RUNNING HEAD: Multi-alternative Context Effects Obtained Using an Inference Task

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Abstract

When decision-makers are faced with a choice among multiple options that have several attributes, preferences are often influenced by how the options are related to one another. For example, consumer preferences can be influenced and even reversed by the context defined by available products. This paper discusses three standard context effects found in the preferential choice literature: the attraction, similarity, and compromise effects. While decision theorists have attempted to explain these three effects under single modeling accounts, it has never before been demonstrated that these effects can be obtained under the same experimental paradigm. A set of experiments demonstrating the three effects in an inference task is described. The paradigm is completely novel as there is no previous experimental work examining the standard context effects in inference. The experiments also add to evidence that the effects are not confined to choices among options with affective value such as consumer products. The experimental results provide evidence that these effects might be a general property of human choice behavior and bring into question explanations of the effects based on the concept of loss aversion asymmetry.

Key Words**:** multi-alternative choice, attraction effect, similarity effect, compromise effect, utility models, inference, loss aversion

Multi-alternative Context Effects Obtained Using an Inference Task

A number of empirical studies have demonstrated the importance of context on choice preferences in situations involving several options that have multiple attributes. Three effects, the attraction (Huber, Payne, & Puto, 1982), the similarity (Tversky, 1972), and the compromise (Simonson, 1989) effects, have been central to research on contextual sensitivity in multi-alternative decision-making. While decision theorists have attempted to explain these three effects under single modeling accounts, there has been no empirical evidence suggesting that the three effects can be obtained under the same experimental paradigm. This paper offers the first account of the three standard context effects occurring in the same domain.

The three standard context effects appearing in the literature, the attraction, similarity and compromise effects, arise in choices among three alternatives that have two attributes. For example, in a typical consumer goods decision task, subjects might be asked to choose among a set of three cars that vary on the two attributes of price and quality. The options can be graphically represented in a two dimensional attribute space as illustrated in Figure 1. In the figure, the x and y axes correspond to the attribute values and points in the space correspond to different options. Context effects arise from changes in relative preferences for the options due to their placement in the attribute space. The attraction effect occurs when a dominated option (e.g., option R_B in Figure 1) increases the probability of selecting the dominant alternative (e.g., B). The similarity effect arises when similar options (e.g., S_B and B) compete with one another and the relative preference for a dissimilar option (e.g., C) increases. The compromise effect occurs when there is an enhancement in the probability of choosing an intermediate alternative (e.g., C) when extreme options (e.g., B and D) are included in the choice set. More details about the effects are given below in the discussion of the experiments.

All three effects violate the simple scalability property (Krantz, 1964; Tversky, 1972). This property states that alternatives in a choice set can be given a strength scale value, u, that is independent from the other options, and the probability of selecting a particular option is determined by the general formula $Pr[x \mid A] = F[u(x), u(y), ..., u(z)]$ 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 including Luce's (1959) "ratio of strengths" model.

The experimental paradigm discussed in this paper is an inference task in which subjects are asked to make decisions about criminal suspects. The three context effects are tested in three separate experiments. The experiments test how people infer which suspect out of a set of three is most likely to have committed a crime based on two different eyewitness testimonies. In these scenarios, the suspects represent the different choice options and the eyewitness testimonies represent the two attributes in a similar manner as a consumer product having attributes of quality and price.

This paradigm is completely novel as there is no previous experimental work examining the three standard context effects in inference. The experiments also add to evidence suggesting context effects are not confined to choices among options that have affective value such as consumer products. In a choice among consumer products, personal desirability plays an important role in how attributes are evaluated. However, in the current paradigm, the task is not to select the most desirable option, but to select the most likely one. In other words, the judge is asked to evaluate the relative likelihood of each alternative on each attribute rather than assess the options based on personal likes and dislikes of attributes.

Previous research has provided evidence of the similarity and attraction effects occurring in domains without affective value. In Tversky's (1972) original demonstration of the similarity effect, he used three types of experimental stimuli: squares containing dots, candidates for a scholarship, and gambles. More recently, Choplin and Hummel (2005) found the attraction effect using unidimensional perceptual stimuli. Maylor and Roberts (2007) obtained the attraction and similarity effects in an episodic memory task and Tsetsos, Usher and McCelland (2011) obtained the similarity effect using time-varying psychophysical stimuli. While these studies have greatly added to our understanding of context effects, they have not demonstrated the occurrence of all three effects in the same non-consumer goods domain.

Experiment 1: The Attraction Effect

The attraction effect refers to an enhancement in the choice probability of an option through the introduction of a similar, but inferior alternative. Consider the choice set {B, D} and two decoys, A_B and A_D, where A_B is a similar but inferior option as compared to B, and A_D is a similar but inferior option as compared to D. The attraction effect occurs when people show a stronger preference for option B when it is presented along with its inferior comparison (A_B), and similarly for option D. Formally, the attraction effect occurs when the probability of choosing B is greater when the decoy favors B as compared to when it favors D and vice versa: $Pr[B \mid \{B, D, A_B\}] > Pr[B \mid \{B, D, A_D\}]$ and $Pr[D \mid \{B, D, A_B\}] < Pr[D \mid \{B, D, A_D\}]$. This method of using all ternary choice sets to test the effect follows from Wedell (1991) and helps to achieve a more powerful test by increasing the effect size.

