RUNNING HEAD: NOT JUST FOR CONSUMERS: CONTEXT EFFECTS ARE FUNDAMENTAL TO DECISION-MAKING

Not just for consumers: Context effects are fundamental to decision-making

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Abstract

Context effects – preference changes depending on the availability of other options – have attracted a great deal of attention among consumer researchers studying high-level decision tasks. Our experiments show that these effects also arise in simple perceptual decision-making tasks. This casts doubt on explanations limited to consumer choice and high-level decisions and indicates that context effects may be amenable to a general explanation at the level of the basic decision process. Here we demonstrate for the first time that three important context effects from the preferential choice literature – similarity, attraction, and compromise effects – all occur within a single perceptual decision task. Not only do our results challenge previous explanations for context effects proposed by consumer researchers, they also challenge the choice rules assumed in theories of perceptual decision-making.

Key Words**:** preferential choice, attraction effect, similarity effect, compromise effect, perceptual decision-making

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Numerous studies have examined the role of context on preference in multi-alternative decision-making: that is, how choices between a fixed set of options can be altered by the inclusion of other options. In the preferential choice literature, three effects have been central to research on contextual sensitivity: the attraction (Huber, Payne, & Puto, 1982), similarity (Tversky, 1972), and compromise (Simonson, 1989) effects. Although decision theorists have found substantial evidence that these effects occur in high-level decision-making tasks, there is little evidence (Choplin & Hummel, 2005; Tsetsos, Usher, & McCelland, 2011) suggesting that the effects also arise in low-level tasks such as simple perceptual decision-making. This paper presents the first report of all three context effects within the same perceptual decision task.

To illustrate the context effects, consider someone choosing between two cars to purchase; one is inexpensive but poor quality, the other is higher quality but expensive. The decision-maker chooses between the cars by evaluating two attributes, economy and quality. A “context effect” of the sort we examine arises when a third choice is added to the choice set, resulting in the decision-maker changing his or her mind about the original two cars. The three effects arise by selecting the third choice to have particular relationships with the original two choices. Figure 1 schematically represents the positions of various options within a two dimensional space defined by two attribute values.

The attraction effect is an enhancement in the choice probability of one of the two original options (the “focal” option) through the introduction of a similar, but inferior "decoy" option. In the cars example, the "decoy" might be similar to the expensive, high quality car but slightly inferior on both attributes. That is, the "decoy" is more expensive and lower quality. More generally, consider a choice set {X, Y} and two decoys, A_X and A_Y, where A_X is similar but slightly inferior to X, and A_Y is a similar but inferior to Y. The attraction effect occurs when people show a stronger preference for X when it is presented along with its inferior comparison (A_X), and similarly for Y. Formally, the attraction effect occurs when the probability of choosing X is greater when the decoy favors X as compared to when in favors Y and vice versa: $\Pr[X \mid \{X, Y, A_X\}] > \Pr[X \mid \{X, Y, A_Y\}]$ and $\Pr[Y \mid \{X, Y, A_X\}] < \Pr[Y \mid \{X, Y, A_Y\}]$.

In our attraction effect experiment, three different types of decoys were tested: range, frequency, and range-frequency. These decoys differ only in the manner in which they are inferior to the focal options, as illustrated in Figure 1. The range decoy (R) refers to an option that is a little weaker than the focal alternative on the focal alternative's weakest attribute – so a range decoy increases the range of the attribute dimension on which the focal alternative is the weakest. The frequency decoy (F) refers to an option that increases the frequency of the attribute dimension on which the focal option is superior. The range-frequency decoy (denoted RF) combines range and frequency manipulations. All three decoy types were tested because previous research (Huber et al., 1982) demonstrates the different decoys result in different magnitudes of the attraction effect.

The similarity effect occurs when an option is added that is slightly different from, but equally attractive to, an existing option, and the probability of selecting the dissimilar option increases. For example, the addition of a car similar to the expensive, high quality car results in the decision-maker preferring the inexpensive, low quality car. Informally: when there are two very similar options, an option dissimilar to both becomes more attractive. Consider a choice set {X, Y} and two decoys, S_X and S_Y, where S_X is similar to X, and S_Y is similar to Y (see Figure 1). The similarity effect occurs when the probability of choosing X is greater when the decoy is similar to Y as compared to when it is similar to X and vice versa: $Pr[X | \{X, Y, S_X\}] < Pr[X | \{X, Y, S_Y\}]$ and $Pr[Y | \{X, Y, S_X\}] > Pr[Y | \{X, Y, S_Y\}]$.

