most participants (94%) thought the second description was consistent with their decision making process (binomial test $p < .01$). In addition, we checked whether the calculations of the arithmetic problems were correct. Of the 111 valid participants, 97 participants finished all five problems correctly, and the other 4 participants each gave a wrong answer on one problem (but right in the other four problems). These results indicated that the participants calculated the arithmetic problems seriously and the mathematical operation should be effective.

Results and Discussion

In both two versions, most participants preferred Wheel 1 to Wheel 2. Specifically, thirty-nine out of fifty-seven participants in the probability-prominent version (68%) preferred Wheel 1 to Wheel 2, and twenty-nine out of fifty-four participants in the money-prominent version (54%) preferred Wheel 1 to Wheel 2.The difference between the two versions was not significant (χ^2 (1, N=111) = 2.53, $p > .05$), indicating that the preference for the wheel did not change as a function of the graphical format when the mathematical operation was introduced before the wheel choice task. The disappearance of the graph framing effect when encouraging the logical processing suggests that attribute substitution was responsible for the preference change in decision making. This finding is consistent with our two-process model of the graph framing effect.

General Discussion

In contrast to the axiom of description invariance, researchers interested in decision framing effects are accumulating evidence that different representations of the same problem do not yield the same preference. In particular, preferences are often influenced by the description of the options (Tversky & Kahneman, 1981). However, previous research on framing effects has commonly utilized verbal scenarios (e.g., Schneider, 1992). In contrast, the present study manipulated the graphical representation of options by framing the figure employed in questions and found that preference was affected, even when the wording of the problem as well as the numerical information was constant. Our evidence showed that such a graph framing effect could be detected across different types of graphical displays. The most important difference between the graph framing effect and the traditional framing effect is the role played by visual perception. As outlined in the two process model in Fig. 3, a heuristic judgment elicited by perceptual salience about the numerical difference between options provided for a given attribute is important to account for the observed changes in preference. Obviously, the bridge between perceptual representation and framing effects is a key area for future research.

Comparison with related research

Previous researchers have also warned that graphs might be potentially misused to induce judgment bias. For instance, Huff (1954) showed how simple manipulations of the x- and y-axes can exaggerate differences and create physical and perceptual distortions. However, the present study differs from the work of Huff in several aspects. First, although Huff provided some vivid and impressive illustrations of graphical manipulations, he failed to provide any empirical evidence that the perceptual distortions could cause the judgment bias. But we confirmed our model based on empirical evidence. Second, we demonstrated that preference could be affected by graphical manipulations not only in coordinate displays but also in sector displays; whereas sector displays were not involved in Huff's illustrations. Finally, we related the graph framing effect in the present study to the framework of attribute substitution. Thus, we predicted that physical distances would affect the perceived numerical distance on the corresponding dimension. Huff, however, did not go beyond perceptual distortions demonstrations to present a theoretical mechanism of the judgment bias caused by graphical manipulations.

In addition, the present study can be compared with work on the contrast effects of choice preference. In particular, Simonson and Tversky (1992) demonstrated a tradeoff contrast effect in consumer choices. Consider, for example, a consumer who is evaluating two personal computers; one has 3G memory and costs $1200 (x) and the other has 2G memory and costs $1000 (y). The choice between x and y then depends on whether the consumer is willing to pay $200 more for an additional 1G of memory. Consistent with the tradeoff contrast effect, the consumer is more likely to select x if the choice set includes other pairs of options for which the cost of additional memory is greater than that implied by the comparison between x and y. Both tradeoff contrast effects and graph framing effects suggest that choice preference is malleable rather than stable. The point is that different factors were investigated by this study and Simonson and Tversky's work. Tradeoff contrast effects imply that choice preference may be affected when introducing the extra pairs of options as a background. However, no extra options were introduced in the decision process of the present study, and the reason for the occurrence of the graph framing effect should be attributable to the physical aspects of the graphical representation.

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Related choice models to graph framing effects

Based on attribute substitution and a trade-off between dimensions, our two-process model may account for the underlying mechanism of graph framing effects. Below, we also analyze other choice models that may potentially be related to graph framing effects.

The S-shaped value function of prospect theory

With respect to the type of framing effect, van Schie and van der Pligt (1995) made a distinction between prospect framing (i.e., framing the same choice problems in terms of either gains or losses) and outcome salience (i.e., emphasizing either only positive outcomes or only negative outcomes of choice options). They showed that prospect framing and outcome salience should be understood as distinct, independent processes. With respect to prospect framing, prospect theory (Kahneman & Tversky, 1979) claimed that the psychophysics of an S-shaped value function is theorized to drive framing effects. That is, according to prospect theory, the framing effect occurs because the outcomes are represented differently depending upon whether they are expressed as gains or losses. Note that only prospect framing rather than outcome salience can be accounted for by this S-shaped value function. According to van Schie and van der Pligt (1995), the type of graph framing effects revealed in the present study should be classed as outcome salience rather than prospect framing, since the distinction between gains and losses was not at all involved in the manipulation process. Thus the S-shaped value function of prospect theory is not suitable to predict the graph framing effect in this study.

The similarity choice model

The similarity choice model (Leland, 1994; Rubinstein, 2003) argued that individuals base their choice decisions on judgments about the similarity or dissimilarity of dimensions across alternatives. If two options look similar with respect to a given decision dimension, that dimension is given little or no weight in a choice. Furthermore, a variety of judgment heuristics, such as the amalgamation heuristic (Ranyard, 1995) and the cancellation heuristic (Bonini, Tentori, & Rumiati, 2004), are based on the similarity between alternatives. The similarity choice model, however, may be not able to predict our findings. This is because, according to the similarity choice model, the similarity comparisons between options are restricted to manipulations of the objective numbers, whereas in our study the numbers (and their numerical difference) were kept constant. We only manipulated the graphical representation of the numbers.

Differentiation and consolidation theory

The differentiation and consolidation theory of decision making models human decision making as an active process in which one alternative is gradually differentiated from other available alternatives (Svenson, 1992). Although this theory sounds similar to the equate-to-differentiate approach, the difference between them is obvious. For example, differentiation and consolidation theory explicitly links pre-decision processes (differentiation) with post-decision processes (consolidation) and considers pre-decision processes as a preparation for the post-decision future. In contrast, the equate-to-differentiate approach typically focuses on pre-decision processes rather than on post-decision processes and posits that small differences should be equated whereas not-small differences should be accentuated. Post-decision processes would not be seem to be involved in graph framing effects, thus the equate-to-differentiate approach appears to be better suited to our scenarios than the differentiation and consolidation theory.

Common representation of numerical difference and spatial physical stimuli

Earlier studies have shown that the magnitude representation that supports the processing of numerical differences may be highly related to an underlying magnitude code that supports the processing of spatial physical stimuli (Dehaene, 1989). By comparing angles, lines, and numbers, Fias, Lammertyn, Reynvoet, Dupont, and Orban (2003) found that the processing of various forms of quantitative information shares a common cerebral representation of magnitude or quantity. Some brain-imaging studies utilizing fMRI scanning have showed that this common processing substrate usually occurs around the intraparietal sulcus (IPS) (Pinel, Piazza, Le Bihan, & Dehaene, 2004; Seron & Fias, 2006). These findings introduce an intriguing perspective to explore the underlying neural basis of graph framing effects. Perhaps, the reason that physical aspects in graphs can affect the perceived numerical difference lies in the fact that a common neural basis of magnitude or quantity exists among various forms of quantitative information. Future research should test the link between the graph framing effect and the activation of the IPS and further open the door to exploring the inter-relations between processes of perception and cognition.

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