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Implications of Stimulus Sampling on the Attraction Effect

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Abstract

Context effects in multi-attribute decision making are important findings that challenge large classes of rational choice theories, while also providing innovative consumer product strategies. Trueblood (2012) is the first demonstration of the attraction, similarity and compromise context effects using the same experimental paradigm. A closer examination of the attraction effect experiment reveals that the choice probability estimation procedure gives rise to systematic properties in the choice sets, which in this paper are collectively termed as the sum-highest property. Conducting a simulation study reveals that the sum-highest property can affect a large number of choice sets. This is followed by an experiment that shows that people are biased towards options which satisfy the sum-highest property. These results provide a plausible alternate explanation to the attraction effect in studies which use similar estimation procedures, while also highlighting choice behavior under the sum-highest property as a potential principle of multi-attribute decision making.

Keywords: choice probability estimation; context effects; attraction effect; multi-attribute choice; stimuli generation.

Introduction

Context effects are a class of observations in the preferential choice literature where the preference between options can be altered by a change in context such as the addition of alternatives to the choice set. The three most widely studied context effects are the attraction effect (Huber & Puto, 1983), the compromise effect (Simonson, 1989), and the similarity effect (Tversky, 1972).

Multi-alternative decision making refers to any situation where there is a choice between more than two options. For example, a simple question such as “What is your favorite number between 1 and 10?” is a choice between 10 alternatives. When each alternative is further characterized by additional information, the common nomenclature is multi-attribute decision making. For example, in a choice between cars, each car may be characterized by attributes such as “Mileage”, “Horsepower”, “Price” etc. Taken together, the term multi-alternative multi-attribute decision making refers to any choice where there are more than two alternatives and each alternative is described by at least two attributes.

The attraction effect is a context effect where given a two-alternative multi-attribute choice set, the addition of a third alternative, the decoy, which is inferior to one of the initial alternatives, the target, increases the preference for the target. In the similarity effect, the addition of a third option which is similar to one of the initial options in a two alternative choice set, results in an increase in preference for

the dissimilar option. In the compromise effect, the addition of an intermediate option, to a choice set consisting of two extreme options, alters the preference towards the intermediate option, which is a compromise between the two extreme options.

Context effects allow for manipulation of choice probabilities by clever addition of alternatives to a choice set and hence are of practical importance in consumer product placement. Additionally, these context effects also provide significant insight into theoretical endeavors of human decision making. To illustrate this point, let's consider the violation of the simple scalability property of choice. The simple scalability property states that each option in a complete choice set can be assigned a single scaled value, u , independent of other options in the choice set. For example, u can be a utility function which assigns each member of the choice set $\{a_1, a_2\}$ to a real number. The choice probability for any option is then determined by a function, F , which for option $\{a_1\}$ is given by $P(a_1 | \{a_1, a_2\}) = F(u(a_1), u(a_2))$ and for option $\{a_2\}$ is given by $P(a_2 | \{a_1, a_2\}) = F(u(a_2), u(a_1))$, where F is always strictly increasing in the first argument and strictly decreasing in the rest.

To see why the three context effects violate the simple scalability property via a single demonstration, let us narrow our focus by considering the case where the three context effects result in a change in preference order in the complete choice set. It is important to note that a change in preference order is a sufficient but not necessary condition for these context effects to hold¹. A change of preference order is a violation of the simple scalability property because theories which assume the simple scalability property start with defining fixed utilities over the entire choice set. For example, let us consider a choice set $\{A, B\}$ where A is slightly more preferable than B . This implies that $P(A | \{A, B\}) = F(u(A), u(B)) > P(B | \{A, B\}) = F(u(B), u(A))$, which in turn implies that $u(A) > u(B)$. However, in the case of the attraction effect, the addition of option C can result in option B becoming the most preferred option in the complete choice set $\{A, B, C\}$. This implies that $P(B | \{A, B, C\}) = F(u(B), u(A), u(C)) > P(A | \{A, B, C\}) = F(u(A), u(B), u(C))$, which in turn implies that $u(B) > u(A)$, which is a contradiction. Similar arguments can be used to show how the compromise and similarity effects violate the simple scalability property.

¹ A more general treatment is to show the attraction effect as a violation of the regularity property of choice, which is not discussed in this paper.