The compromise effect occurs when an option is made more attractive when presented as a compromise between alternatives. For example, a third car that is moderately expensive and has moderate quality is preferred over the original options because it represents a compromise between them. More generally, consider a choice set {X, Y} and two decoys, C_X and C_Y, where C_X is an extreme option that makes X assume the middle ground, and C_Y is an extreme option that makes Y assume the middle ground (see Figure 1). The compromise effect occurs when the probability of choosing X is greater when X is a compromise rather than an extreme alternative and vice versa: $Pr[X | \{X, Y, C_X\}] > Pr[X | \{X, Y, C_Y\}]$ and $Pr[Y | \{X, Y, C_X\}] < Pr[Y | \{X, Y, C_Y\}]$.

The three effects have been important for preference theories because they violate an intuitively appealing property called “simple scalability” (Krantz, 1964; Tversky, 1972). This property states that alternatives in a choice set can be given a strength scale value, s, that is independent from the other options, and the probability of selecting a particular option is determined by the strength using the formula $Pr[x | A] = F[s(x), s(y), ..., s(z)]$, where F is an increasing function in the first variable and a decreasing function in the remaining variables. This property underlies most of the utility models used to study choice behavior and choice rules assumed in theories of perceptual decision-making, including Luce's (1959) "ratio of strengths" model.

To illustrate the violation, consider the attraction effect. According to the simple scalability property the inequality $\Pr[X \mid \{X, Y, A_X\}] > \Pr[X \mid \{X, Y, A_Y\}]$ implies that the strength of A_X is less than the strength of A_Y. However, the inequality $\Pr[Y \mid \{X, Y, A_X\}] < \Pr[Y \mid \{X, Y, A_Y\}]$ implies that the strength of A_Y is less than the strength of A_X. Because these two statements cannot both be true, the property is violated. Violations of the property by the similarity and compromise effects follow a similar argument. Models of preference have been adapted to account for these findings in terms of properties specific to high-level choices. However, if the same violations occur in more elementary decision-making tasks, it may be worthwhile to reconsider the psychological locus of the effects.

Context effects have been demonstrated in a wide range of high-level decision-making tasks such as choices among consumer products (Huber et al., 1982; Simonson, 1989, Pettibone & Wedell, 2000) including real in-store purchases (Doyle, O'Connor, Reynolds, & Bottomley, 1999), choices among candidates for scholarships (Tversky, 1972) and in elections (Pan, O'Curry, & Pitts, 1995), choices among gambles (Tversky, 1972; Wedell, 1991), likelihood judgment problems (Windschitl & Chambers, 2004), choices in episodic memory tasks (Maylor & Roberts, 2007), selection of mates (Sedikides, Ariely, & Olsen, 1999), and choices in inference problems (Trueblood, 2012). These experiments demonstrate that context effects play a significant role in behavior and can impact real-life decisions.

Although the evidence for context effects in high-level decision-making is quite substantial, there is much less evidence for these effects in low-level tasks. In Tversky's (1972) original demonstration of the similarity effect, his perceptual stimuli did not produce a significant effect, but Choplin and Hummel (2005) found a significant attraction effect with ovals and line segments in a similarity judgment paradigm. Tsetsos et al. (2011) obtained the similarity effect using time-varying psychophysical stimuli. Although these studies have added to our understanding of context effects, the evidence is distributed across different experimental paradigms, and there is still no demonstration that all three effects can arise in the same low-level decision-making task, which may explain why these findings have had less impact.

Besides illustrating that the three context effects can occur in a simple perceptual task, the current paper adds to recent evidence that all three can be obtained under the same experimental paradigm (Trueblood, 2012). Decision theorists have attempted to explain the three effects with a single model (Roe, Busemeyer, & Townsend, 2001; Usher & McClelland, 2004). However, until recently, there has been no evidence indicating that the three effects can occur in the same paradigm in either consumer choice or perception. Because these models assume that a single set of cognitive mechanisms produce the three effects, it is crucial to demonstrate the effects in the same paradigm. The current experiments also use within-subjects manipulations unlike, for example, Choplin and Hummel (2005), thus demonstrating that context effects in perception occur at the individual level: within the same people as well as within the same paradigm.

Experiment 1 investigated the attraction effect using simple perceptual stimuli and three types of decoys: range, frequency, and range-frequency. Experiments 2 and 3 investigated, respectively, the similarity and compromise effects. Tables S1, S2, and S3 in the supporting information available on-line provide parametric details of the stimuli used in each experiment.

Experiment 1: The Attraction Effect

Method

Fifty-three undergraduate students from the University of Newcastle participated for course credit, completing the computer-based experiment online at a time of their choosing. Participants were instructed that they would see three rectangles on each trial and should select the rectangle that had the largest area using the keyboard. They did not receive any feedback during the experiment so there were no consequences for their selections.