A further distinction is made by the three different types of dominated options: range, frequency, and range-frequency decoys (Huber et al., 1982). Figure 1 shows a graphical representation of these different decoys. Range decoys (denoted R_B and R_D in Figure 1) refer to options that increase the range of the attribute dimension on which the focal alternative is the weakest. In other words, these decoys are dominated on the focal alternative's weakest attribute. Throughout the article, the term focal is used to refer to the option that is enhanced by the addition of a third alternative. For example, B would be considered a focal option in the choice set {B, D, R_B} because it is enhanced by R_B. Frequency decoys (denoted F_B and F_D) are dominated on the focal alternative's strongest attribute value. These decoys increase the frequency of options with attribute values similar to the focal alternative's superior dimension. Range-frequency decoys (denoted RF_B and RF_D) combine both a range and frequency manipulation. Thus, these decoys are dominated on both the focal's strongest and weakest attributes. All three decoys were included in this experiment because previous findings have shown that they produce different magnitudes of the attraction effect (Huber et al., 1982).

To test the attraction effect, six different ternary choice sets were used. The six sets arise from two choice sets for each of the three types of decoys (i.e., range, frequency, and range-frequency). The two choice sets for each type of decoy were designed to compare choice probabilities when the decoy favors option B with choice probabilities when the decoy favors option D as shown in Figure 1. For example, the range attraction effect occurs when $Pr[B \mid \{B, D, R_B\}] > Pr[B \mid \{B, D, R_D\}]$ and $Pr[D \mid \{B, D, R_B\}] < Pr[D \mid \{B, D, R_D\}]$.

The attraction effect violates the simple scalability property because according to this property the inequality $Pr[B \mid \{B, D, R_B\}] > Pr[B \mid \{B, D, R_D\}]$ implies that the strength of R_B is less than the strength of R_D. However, the inequality $Pr[D \mid \{B, D, R_B\}] < Pr[D \mid \{B, D, R_D\}]$ implies the exact opposite - the strength of R_D is less than the strength of R_B.

Method

Forty-seven undergraduate students from Indiana University participated for course credit. Participants were told they would see three suspects of a crime on each trial and were instructed to select the suspect that seemed most likely to have committed the crime based on the strengths of two different eyewitness testimonies. Subjects were told that the strengths of the eyewitness testimonies were reported on a 0-100 scale with 0 implying very weak evidence of guilt and 100 implying very strong evidence of guilt. Subjects were also told that the testimonies of both eyewitnesses were equally valid and important and that the strengths of the testimonies were equated. Subjects did not receive any feedback during the experiment so there were no consequences for their selections.

Eyewitness strengths were determined by selecting a pair of points from the two dimensional eyewitness strength space illustrated in Figure 1. For example, suspects associated with location B in Figure 1 were drawn from a bivariate normal distribution with mean (35, 65) and with variance equal to 1 on each dimension and no correlation. Allowing for noise in the eyewitness strength values helped introduce variation in the task. The eyewitness strengths for other suspects (e.g., locations D and R_B in Figure 1) were determined in a similar manner. The suspects and eye-witness strengths were presented in a table format with different suspects in different rows. The row location of the suspects was randomized across the experiment. Table 1 gives sample values for the range attraction effect and is formatted similarly to the experimental presentation. Suspect initials were included to reinforce the use of a different set of suspects on each trial.

Each participant completed 240 randomized trials which were divided into 40 range trials, 40 frequency trials, 40 range-frequency trials, and 120 filler trials. The 40 trials for each type of decoy were further divided so that the decoy was placed near one alternative for half of the trials and near the other alternative for the remaining trials. The filler trials also used ternary choice sets and always contained one alternative that was clearly superior. These trials were used to assess accuracy throughout the experiment.

Results and discussion

Figure 2a shows the mean choice probability for the focal alternative compared to the mean choice probability for the non-focal alternative and decoy collapsed across both possible positions of the decoy (i.e., favoring B versus favoring D). Figure 2b shows a scatter plot of individual choice probabilities for the range, frequency, and range-frequency decoys. In the figure, each point represents an individual participant's choice probabilities for the focal alternative plotted on the x-axis and the non-focal alternative plotted on the y-axis. Again, the choice probabilities for focal and non-focal options are collapsed across both possible positions of the decoy.

For data analyses, two subjects were removed because their accuracy was two standard deviations lower than the average accuracy on the filler trials. 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 ($t = 2.631$, $p = 0.012$). The three decoys were also analyzed individually by comparing the range choice sets {B, D, R_B} and {B, D, R_D}, the frequency choice sets {B, D, F_B} and {B, D, F_D}, and the range-frequency choice sets {B, D, RF_B} and {B, D, RF_D}. The range decoy produced the largest difference in choice probability between the focal (*M* = 0.56) and non-focal (*M* = 0.39) options ($t = 2.819$, $p = 0.007$). The frequency decoy produced the second largest difference between the focal (*M* = 0.52) and non-focal (*M* = 0.39) options ($t = 2.390$, $p = 0.021$). The range-frequency decoy produced the smallest effect (*M* = 0.52 for focal verses *M* = 0.41 for non-focal), but was still significant ($t = 2.216$, $p = 0.032$).