Context Effects: Unified Theoretical and Experimental Accounts

As the study of human decision making has advanced, there has been a proliferation of theoretical models of decision making (see Rieskamp, Busemeyer, & Mellers (2006) for details). With respect to context effects in multi-attribute decision making, cognitive models such as the Multialternative Decision Field Theory (MDFT) model (Roe, Busemeyer & Townsend, 2001) are especially important because they predict violations of properties such as simple scalability, while also modeling the dynamics of the decision making process.

Trueblood (2012), via three separate experiments, demonstrated the attraction effect, the similarity effect, and the compromise effect within one experimental paradigm. The paradigm was an inference task where subjects were asked to choose between three criminal suspects, based on eyewitness testimony strength from two independent eyewitnesses. The three suspects corresponded to the three alternatives, and the eyewitness testimonies corresponded to the two attributes. The eye witness testimony strengths ranged between 0-100. Subjects were asked to choose the suspect they think is most likely to have committed the crime. This paper is of profound importance because it is the first time that someone has shown the three context effects in the same experimental paradigm, which in turn adds to the validity of single modeling accounts such as MDFT. Moreover, since the context effects were induced in an inference task where the stimuli have no affective value as compared to tasks based on consumer preferences, these results question models such as the Leaky Competing Accumulator model (Usher & McClelland, 2004), which assume loss-aversion asymmetry (Tversky & Simonson, 1993) as a fundamental principle of context effects.

Attraction Effect

The attraction effect is an important theoretical finding because it challenges decision making theories which assume the simple scalability property. It is robust across task type and has been demonstrated in various domains including choices between political candidates (Sue O'Curry & Pitts, 1995), an episodic memory task (Maylor & Roberts, 2007), and a perceptual decision making task (Trueblood, Brown, Heathcote, & Busemeyer, 2013).

The attraction effect is general enough to have multiple formulations, but for the purposes of this paper it is explicitly defined as a context effect where given a two-alternative two-attribute choice set {target, competitor}, the addition of a third alternative, {decoy}, which is dominated by {target}, increases the preference for {target}. The nomenclature of referring to the three alternatives as the target {T}, the competitor {C}, and the decoy {D} is followed. As one example, let's assume people are indifferent to the choice between {T} and {C}, where {T} is superior (has a higher value) to {C} on one attribute and inferior (has a lower value) on the other. Option {D} is inferior to {T} on one attribute and equal or inferior on the

other. The addition of {D} to the initial choice set {T, C} results in an increase in preference for {T}, and this is called the attraction effect.

The attribute on which an option is superior to another option is called its stronger attribute, while the attribute on which an option is inferior to another option is called its weaker attribute. The decoy {D} can be further distinguished into three types based on its position in the two dimensional attribute space: range decoy (R), frequency decoy (F), and range-frequency decoy (RF). Range decoys are options that are equal on the target's stronger attribute but inferior on the target's weaker attribute. Frequency decoys are options that are equal on the target's weaker attribute but inferior on the target's stronger attribute. Range-frequency decoys are options that are inferior to the target on both the attributes. The different decoy types have previously been shown to produce variable effect sizes (Huber, Payne, & Puto, 1982).

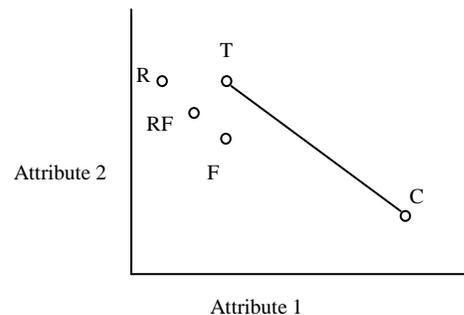


Figure 1: Two dimensional attribute space showing the positions of the range decoy (R), frequency decoy (D), and the range-frequency decoy (RF) relative to the Target (T) option

Figure 1 is a representation of the various options in a two dimensional attribute space. T and C denote the target and competitor options respectively. T is inferior to C on attribute value 1, while being superior to C on attribute value 2. Hence, attribute 1 is called the target's weaker attribute and attribute 2 is called its stronger attribute. R, F and RF denote the three types of decoys. The decoys are all hovering around T because they are trying to increase the preference for the target option. R is equal on T's stronger attribute, i.e. attribute 2, and inferior on T's weaker attribute, i.e. attribute 1. F is equal on T's weaker attribute, i.e. attribute 1, and inferior on T's stronger attribute, i.e. attribute 2. RF is inferior on both of T's attributes. The positions of T and C can be switched, in which case the decoys will also move along with T.

