SEMANTIC GIST IN CONJUNCTION AND DISJUNCTION FALLACIES IN EPISODIC SOURCE MEMORY

A Thesis

Presented to the Faculty of the Graduate School

of Cornell University

In Partial Fulfillment of the Requirements for the Degree of

Master of Arts

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January 2015

ABSTRACT

Although disjunction and conjunction fallacies have been studied extensively in decision making, relatively few studies explore the fallacies in memory. The goal of the present experiments is to look at the behavior of these decision fallacies in episodic source memory. In particular, I compared the effects of semantic gist processing on the fallacies. One-hundred-and-thirty-four undergraduates took a standard source memory task that contained either a disjunctive probe (was the word on List 1 OR List 2?) or a conjunctive probe (was the word on List 1 AND List 2?). Both the disjunction and conjunction fallacies varied as a function of theoretically motivated manipulations, suggesting that they can be explained by core memory ideas.

Acknowledgements

I would like to thank Dr. Charles Brainerd, my advisor and committee chair, for his outstanding guidance for the past few years. I would not have made it this far without his mentoring and encouragement every step of the way, and for that I am extremely grateful. I would also like to thank Dr. Valerie Reyna for her kind words throughout my career and being a constant presence of reassurance even during the most stressful times of graduate school. I am also very thankful for Dr. Stephen Ceci for taking the time to be involved in both my Master's thesis as well as my undergraduate thesis a few years ago.

I would also like to extend my thanks to the Human Development Graduate Department, as they have been nothing short of outstanding in helping the new graduate students to be integrated into their program. Especially during the first year, they provided ample support for any questions and concerns, and also pointed the way towards funding opportunities such as the NSF. It has been a wonderful learning experience that led up to the completion of this paper, and I cannot express enough gratitude to those who made this possible.

Table of Contents

List of Tables

List of Figures

INTRODUCTION

Disjunction and conjunction fallacies have been studied extensively in the decision literature but little is known about their possible memory counterparts. Situations in which one is required to remember conjunctive/disjunctive events are frequently encountered in everyday life, such as during eyewitness interviews (e.g., “was the suspect tall?”, “was the suspect male?”, “was the suspect tall *and* male?”), and yet whether such situations are liable to the same types of fallacies reported in the decision literature is largely unknown because such matters have not been the target of systematic investigation in the memory literature.

In the remainder of this section, I will discuss prior research on fallacies in probability judgment, and then the theory behind predicting these same kinds of fallacies in episodic memory. Then, I will describe the few experiments that have explored a memory analogue of one type of fallacy, and how their results fit the theory that links fallacies in judgment and decision making to fallacies in memory. Finally, I will discuss the present experiments, and how they will provide further evidence that fallacies in episodic memory are not too different from fallacies in decision making.

Fallacies in Judgment and Decision Making

The irrationalities of human decision making have been studied for many years. Hundreds of papers have documented phenomena such as the sunk cost effect (Arkes & Blumer, 1985; Kanodia et al., 1989), the anchoring heuristic (Englich et al. 2006; Kahneman & Tversky, 1973), and the endowment effect (Thaler, 1980; van de Ven et al. 2005). These are often stated to be due to mental shortcuts that people take to focus on important aspects of a complex task while ignoring other aspects in the process, and although these shortcuts are not problematic in most circumstances, they lead to some of the baffling irrationalities mentioned. Among these are probability fallacies, where people violate the laws of chance when judging the likelihood of certain events. People's intuitive probability judgments are often inconsistent with the laws of chance, and these violations have been a topic of interest to many researchers. One such example is the gambler's fallacy, (Clotfelter & Cook, 1991) where given two independent events, people believe that one event becomes more likely to occur depending on the outcome of the other event. For instance, let us take a situation where we have to guess the outcome of a fair coin flip. The probability that the coin will land on heads is 0.5, and this probability is independent of whether or not the coin landed on heads or tails in an earlier flip. In the gambler's fallacy, people believe that it will be more or less likely for the coin to land on heads depending on the previous outcomes.