The results support previous evidence that the attraction effect can be generalized to domains where the options do not have affective value. Further, like the consumer preference experiments by Huber et al. (1982), the range decoy produced the largest effect out of the three types of decoys.

Experiment 2: The Similarity Effect

The similarity effect occurs when a competitive option similar to one of the existing alternatives is added to the choice set and the probability of selecting the dissimilar option increases. Consider the choice set {B, C} and two decoys, S_B and S_{C1}, where S_B is similar to B, and S_{C1} is similar to C as illustrated in Figure 1. The similarity effect occurs when the probability of choosing B is greater when the decoy is similar to C as compared to when it is similar to B and vice versa: $Pr[B \mid \{B, C, S_B\}] < Pr[B \mid \{B, C, S_{C1}\}]$ and $Pr[C \mid \{B, C, S_B\}] > Pr[C \mid \{B, C, S_{C1}\}]$. To test the similarity effect, four ternary choice sets were used. In Figure 1, these sets are {B, C, S_B}, {B, C, S_{C1}}, {C, D,

S_{C2}}, {C, D, S_D}. In all of the sets, the decoy (i.e., S_B, S_{C1}, S_{C2}, and S_D) is a more extreme option in the sense that it has more extreme attribute values than the similar alternative.

Like the attraction effect, the similarity effect also violates the simple scalability property. According to the property, the inequality Pr[B |{B, C, S_B}] < Pr[B | {B, C, S_{C1}}] implies that the strength of S_B is greater than the strength of S_{C1}. Yet, the inequality Pr[C | {B, C, S_B}] > Pr[C | {B, C, S_{C1}}] implies the opposite.

Method

Fifty-one undergraduate students from Indiana University participated for course credit. Participants received the same instructions as in the attraction experiment.

Each participant completed 240 randomized trials which were divided into 60 trials using options B and C, 60 trials using options C and D, and 120 filler trials. The 60 trials testing the similarity effect 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. The filler trials were the same as before.

Results and discussion

Figure 3a shows the mean choice probability of the focal alternative compared to the mean choice probability of the non-focal alternative and decoy collapsed across the two different trial types (i.e., trials using options B and C and trials using options C and D) and both possible positions of the decoy. Here, the term focal refers to the dissimilar alternative because this is the alternative that is enhanced by the decoy. Figure 3b shows a scatter plot of individual participant's choice probabilities for the focal alternative and the non-focal alternative collapsed across the two trial types and both possible positions of the decoy.

For data analyses, three subjects were removed because their accuracy was two standard deviations lower than the average accuracy on the filler trials. Across the two trial types, the choice probability for the focal alternative ($M = 0.51$) was significantly larger than the choice probability for the non-focal alternative ($M = 0.30$) ($t = 4.743$, $p < 0.001$). Analyzing the two trial types separately, both the trials using options B and C ($t = 5.701$, $p < 0.001$) and the trials using options C and D ($t = 3.673$, $p < 0.001$) produced significant similarity effects.

The results support previous evidence that the similarity effect arises in a number of domains (Tversky, 1972; Maylor & Roberts, 2007; Tsetsos et al., 2011).

Experiment 3: The Compromise Effect

The compromise effect occurs when an option is selected more often when it appears to be a compromise with respect to the other alternatives in the choice set than when it appears to be an extreme. Specifically, suppose that there are two ternary choice sets {A, B, C} with A and C being extremes and {B, C, D} now with B and D as extremes. The compromise effect occurs when B is preferred more often in the first set than in the second set so that $Pr[B \mid \{A, B, C\}] > Pr[B \mid \{B, C, D\}]$ and when C is preferred more often in the second set than in the first set so that $Pr[C \mid \{A, B, C\}] < Pr[C \mid \{B, C, D\}]$.

Following the experimental design of Simonson (1989), the compromise effect was tested using three ternary choice sets. In Figure 1, these sets are {A, B, C}, {B, C, D}, {C, D, E}. The alternatives B, C, and D are each a compromise alternative in exactly one set and an extreme alternative in one or two of the other sets. To test for the effect, the probability of selecting these alternatives when they are compromise options is compared to the probability of selecting them when they are extremes. Because C appears as an extreme option in two choice sets, there are a total of four comparisons that can be made: B in sets {A, B, C} and {B, C, D}; C in sets {A, B, C} and {B, C, D}; C in sets {B, C, D} and {C, D, E}; and D in sets {B, C, D} and {C, D, E}.

As with the other two effects, the compromise effect also violates the simple scalability property. The property implies that if Pr[B | {A, B, C}] > Pr[B | {B, C, D}] then the strength of A is less than the strength of D. However, the property also implies that if Pr[C | {A, B, C}] < Pr[C | {B, C, D}] then the strength of A is greater than the strength of D.

Method

Fifty-two undergraduate students from Indiana University participated for course credit. Participants received the same instructions as in the attraction experiment.

Each participant completed 240 randomized trials which were divided into 40 trials with the {A, B, C} choice set, 40 trials with the {B, C, D} choice set, 40 trials with the {C, D, E} choice set, and 120 filler trials. The filler trials were the same as before.

Results and discussion

Figure 4a shows the mean choice probability of the compromise alternatives compared to the mean choice probability of the extreme alternatives collapsed across the three choice sets. Figure 4b shows a scatter plot of individual participant's choice probabilities for the compromise alternatives and the extreme alternatives collapsed across the three choice sets.