Sum-Highest Property

Choices are inherently probabilistic and to elicit people's preferences, choice probabilities of options need to be estimated. The estimate is usually a frequentist estimation of probability, where the same choice set is presented to the

subject multiple times. Since this procedure is somewhat artificial, two common methods are often used to overcome this problem. The first method involves presenting the same choice set to a subject on multiple occasions, interwoven with other tasks in between. In the second method, which is the focus in this paper, data is drawn from probability distributions with enough noise added to introduce variation in the task, without fundamentally changing the original choice set. Drawing from probability distributions solves the problem of estimating choice probabilities, but comes with the risk of inducing properties in the data which one might not be aware of, which then may lead to confounds in the results. One such candidate condition is the sum-highest property which in this paper is defined as follows.

1. One attribute of the target option has the highest value amongst all attributes across all options.
2. The sum of attribute values for the target is greater than the sum of attribute values for the competitor and the sum of attribute values for the decoy.

	Eyewitness Testimony Strength 1	Eyewitness Testimony Strength 2
Convict A	65	35
Convict B	36	63
Convict C	62	33

Figure 2: An example of a choice set where the target option satisfies the sum-highest property

Figure 2 is an example of a choice set where the sum-highest property is satisfied. The graphical user interface is similar to the one used for stimuli presentation in the experiment which follows, although the numbers are simplified for exposition. In this example, Convict A is the target option, Convict B is the competitor option, and Convict C is the decoy option. Convict A satisfies the sum-highest property because 1) one of its attribute values (Eyewitness Testimony Strength 1 = 65) is greater than all the other 5 attribute values (35, 36, 63, 62, 33) and 2) its sum of attribute values ($65 + 35 = 100$) is greater than sum of attribute values for Convict B ($36 + 63 = 99$) and sum of attribute values for Convict C ($62 + 33 = 95$).

Current Study

One line of investigation which has not received much discussion in the multi-attribute decision making literature,

is the effect that stimuli generation, using probability distributions, has on estimation of choice probabilities. In this paper, a type of stimuli generation effect, collectively called the sum-highest property, is introduced, and its implications are investigated in the context of the attraction effect, which is a representative multi-alternative multi-attribute decision phenomenon. The paper is divided into two main parts: a simulation study followed by a simple experiment. Having decided upon the sum-highest property as a candidate condition under which the attraction effect might not hold, it is important to ascertain what proportion of the stimuli can be affected by this property. For this purpose, in the simulation study, empirical distributions of target options satisfying the sum-highest property, using the stimuli generation scheme from Trueblood (2012), were constructed, to check how often it can be expected that the target option satisfies the sum-highest property. This was followed by an experiment which tested the consequence of this property being satisfied.

To presage the results, the simulation study reveals that a large proportion of target options satisfying the sum-highest property can be expected. Furthermore, the results from the experiment suggest a possible alternative explanation to the attraction effect in experiments which use similar probabilistic stimuli generation schemes for choice probability estimation.

Simulation Study

To gain understanding of how likely is it that target options will satisfy the sum-highest property in actual experiments, empirical distributions were constructed by replicating the probabilistic stimuli generation scheme for the inference task from Trueblood (2012).

Method

A total of six distributions, two for each decoy type, were constructed using the stimuli generation scheme specified below, sample size of 20, and ($n=10,000$). The sample size was 20 to remain faithful to the Trueblood study where there were 40 decisions for each decoy type, with each decoy type being represented by two ternary choice sets. All the means and variances were the same as Trueblood's study. The initial options were drawn from bivariate Gaussians with means (33.6, 66.55) and (66.1, 34.05) respectively. Range decoys were drawn from a bivariate Gaussian with mean (28.55, 66.55) for one half of the cases and (66.1, 28.35) for the other half. Frequency decoys were drawn from a bivariate Gaussian with mean (33.6, 61.3) for one half of the cases and (60.45, 34.05) for the other half. Range-Frequency decoys were drawn from a bivariate Gaussian with mean (28.1, 60.9) for one half of the cases and (60.25, 28.75) for the other half. For each option, the bivariate Gaussians had a variance of 1 on each dimension with no correlation, to introduce variation in the task. Dividing the decoys into two halves, of 20 each, ensured that both possible positions in the two dimensional attribute

space were chosen as the target option an equal number of times.

Results and Discussion

The empirical distribution of target options which satisfy the sum-highest property, drawn from the bivariate Gaussians specified above, sample size of 20, and ($n = 10,000$) are presented in Figures 3.1 - 3.3.