The rectangle stimuli varied in height and width, with these two features acting as attribute dimensions analogous to price and quality in the cars example. Anderson and Weiss (1971) provide evidence that height and width are perceived separately and then integrated to form area estimates. Even if the rectangles are perceived as unidimensional stimuli (e.g., in terms of aspect ratio), that does not affect the implications of our experimental outcomes (e.g., Choplin and Hummel, 2005, used unidimensional stimuli in their attraction effect experiments.)

The height and width of each rectangle was specified in pixels. For example, the rectangles associated with location X in Figure 1 were drawn from a bivariate normal distribution where height and width had mean (50, 80) and variance 2 on each dimension with no correlation. Allowing for noise in the height and width of the rectangles helped introduce variation in the task. The height and width of rectangles at other locations in

Figure 1 were determined in a similar manner. The rectangles corresponding to alternatives X and Y were selected so that on each trial they had the same area.

On each trial, three rectangles were presented horizontally on the screen. The rectangles were solid black and the background screen was white. The vertical placements of the rectangles varied so that they did not all sit on the same horizontal axis. The rectangles were numbered from left to right, and the location of different rectangles (i.e., decoy, focal, and non-focal) was randomized across trials.

Each participant completed 720 randomized trials, which were divided into 180 range trials, 180 frequency trials, 180 range-frequency trials, and 180 filler trials. The 180 trials for each type of attraction decoy were further divided so that in the attribute space the decoy was placed near one alternative for half of the trials and near the other alternative for the remaining trials. Counterbalancing the stimuli in this way avoids confounding the context effects with many biased guessing strategies. The filler trials also used ternary choice sets and contained one rectangle that clearly had a larger area than the rest, providing the participant with an objectively correct option. The number of correct choices in filler trials provided an estimate of accuracy.

Results

Four subject's data were removed from further analysis because their filler trial accuracy was two standard deviations lower than the average. Figure 2 illustrates the stimuli and results from the range decoy trials, which showed a clear attraction effect. The mean choice probabilities for all three decoys are shown in Figure 3, with the probability for the focal alternative compared to the probability for the non-focal alternative and collapsed across both possible positions of the decoy (i.e., favoring X versus favoring Y).

Across the three types of decoys, the choice probability for the focal alternative was significantly larger than the choice probability for the non-focal alternative ($t(48) = 2.601$, $p = 0.012$). Analyzing the three types of decoys alone, we found that the range decoy produced the strongest effect ($t(48) = 3.616$, $p < 0.001$) followed by the range-frequency decoy ($t(48) = 2.085$, $p = 0.042$). The frequency decoy produced a minimal effect ($t(48) = 1.135$, $p = 0.262$), confirming previous evidence that frequency decoys produce very weak attraction effects (Huber et al., 1982). The proportions of subjects showing each effect were 69% with the range decoy, 61% with the range-frequency decoy and 59% with the frequency decoy. Similar proportions occurred in Choplin and Hummel's (2005) attraction experiment involving ovals where 58% of subjects selected the focal option.

Conclusions

The range and range-frequency decoys produced the standard attraction effect. Further, the ordering of effect size across the three decoys (i.e. range followed by range-frequency followed by frequency) replicated Huber et al. (1982) for choices among consumer goods. Thus, the attraction effect not only generalizes to simple perceptual tasks, but it retains the same ordering of effect size as in high-level tasks.

Experiment 2: The Similarity Effect

Method

Sixty-two undergraduate students from the University of Newcastle participated for course credit, under the same conditions, instructions and design as experiment 1, differing only in the height and width of the rectangle stimuli. There were two choice sets testing the similarity effect when height was greater than width and two choice sets testing the similarity effect when width was greater than height. The two choice sets for each location arise from the two possible placements of the decoy option (i.e., near one alternative versus the other).

Each participant completed 720 randomized trials, 270 with choice sets where height was greater than width, 270 with choice sets where width was greater than height, and 180 filler trials. The similarity trials were further divided so that the decoy was a similar, competing option placed near one alternative for half of the trials and near the other alternative for the remaining trials. Filler trials were the same as in experiment 1.

Results

All participants had accuracy within two standard deviations of the average accuracy on the filler trials. Mean choice probabilities for the similarity effect are shown in Figure 4, with the probability of the focal alternative compared to the probability of the non-focal alternative collapsed across the two different types of choice sets (i.e., height greater than width and width greater than height) and decoy positions. Here, the term focal refers to the dissimilar alternative because this is the alternative that should be enhanced by the decoy if the similarity effect is observed.