For data analyses, one subject was removed because his or her accuracy was two standard deviations lower than the average accuracy on the filler trials. Across the three choice sets, the choice probability for the compromise alternative ($M = 0.48$) was significantly larger than the choice probability for the extreme alternative ($M = 0.38$) ($t = 3.796$, $p < 0.001$). In analyzing the four possible comparisons separately, three out of the four comparisons were significant. Specifically, the probability of selecting C in set {B, C, D} as compared to set {A, B, C} was significantly larger ($t = 4.469$, $p < 0.001$), the probability of selecting C in set {B, C, D} as compared to set {C, D, E} was significantly larger ($t = 2.587$, $p = 0.013$), and the probability of selecting D in set {C, D, E} as compared to set {B, C, D} was significantly larger ($t = 4.404$, $p < 0.001$). However, there was no significant difference in the probability of selecting B in set {A, B, C} as compared to set {B, C, D} ($t = 1.224$, $p = 0.227$). Even though there was not a significant difference between the choice probabilities for option B, the simple scalability property is still violated by the other comparisons.

The results provide the first evidence that like the attraction and similarity effects, the compromise effect is not limited to situations involving options that have affective value.

General Discussion

Because most utility models cannot be used to explain the three context effects due to violations of simple scalability, developing a single theoretical framework to model all three effects is an ongoing problem of interest for cognitive modelers. Currently, there are two models that account for the three effects: Multi-alternative Decision Field Theory (MDFT) (Roe, Busemeyer, & Townsend, 2001) and the Leaky Competing Accumulators (LCA) model (Usher & McClelland, 2004). Both models are part of a class of models called sequential sampling models. These models assume that information is accumulated stochastically over time, and a decision is elicited after the accumulated information reaches a certain threshold. These models also capitalize on Tversky's (1972) elimination by aspects heuristic by incorporating a sequential scanning of attributes. Because the models assume that a single set of cognitive mechanisms produce the three effects, demonstrating the effects in the same experimental paradigm provides a crucial test of this assumption. The current experiments represent the first attempt at performing this test.

Further, the existence of the three effects in a domain where the options do not have affective value poses a challenge to accounts of context effects based on the concept of loss-aversion asymmetry (Tversky & Simonson, 1993). Because the effects have customarily been demonstrated in tasks related to consumer preferences, where there are obvious possible losses, it has been difficult to determine whether or not loss-aversion is a prerequisite concept for context effects. The present research takes the first step at addressing whether or not loss aversion is necessary for explaining the effects by providing evidence for the effects in inference, where the notion of gains and losses is less clear or even altogether absent.

While the MDFT and the LCA model have much in common and even provide the same explanation for the similarity effect, they offer strikingly different explanations for the attraction and compromise effects. MDFT models the attraction and compromise effects with a distance function which compares options along dominance and indifference dimensions (Hotaling, Busemeyer, & Li, 2010). On the other hand, the LCA model accounts for these effects by assuming that alternatives are compared to one another by an asymmetric value function which is consistent with Tversky and Kahneman's (1991) and Tversky and Simonson's (1993) loss-aversion function.

In multi-alternative decisions where people are not given an explicit reference option, it is believed that options are evaluated in relation to one another (Tversky & Simonson, 1993). In the LCA model, when an option is being considered, an individual evaluates the advantages and disadvantages of that option along each attribute with respect to the other alternatives in the choice set. By weighting disadvantages more than advantages as described in Tversky and Kahneman (1991), the LCA model produces the attraction and compromise effects. The asymmetric weighting of advantages and disadvantages follows from the assumption that people exhibit more aversion for losses as compared to gains (Tversky & Kahneman, 1991; Tversky & Simonson, 1993). In a task where someone must select the most desirable option as in a choice among consumer products, an asymmetric weighting of gains and losses could be reasonable. However, in the current experiments, it is not clear why an individual would weight differences in eyewitness testimonies favoring one suspect more than differences in favoring another suspect. While it is true that an individual might feel loss if the wrong suspect is selected, this is a loss related to the correctness of the choice rather than a loss due to tradeoffs among attributes.

While the experiments bring into question loss/gain asymmetry, further experiments and tests are needed to completely rule out the use of other asymmetric functions. It could be 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. Both MDFT and the LCA model make rich dynamic predictions about the time course of choice preferences, and it could be possible to discriminate the two models on this basis as discussed in Usher, Tsetsos and Chater (2010). Because the current experimental design is non-dynamic, future experimental paradigms are needed to address these issues.