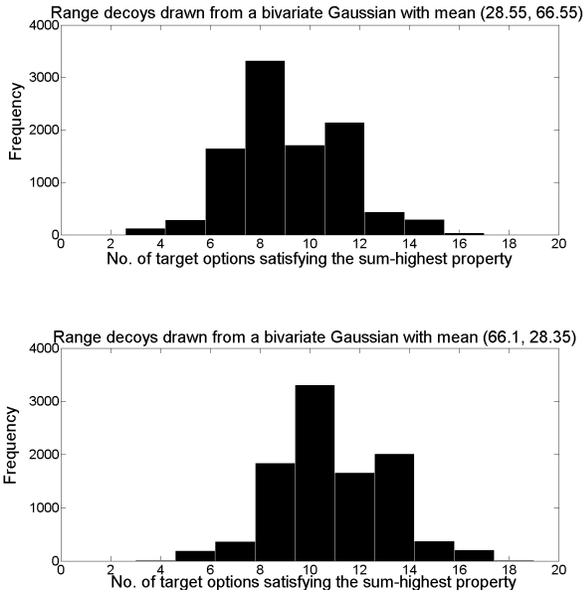


Figure 3.1: Empirical distributions of target options which satisfy the sum-highest property in range decoy choice sets (sample size = 20, $n = 10,000$)

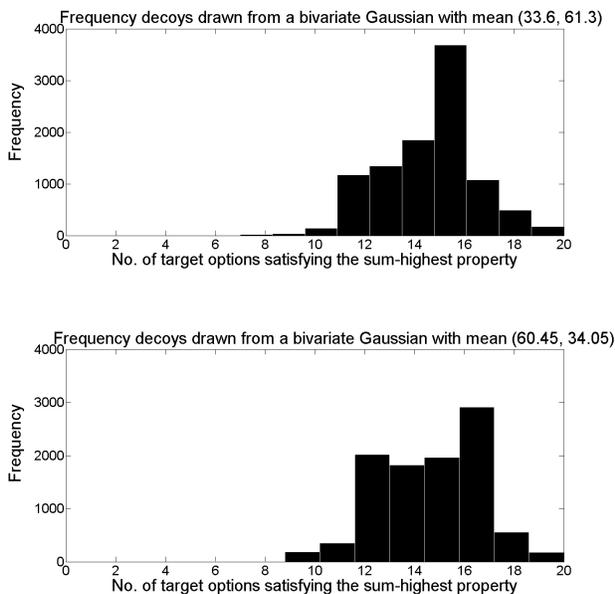


Figure 3.2: Empirical distributions of target options which satisfy the sum-highest property in frequency decoy choice sets (sample size = 20, $n = 10,000$)

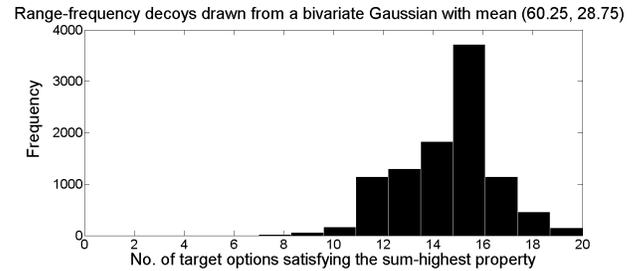
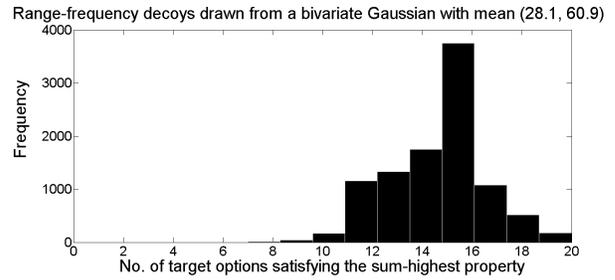


Figure 3.3: Empirical distributions of target options which satisfy the sum-highest property in range-frequency decoy choice sets (sample size = 20, $n = 10,000$)

Clearly, a large proportion of target options are expected to satisfy the sum-highest property, which supports its relevance and justifies further examination of choice behavior when this property is satisfied. The consequences of the sum-highest property are explored in the experiment that follows.

Experiment

The goal of this experiment was to test the hypothesis that people are strongly biased towards the target option when it satisfies the sum-highest property, even before the addition of the decoy option.

Method

Participants 14 undergraduate students from the University of Texas at Dallas participated in this experiment for course credit.