The choice probability for the focal alternative was significantly larger than the choice probability for the non-focal alternative ($t(61) = 2.882$, $p = 0.006$). This effect was consistent, occurring both in trials where height was greater than width ($t(61) = 2.161$, $p = 0.035$) and where width was greater than height ($t(61) = 3.523$, $p < 0.001$), with 69% of subjects demonstrating the effect for both types of choice sets. The number of subjects demonstrating the effect is clearly more than Tversky's (1972) perceptual experiment in which only 3 out of 8 subjects showed the effect, but it is a little less than Tversky's (1972) tasks involving candidates and gambles in which 6 out of 8 and all 8 subjects demonstrated the effect respectively[1].

Conclusions

The results of Experiment 2 support the conclusion that the similarity effect generalizes to low-level tasks and confirms previous evidence for the similarity effect in perception (Tsetsos et al., 2011).

Experiment 3: The Compromise Effect

Method

Sixty-three undergraduate students from Indiana University participated for course credit. Participants completed the computed-based experiment in the laboratory. The instructions and experimental design were identical to experiments 1 and 2 differing only in the height and width of the rectangle stimuli. The experiment used two choice sets to test the compromise effect: {X, Y, C_X} and {X, Y, C_Y}, where all of the rectangles had equal area but height C_X < height X < height Y < height C_Y, so X and Y were both compromise and extreme options.

Each participant completed 720 randomized trials, 360 testing the compromise effect and 360 filler trials. The former trials were further divided so that the decoy was an extreme option compared to one alternative for half of the trials and an extreme option

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[1] The number of subjects was calculated from Table 1 in Tverksy (1972) by averaging across the different choice sets for each individual.

compared to the other alternative for the remaining trials. Filler trials were the same as before.

Results

Four subjects were removed from further analysis because their filler accuracy was two standard deviations lower than the average. Mean choice probabilities for the compromise effect are shown in Figure 5, with the probability of the compromise alternatives compared to the probability of the extreme alternatives collapsed across the two positions of the decoy. The choice probability for the compromise alternative tended to be larger than for the extreme alternative collapsed across the two positions of the decoy ($t(58) = 1.967$, $p = 0.054$). The difference would be significant if a one-tailed t-test was applied. Such a test is justified because there is a clear hypothesis on the direction of the result. Further, the result is fairly consistent with 66% of subjects showing the effect.

Conclusions

The results provide the first evidence that, like the attraction and similarity effects, the compromise effect can arise in low-level tasks.

General Discussion

Previous research in consumer and perceptual preference has demonstrated that decisions are sensitive to context; however, these two literatures have mostly been independent. Our research demonstrates the potential utility of a unified account by showing that three context effects from the consumer choice literature also occur in a perceptual choice task. That is, our experiments suggest that these context effects are a general feature of human choice behavior because they are a fundamental part of decision-making processes. As such, our results challenge explanations of these effects exclusively in terms that are unique to high-level decision-making, and call for a common theoretical explanation that applies across paradigms.

Although the study of context effects in preference and perception has generally proceeded independently, Dhar and Glazer (1996) argued that researchers should examine the similarities and differences in context effects across domains because mechanisms in existing theories of perceptual choice might be sufficient to account for the standard effects found in preferential choice. Table 1 compares choice probabilities from different experiments testing the effects across a variety of domains. The table shows that context effects generalize across a range of tasks; however, effect size varies by task. Future research is needed to understand why the effects are larger in some domains than others. One possible explanation is the effects become smaller with faster response times. This hypothesis is consistent with experiments by Pettibone (2012) showing the attraction and compromise effects increase with deliberation time.

By demonstrating context effects in perception we bring into question choice rules often used in theories of perceptual decision-making, in the same way that early models for consumer preference – with simple scalability – were challenged by context effects in consumer choice. This challenge extends to the ratio of strengths rule, signal detection models, and other choice models that satisfy simple scalability (Luce, 1959; Medin & Schaffer, 1978; Nosofsky, 1986).

Recently, researchers have turned to modeling approaches that incorporate the dynamics of the decision-making process to account for context effects[2]. Two dynamic

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[2] It should be noted that comparison-induced distortion theory (Choplin & Hummel, 2002, 2005) offers an alternative approach to modeling both perceptual and

cognitive models, Multi-alternative Decision Field Theory (MDFT: Roe et al., 2001) and the Leaky Competing Accumulators model (LCA: Usher & McClelland, 2004) can account for the similarity, compromise and attraction effects in consumer choice using a single set of cognitive principles. Both models are sequential sampling models that assume information is accumulated over time until a decision criterion is reached. The models also incorporate a sequential scanning of attributes, adopting ideas from Tversky's (1972) elimination by aspects heuristic.