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Table 1

Sample values for the range attraction effect formatted similarly to the experimental presentation. The suspects listed in the three rows correspond to options D, B, and R_D *in Figure 1 respectively.*

Suspect	*Eyewitness 1 strength*	*Eyewitness 2 strength*
1. Suspect D.C.B.	66	34
2. Suspect R.J.L	33	67
3. Suspect T.G.K.	66	30

Figure Captions

Figure 1. The various options used in the inference experiments plotted in a two dimensional space defined by the two attribute values. The context effects were assessed by comparing ternary choice sets to other ternary choice sets. Options labeled R, F, and RF refer to attraction decoys where R represents range decoys, F represents frequency decoys, and RF represents range-frequency decoys. Range decoys are dominated on the focal option's weakest attribute, frequency decoys are dominated on the focal option's strongest attribute, and range-frequency decoys are dominated on both of the focal option's attributes. The choice sets $\{B, D, R_B\}$ and $\{B, D, R_D\}$ were used to assess the range attraction effect, choice sets $\{B, D, F_B\}$ and $\{B, D, F_D\}$ were used to assess the frequency attraction effect, and choice sets $\{B, D, RF_B\}$ and $\{B, D, RF_D\}$ were used to assess the range-frequency attraction effect. Options labeled S refer to similarity decoys. The choice sets $\{B, C, S_B\}$, $\{B, C, S_{C1}\}$, $\{C, D, S_{C2}\}$, $\{C, D, S_D\}$ were used to assess the similarity effect. The choice sets {A, B, C}, {B, C, D}, and {C, D, E} were used to assess the compromise effect.

Figure 2. Experimental results for the attraction effect. (a) Mean choice probabilities for focal and non-focal options with range, range-frequency, and frequency decoys. Error bars show the standard error of the mean. (b) Individual choice probabilities for focal and non-focal options with range, range-frequency, and frequency decoys. Choice probabilities for the focal option are plotted along the x-axis, and choice probabilities for the non-focal option are plotted along the y-axis. Individual choice probabilities for a particular alternative were calculated by counting the number of times a participant selected that alternative for all of the trials of a particular type. Points that fall below the

diagonal line indicate subjects that demonstrated the effect because these points represent individuals who selected focal options more often than non-focal options. The individual choice probabilities fall mostly along the negative diagonal because the decoy alternative is rarely selected.

Figure 3. Experimental results for the similarity effect. (a) Mean choice probability with error bars showing the standard error of the mean. (b) Individual choice probabilities. Choice probabilities for the focal option are plotted along the x-axis, and choice probabilities for the non-focal option are plotted along the y-axis. Points that fall below the diagonal line indicate subjects that demonstrated the effect.

Figure 4. Experimental results for the compromise effect. (a) Mean choice probability with error bars showing the standard error of the mean. The term decoy is used here to refer to options that always appear as extremes and never compromises (e.g., options A and E in Figure 1). (b) Individual choice probabilities. Choice probabilities for the compromise option are plotted along the x-axis, and choice probabilities for the extreme option are plotted along the y-axis. Points that fall below the diagonal line indicate subjects that demonstrated the effect.

Figure 1

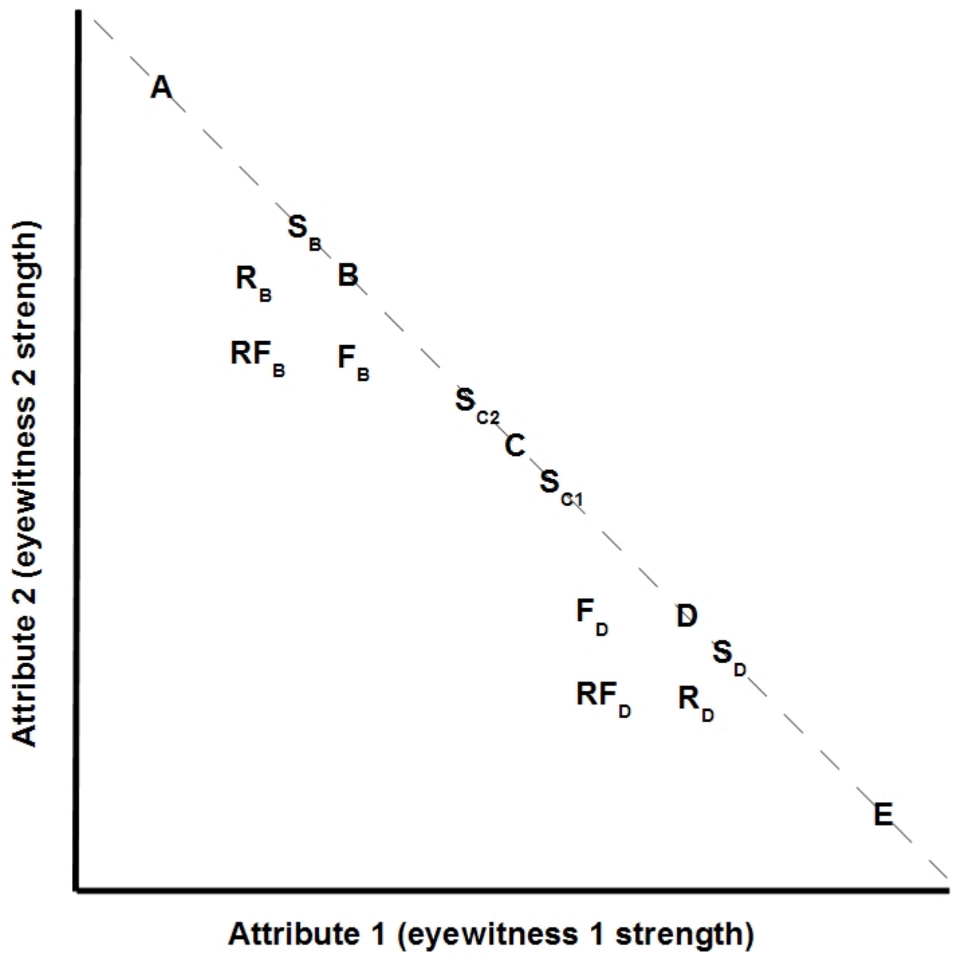

A
S_B
R_B
B
RF_B
F_B
S_C2
C
S_C1
F_D
D
S_D
RF_D
R_D
E
Attribute 2 (eyewitness 2 strength)
Attribute 1 (eyewitness 1 strength)