Stimuli The options in the “control scheme” group were drawn from bivariate Gaussians with means (33.6, 66.55) and (66.1, 34.05) respectively, and a variance of 2 on each dimension with no correlation. The options in the “sum-highest scheme” group were chosen similarly with the added constraint that target options satisfy the sum-highest property. Both possible positions in the two-dimensional attribute space were chosen as the target an equal number of times. Each subject made a total of 144 decisions. They encountered these decisions in two blocks of 72 decisions each. The inter-stimulus interval was 1 second. The order of choice sets within each block was randomized across

subjects. The order of option types (target and competitor) in choice sets was completely counterbalanced within experimental blocks.

The stimuli generation scheme for the “control scheme” was purposely chosen to strongly mimic the stimuli generation scheme from Trueblood’s study. As shown in the simulation study, such a probabilistic stimuli generation scheme will give rise to a certain number of target options satisfying the sum-highest property, which if the hypothesis that subjects are biased towards the target option when it satisfies the sum-highest property holds, makes it more difficult for the results to reach statistical significance. Furthermore, by using a stimuli generation scheme for the control that has been tested in a previous study, the risk of inducing additional unknown properties in the data was also mitigated.

Procedure Subjects were instructed that their task requirement was to select, from a binary choice set, the most likely crime suspect based on the strength of two eyewitness testimonies. They were told that the testimonies are reported on a scale of 0-100, where 0 implies very weak evidence of guilt and 100 implies a very strong evidence of guilt. Subjects were also informed that the strength of testimonies from both witnesses are equally valid and important. The presentation of choices and the registration of subject responses were carried out via a graphical user interface programmed in MATLAB. To avoid fatigue, subjects were encouraged to take breaks between experimental blocks.

Results and Discussion

A 1 factor-within subjects ANOVA was used to analyze the data. “Stimuli generation scheme” was the independent variable with two levels (“sum-highest scheme” and “control scheme”). The dependent variable was the proportion of times a participant chose the target option, which was the estimate of the probability of choosing the target option. As shown in Figure 4, the mean choice probability for the target option in the “sum-highest scheme” ($M = 0.92$, $S = 0.09$) was greater than the “control scheme” ($M = 0.50$, $S = 0.03$) group, $R^2 = 0.91$, $F(1, 13) = 301.37$, $MS_e = 0.004$, $p < 0.01$.

The overwhelming bias towards the target option when it satisfies the sum-highest property, before the addition of a decoy option, opens up the possibility of alternate explanations to the attraction effect. For example, let’s assume we start with an initial choice set {target, competitor}, where the known probabilities are $P(\text{target}) = 0.5$ and $P(\text{competitor}) = 0.5$. Let’s also assume that the addition of the {decoy} option, unknown to the experimenter, makes no difference to the choice probabilities. The experimenter is interested in estimating the unknown probabilities of the complete choice set, i.e. $P(\text{target}) = 0.5$, $P(\text{competitor}) = 0.5$ and $P(\text{decoy}) = 0$. They present the complete choice set 20 times to a subject, with data drawn from the noise added probability distribution discussed earlier. If say, in 8 out of 20 of the choice sets, the

target option satisfies the sum-highest property, then an increase in the probability of the target option will be detected, and this can be misattributed to the attraction effect. For the less drastic case, where there indeed is an increase in probability of the target option after the addition of the decoy, the above reasoning still holds. This is because in this case it is not possible to tease apart the increase due to the attraction effect and the effect of the sum-highest property.