Our demonstration of the three context effects in the same perceptual paradigm using within-subjects manipulations, and a parallel demonstration for inference problems by Trueblood (2012), provide direct support for the assumption made by both theories of a common mechanism operating at the level of individual participants. The phantom decoy effect (Pratkanis & Farquhar, 1992), in which the probability of an asymmetrically dominated option increases when the dominant option is made unavailable, provides a further related challenge for choice theories. We did not study the phantom decoy effect because little is known about the predictions of MDFT and the LCA model with regard to this effect (but see Busemeyer & Johnson, 2004 and Tsetsos, Usher & Chater, 2010 for a brief discussion). Future research is needed to study this effect in perception as well as predictions from the models.

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preferential choice behavior. In this theory, biased evaluations arise through language-expressible magnitude comparisons. Comparison-induced distortion theory has been successfully applied to attraction effect data, but has not yet been applied to similarity or compromise effect data.

In Tversky and Kahneman's (1991) and Tversky and Simonson's (1993) reference-dependent theory of riskless choice, it is assumed that disadvantages impact the selection process more than advantages. In multi-attribute choice, when an option is being considered, the theory postulates that individuals assess the advantages and disadvantages of that option along each attribute with respect to the other alternatives in the choice set. Disadvantages (losses) are weighted more than advantages (gains) in the decision process. Our demonstration that the three context effects occur in simple perceptual choices calls into question this loss aversion explanation. In our stimuli, the attribute dimensions are nonhedonic and the notion of gains and losses along attributes is absent. Thus, a parsimonious account of context effects that generalizes to a number of domains (consumer goods, inference, perception, etc.) cannot be based on loss aversion.

A similar criticism can be made of the LCA model. Although MDFT and the LCA model share many features, including providing the same explanation for the similarity effect, they have one striking difference. The LCA model accounts for the attraction and compromise effects with an asymmetric value function, consistent with the Tversky and Kahneman (1991) and Tversky and Simonson (1993) loss-aversion function. MDFT, in contrast, accounts for the attraction and compromise effects using a distance function that compares options along dominance and indifference dimensions (Hotaling, Busemeyer, & Li, 2010). The MDFT account is more plausible for both high-level tasks and for the current perceptual experiments because there is no arbitrary weighting of differences in attribute values. Rather, an option's relevance is determined by whether an individual views it as indifferent or as dominated by the other options. Although it is possible to reformulate the asymmetric value function in the LCA model in terms of attention to positive and negative differences rather than to gains and losses, it remains unclear why negative differences are weighted more than positive differences in perceptual decisions about the size of rectangles.

The inclusion of dynamics in MDFT and the LCA model provides them with flexibility that needs to be justified. Response time measures provide one way to test the dynamic assumptions of these models. It might be possible to distinguish MDFT and the LCA model on the basis of response time data as described by Tsetsos et al. (2010). Perceptual choice is an ideal domain for exploring the relationship between preference and response time because choices are made quickly and response time measurement is easy. Future experiments building upon the ones presented here could address these issues.

Author's note

The first author was supported by NSF/IGERT Training Program in the Dynamics of Brain-Body-Environment Systems at Indiana University.

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Table 1. Mean choice probabilities in attraction, similarity, and compromise experiments for focal options followed by non-focal options

Study	Stimuli	Attraction	Similarity	Compromise
Tversky (1972)	perceptual		.41, .44*	
Tversky (1972)	gambles/candidates		.53, .42*	
Huber et al. (1982)	consumer goods	.45, .59*		
Simonson (1989)	consumer goods	.50, .65*		.50, .34
Pettibone & Wedell (2000)	consumer goods			.46, .32
Choplin & Hummel (2005)	perceptual (ovals)	.58, .41		
Trueblood (2012)	inference	.56, .39	.51, .30	.48, .38
current study	perceptual	.51, .46	.37, .32	.42, .40

The * indicates experiments comparing binary and ternary choice sets rather than all ternary sets. The choice probability of the focal option in the binary set is given first followed by the choice probability of the focal option in the ternary set.