Figure 2a

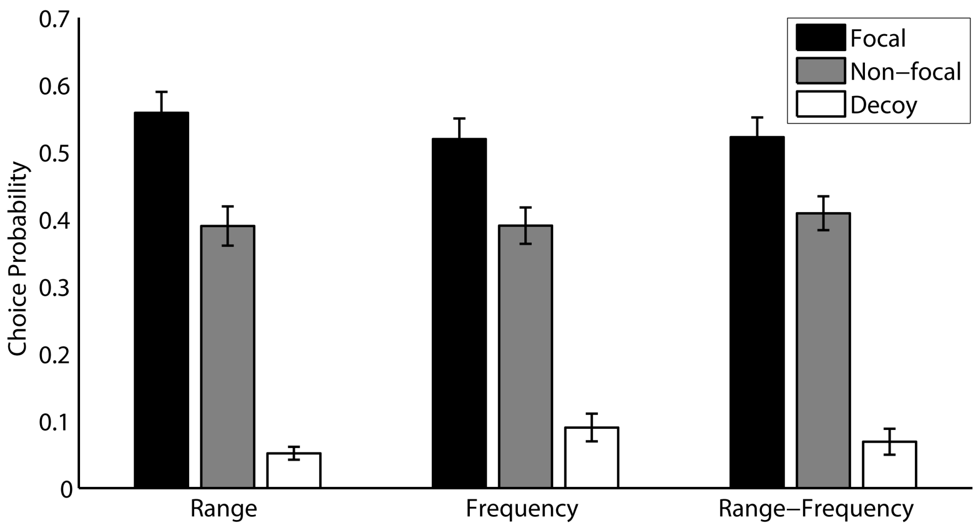

0.7
0.6
0.5
0.4
0.3
0.2
0.1
0
Choice Probability
Focal
Non−focal
Decoy
Range
Frequency
Range−Frequency

Figure 2b

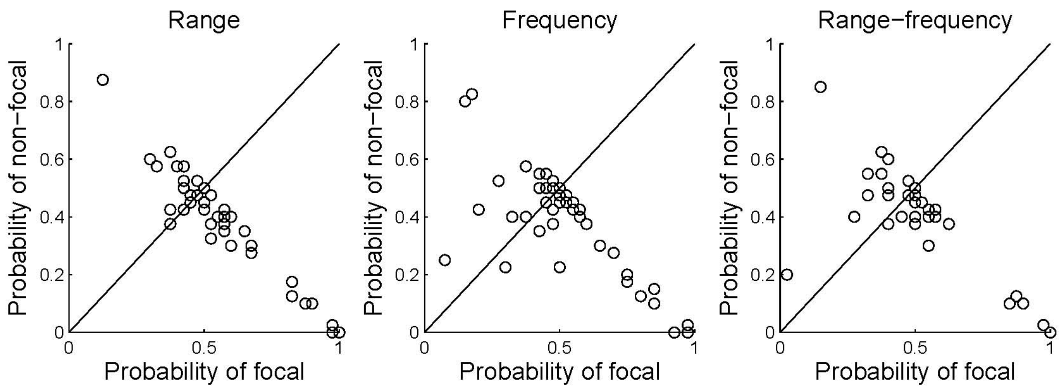

Range
Frequency
Range−frequency
Probability of non−focal
Probability of focal
0
0.2
0.4
0.6
0.8
1
0.5