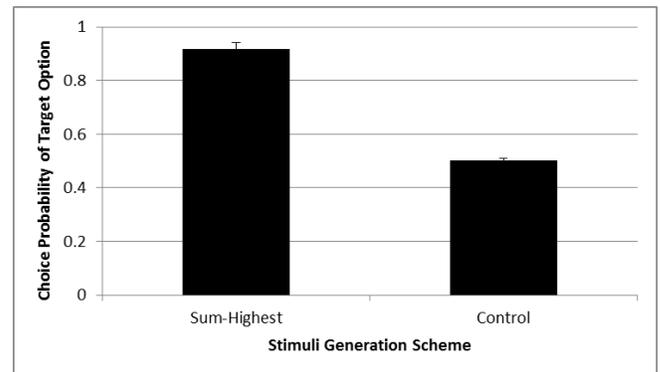


Figure 4: Mean with standard error bars for choice probability of target option

General Discussion

Whenever choice probabilities of a choice set are estimated by presenting the same choice set to a subject multiple times, with the attribute values of the alternatives drawn from probability distributions with noise added to introduce variation in the task, there is a risk of introducing properties in the stimuli which can covertly alter behavior. In this paper, a type of stimuli generation effect, called the sum-highest property, was introduced in the context of the attraction effect, which is a representative multi-attribute decision phenomenon. To gain understanding of the impact of this condition, two main results were presented in this paper. First, it was shown that the stimuli generation scheme for a previously conducted attraction effect study, can give rise to a large proportion of target options satisfying the sum-highest property. This was followed by an experiment which supports the hypothesis that people are strongly biased towards the target option when it satisfies the sum-highest property even before the addition of the decoy option.

One problem with the current study is that it establishes that people are biased towards the target option when it satisfies the sum-highest property, but the demonstration is in the absence of a decoy. Although the bias is very strong, one needs further evidence to be convinced that this bias transfers over in the presence of a decoy. Nandy (2014, in preparation), replicated the experiment from this paper in the presence of a decoy, and found that the bias also holds in the presence of a decoy. Taken together, the experiments strongly suggest that the choice sets which satisfy the sum-highest property are immune to the attraction effect.

The choice sets with options which satisfy the sum-highest property can lie concealed, surrounded by other choice sets which do not suffer from artifacts, and can covertly drive experimental results. Hence, studies which induce the attraction effect, but do not control for the sum-highest property may have inflated effect sizes. Hence, by bringing attention to this problem which may slip an experimenter's awareness, the results in this paper can guide researchers towards better experimental/stimuli design choices, and also towards identification of a potential pitfall in their experimental results.

In addition to the experimental implications, the results of this paper are also informative to theorists interested in process models of decision making. For example, the bias towards an option when it satisfies the sum-highest property gives an insight into the decision process, where people might be solving the decision problem by initially searching for the highest attribute value across all alternatives, followed by a second calculation process where attribute values are summed for each alternative and then compared. Post-experiment verbal feedback from participants strongly hinted at such a strategy.

In conclusion, the attraction effect continues to be an important phenomenon both experimentally and as a tool to further theoretical undertakings. While tackling the question of how stimuli generation can impact choice probability estimation, a condition called the sum-highest property was introduced, and it was shown that this property is not desirable for the purpose of investigating the presence of the attraction effect. Additionally, the sum-highest property is interesting in and by itself, providing an insight into the decision process.

Acknowledgments

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References

- Huber, J., Payne, J., & Puto, C. (1982). Adding asymmetrically dominated alternatives: Violations of regularity and the similarity hypothesis. *Journal of Consumer Research*, 90-98.
- Huber, J., & Puto, C. (1983). Market boundaries and product choice: Illustrating attraction and substitution effects. *Journal of Consumer Research*, 31-44.
- Maylor, E., & Roberts, M. (2007). Similarity and attraction effects in episodic memory judgments. *Cognition*, 105(3), 715-723.
- Nandy, S. (2014). Implications of Random Stimuli Generation on the Attraction Effect. Manuscript in preparation.
- Rieskamp, J., Busemeyer, J., & Mellers, B. (2006). Extending the bounds of rationality: evidence and theories of preferential choice. *Journal of Economic Literature*, 631-661.
- Roe, R., Busemeyer, J., & Townsend, J. (2001). Multialternative decision field theory: A dynamic connectionist model of decision making. *Psychological Review*, 108(2), 370.
- Simonson, I. (1989). Choice based on reasons: The case of attraction and compromise effects. *Journal of Consumer Research*, 158-174.
- Sue O'Curry, Y. P., & Pitts, R. (1995). The attraction effect and political choice in two elections. *Journal of Consumer Psychology*, 4(1), 85-101.
- Trueblood, J. (2012). Multialternative context effects obtained using an inference task. *Psychonomic Bulletin & Review*, 19, 962-968.
- Trueblood, J. S., Brown, S. D., Heathcote, A., & Busemeyer, J. R. (2013). Not just for consumers context effects are fundamental to decision making. *Psychological Science*, 24(6), 901-908.
- Tversky, A. (1972). Elimination by aspects: A theory of choice. *Psychological Review*, 79(4), 281.
- Tversky, A., & Simonson, I. (1993). Context-dependent preferences. *Management Science*, 39(10), 1179-1189.
- Usher, M., & McClelland, J. (2004). Loss aversion and inhibition in dynamical models of multialternative choice. *Psychological Review*, 111(3), 757.