Figure Captions

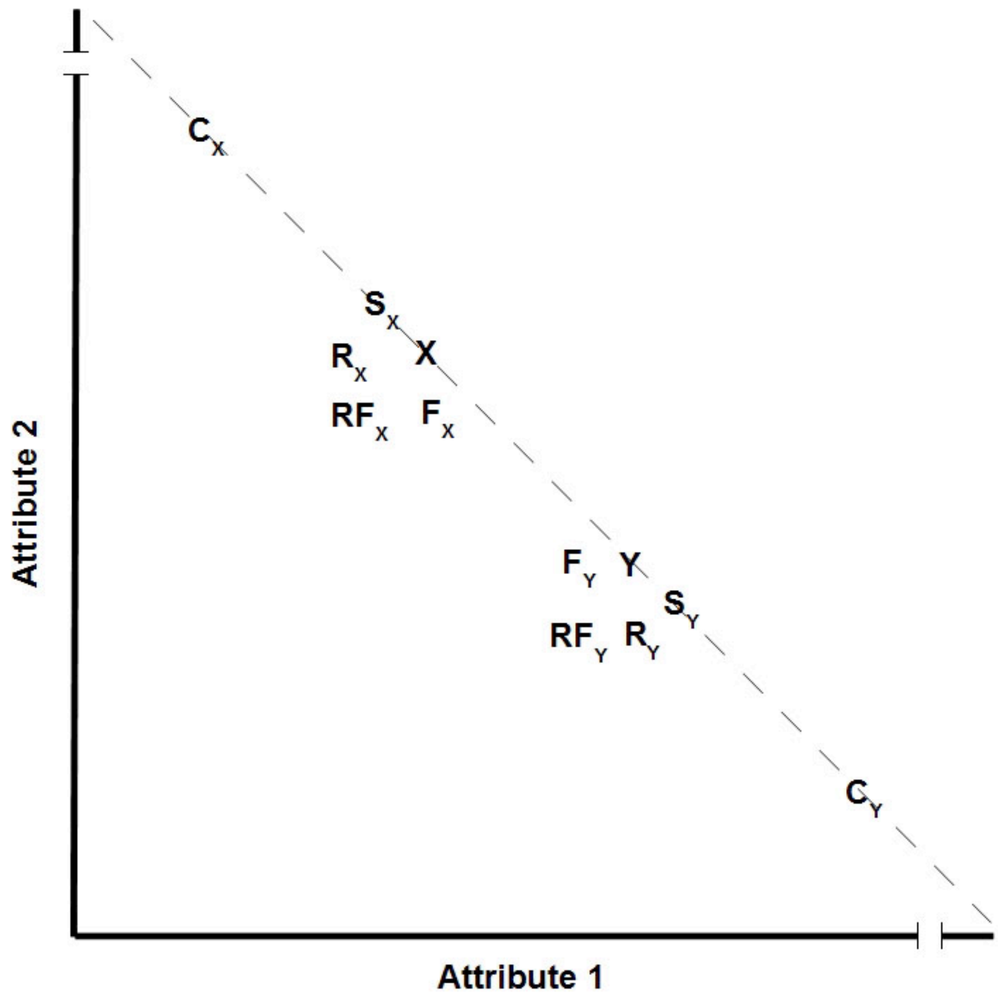
Figure 1. The various locations of options plotted in a two dimensional space defined by the two attribute values. Note that in the car example with attributes of quality and price, the price attribute is decreasing because higher prices are worse than lower prices. Options denoted R represent range decoys and are dominated on the focal alternative's weakest attribute. Options denoted F represent frequency decoys and are dominated on the focal alternative's strongest attribute. Options labeled RF refer to range-frequency decoys and are dominated on both of the focal alternative's attributes. Differences in choice probabilities for sets $\{X, Y, R_X\}$ and $\{X, Y, R_Y\}$ demonstrate the range attraction effect, differences in choice probabilities for sets $\{X, Y, F_X\}$ and $\{X, Y, F_Y\}$ demonstrate the frequency attraction effect, and differences in choice probabilities for sets $\{X, Y, RF_X\}$ and $\{X, Y, RF_Y\}$ demonstrate the range-frequency attraction effect. Options labeled S refer to similarity decoys and differences in choice probabilities for sets $\{X, Y, S_X\}$ and $\{X, Y, S_Y\}$ demonstrate this effect. The compromise effect is demonstrated by comparing the choice sets $\{X, Y, C_X\}$ and $\{X, Y, C_Y\}$. The breaks in the axes indicate that they have limited range.

Figure 2. Stimuli and mean choice probabilities from the attraction effect experiment for trials with a range decoy. The left side of the figure shows the stimuli used when X was the focal option and the right side of the figure shows the stimuli used when Y was the focal option. The presence of the decoy shifted preferences away from the non-focal option toward the focal option.

Figure 3. Experimental results for the attraction effect. Mean choice probability for the range, range-frequency, and frequency effects. Error bars show the standard error of the mean.

Figure 4. Experimental results for the similarity effect. Mean choice probability with error bars showing the standard error of the mean.