Figure 3a

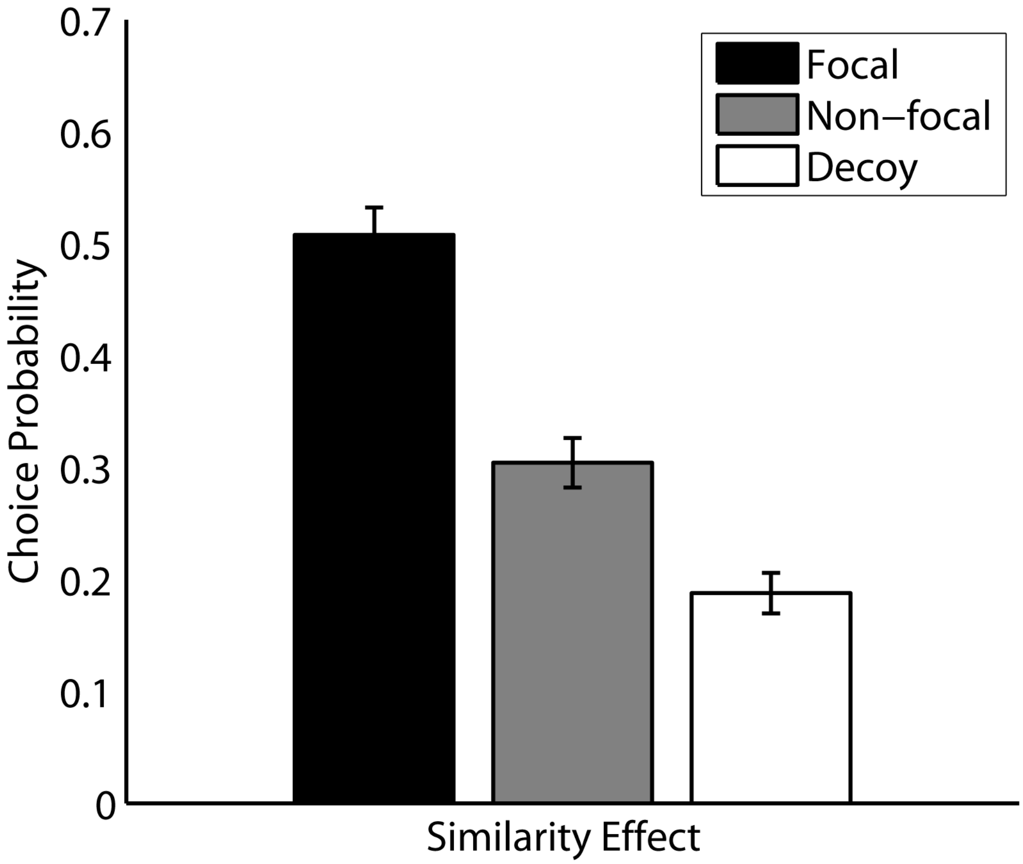

0.7
0.6
0.5
0.4
0.3
0.2
0.1
0
Choice Probability
Focal
Non−focal
Decoy
Similarity Effect

Figure 3b

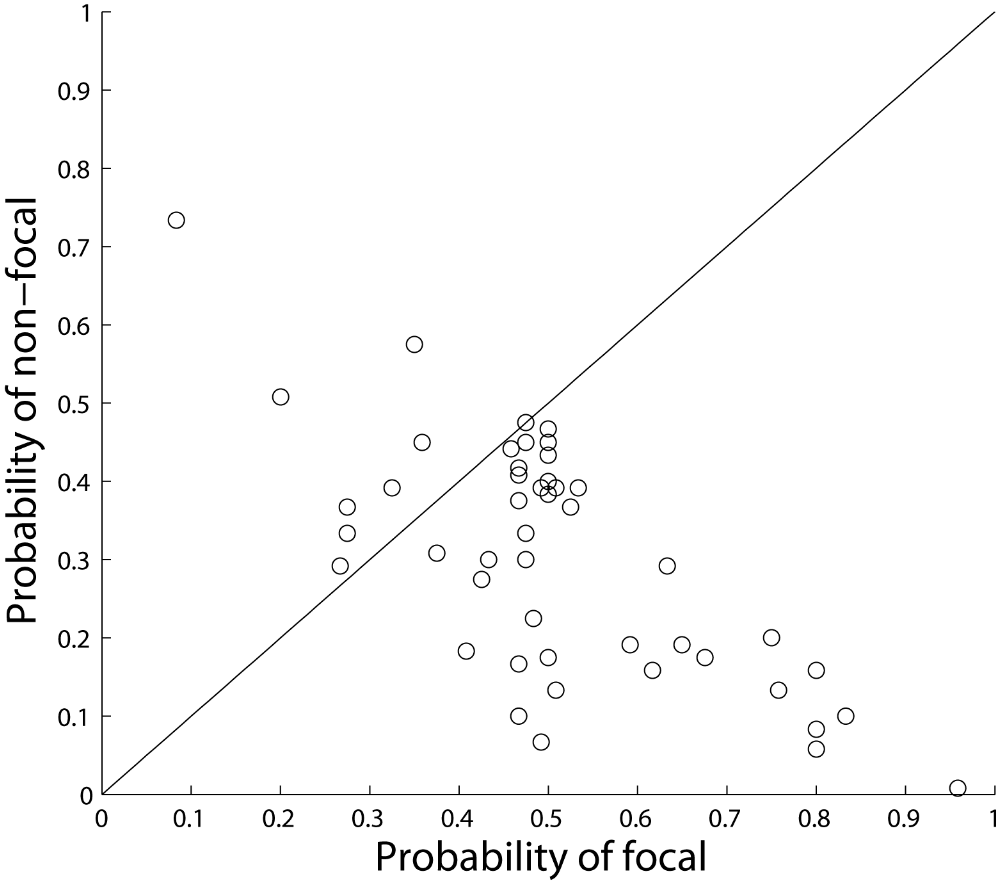

Probability of non−focal
Probability of focal
0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0.9
1