Figure 5. Experimental results for the compromise effect. Mean choice probability with error bars showing the standard error of the mean.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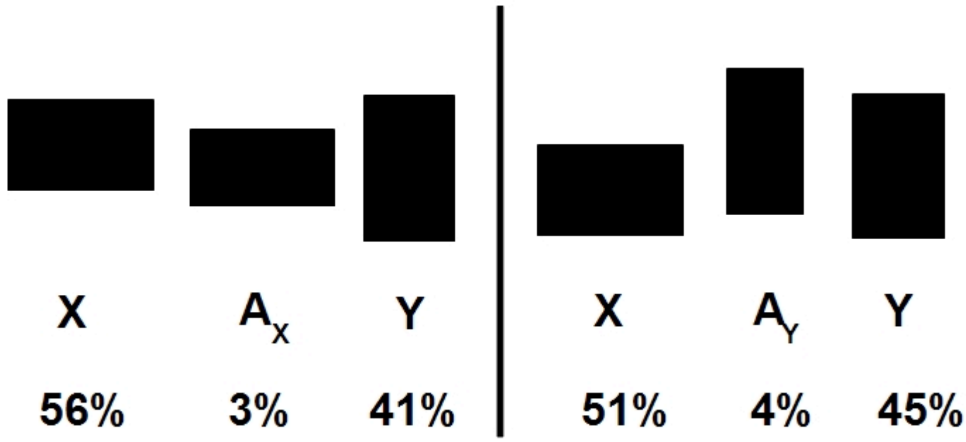
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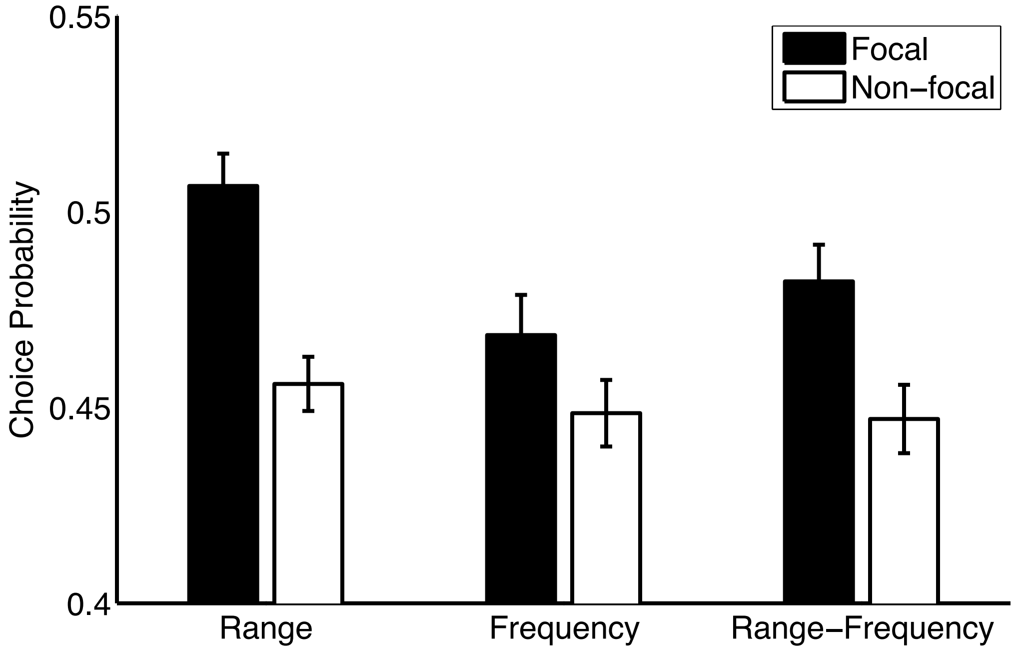