Figure 4a

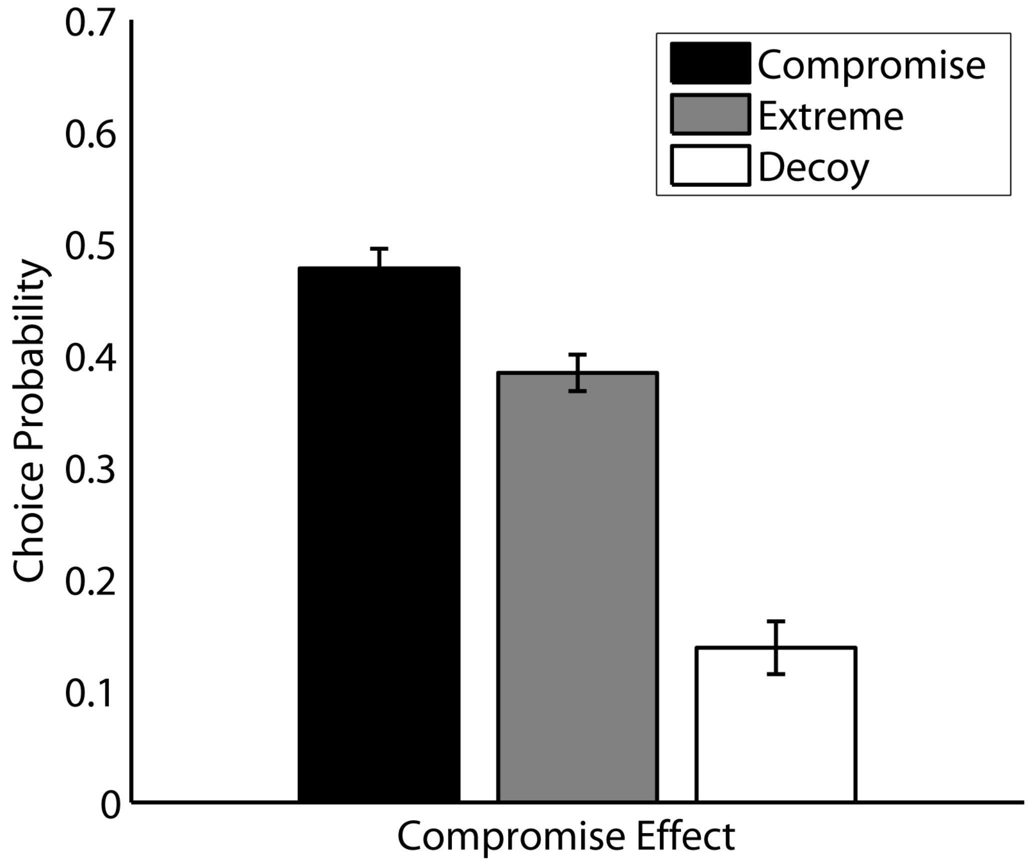
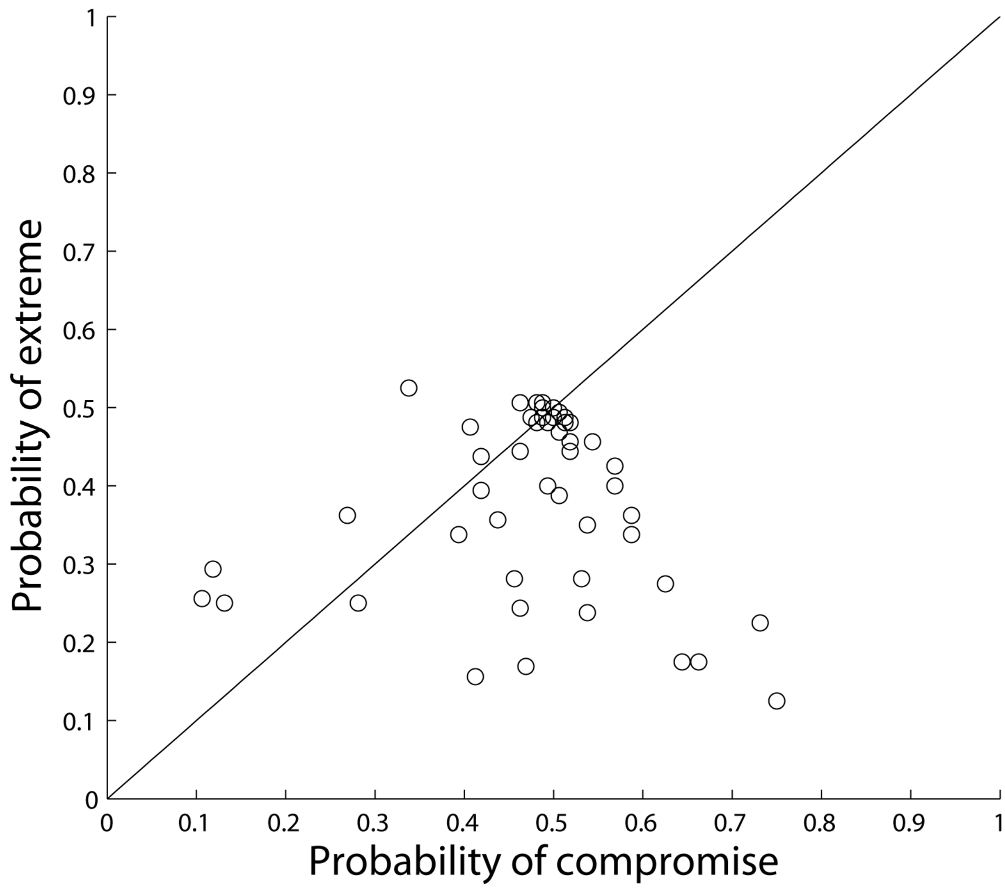

0.7
0.6
0.5
0.4
0.3
0.2
0.1
0
Choice Probability
Compromise
Extreme
Decoy
Compromise Effect

Figure 4b


Probability of extreme
Probability of compromise
0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0.9
1