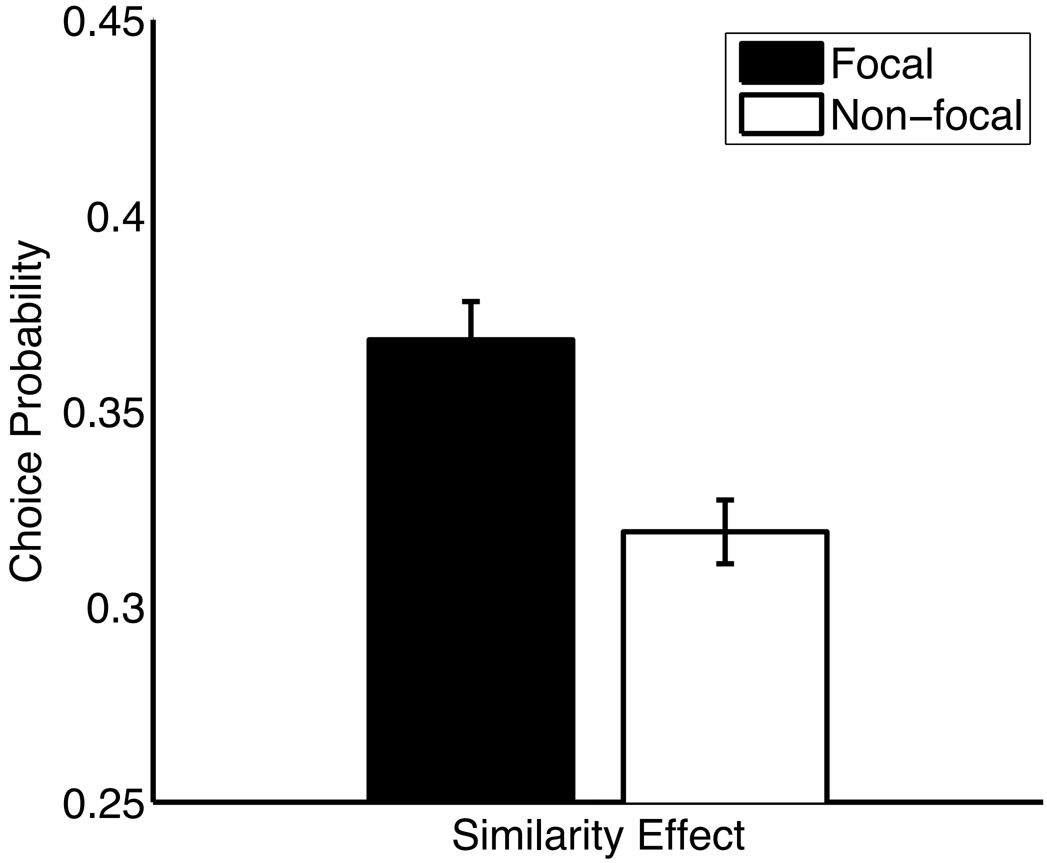
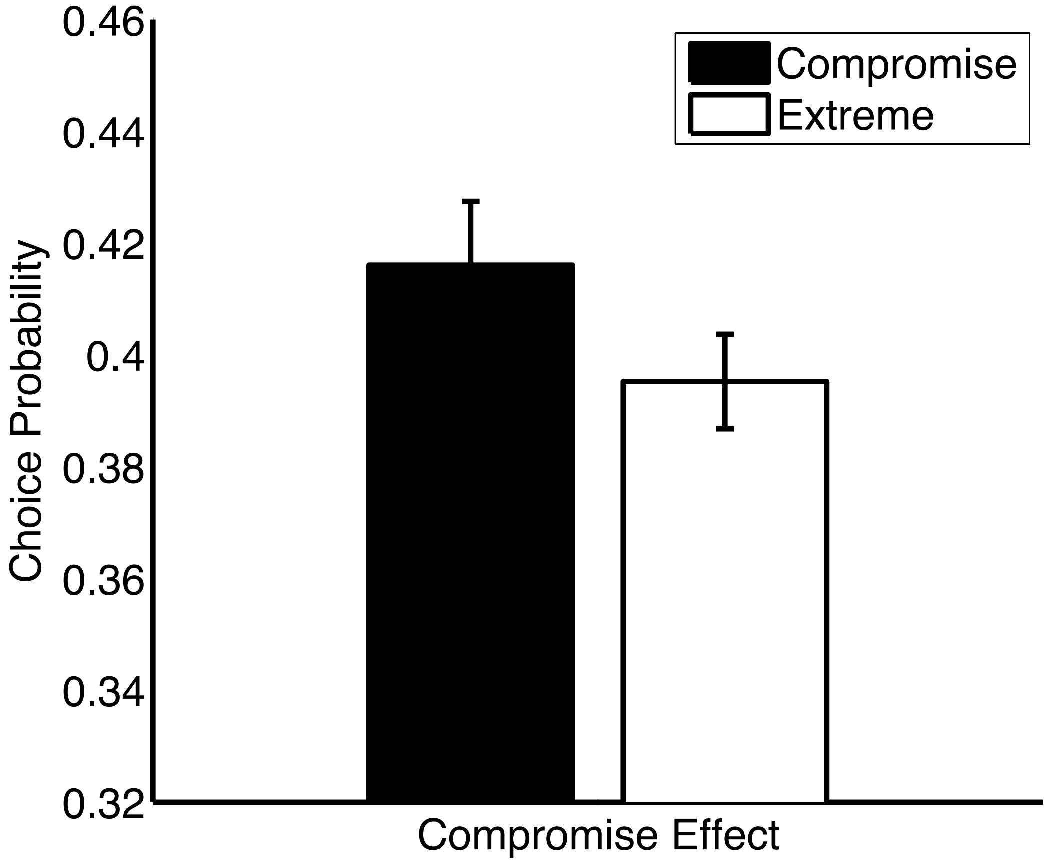
4%
45%


0.55
0.5
0.45
0.4
Choice Probability
Focal
Non−focal
Range
Frequency
Range−Frequency


0.45
0.4
0.35
0.3
0.25
Choice Probability
Focal
Non−focal
Similarity Effect


Compromise
Extreme
Choice Probability
0.46
0.44
0.42
0.4
0.38
0.36
0.34
0.32
Compromise Effect