Within probability fallacies, there are two well-documented ones that will be of interest in the present experiments: the conjunction (Tversky & Kahneman, 1983) and disjunction fallacies (Bar-Hillel & Neter, 1993). The conjunction fallacy was first identified in 1983 by Tversky and Kahneman. In their experiment, now known as the Linda problem, subjects were given a prompt about a woman with liberal views and were asked to rate several statements about her, two key ratings being the probability that (a) Linda is a feminist bank teller and that (b) Linda is a bank teller. Because the description "bank teller" is a subset of the description "feminist bank teller," the probability that Linda is a bank teller must be higher than the probability that Linda is a feminist bank teller. The conjunction fallacy occurs when subjects assign a higher probability that Linda is a feminist bank teller than that Linda is a bank teller. In other words, people judge a proper subset to be more likely than the set to which it belongs.

In the disjunction fallacy, the sum of the judged probabilities of a series of mutually exclusive events [e.g., P(A) + P(B)] is greater than the judged probability of the union of such events [P(AUB)]. For example, a subject may be asked to judge the probability that a single person will (a) die from heart disease, (b) die from cancer, and (c) die from either heart disease or cancer. Because it is not possible to die twice, the probability that a single person will die from either heart disease or cancer must equal the sum of the probability that the person will die from heart disease and the probability that the person will die from cancer. Tversky and Koehler (1994) found that this rule was violated and that the probabilities were subadditive; that is, the sum of the individual events of dying from cancer and dying from heart disease was greater than the judged probability of dying from either cancer or heart disease. Both of these fallacies have been studied extensively, and there is ongoing work on the reason these errors happen (e.g., Tentori et al., 2013; Costello & Watts, 2012).

The traditional theoretical explanation for conjunction and disjunction fallacies is that psychological probabilities are attached to descriptions of events, as opposed to the events themselves. This idea is central to support theory (ST), introduced by Tversky and Koehler (1994), which claims that probability judgments are dependent on the explicitness of the description of the event that is being judged. ST assumes that when people make probability judgments, they retrieve memory support for the event they are judging. Support can be defined as the strength of evidence in favor of a hypothesis about the event, such as the likelihood of it occurring, based on objective data (e.g., the frequency of cardiac disease in the relevant population) or subjective impressions formed from certain heuristics such as availability and representativeness (Kahneman, Slovic, & Tversky, 1982). According to ST, people are not efficient at unpacking a disjunctive description into its individual components, and therefore the amount of support they retrieve for the individual components in a disjunctive description is less than the support they retrieve when the components are presented independently, which produces subadditivity. The fact that disjunctive probes must be unpacked whereas nondisjunctive probes do not, leads to different availability of retrieved support. ST hypothesizes that disjunction and conjunction fallacies can be reduced via attention manipulations that decrease the mental resources necessary to successfully unpack descriptions, and also via memory manipulations that increase retrieved support for packed descriptions.

Traditional approaches to explaining decision fallacies often focus on the limitations of human processing capacity. However, a more recent theory hypothesizes that these fallacies may be due to reliance on certain types of memory traces, and that these fallacies may be nothing more than artifacts of memory encoding and retrieval. Subadditivity can be explained by fuzzy-trace-theory (FTT; Reyna & Brainerd 1995), which assumes that two types of traces can be retrieved. FTT posits that subjects encode and store detailed representations of targets' presentations (verbatim traces) and representations that preserve their bottom-line meaning (gist traces). The theory assumes that reliance on gist rather than verbatim traces is what produces conjunction and disjunction fallacies (Reyna, 2008; Reyna & Brainerd 2008; Wolf & Reyna 2010). Furthermore, Estes (1976) found that relative frequency rather than absolute frequency predicted people's probability judgments, which can be interpreted as a greater preference for gist when making decisions (Reyna & Brainerd 1992). This can contribute to the difficulty many people have in avoiding probability fallacies (e.g. Reyna, Lloyd, & Whalen 2001).

In addition to predicting fallacies in decision-making, Brainerd and Reyna (2008) showed that FTT predicts disjunction fallacies in episodic memory. They demonstrated scenarios that subadditivity could occur in standard false memory designs, where subjects are asked to determine whether or not a probe is a target that appeared at study, a distractor that did not appear at study but is related to a word at study, or an unrelated distractor that is neither a target or related to a word at study. Upon inspection of using a mathematical model that implements FTT's dual-trace distinction, they found that the sum of the probabilities of a test cue being a target and a related distractor, $P(\mathrm{T}) + P(\mathrm{R})$, was greater than the probability of the test cue being either a target or a related distractor, $P(\mathrm{TUR})$, so that $P(\mathrm{T}) + P(\mathrm{R}) > P(\mathrm{TUR})$ rather than $P(\mathrm{T}) + P(\mathrm{R}) = P(\mathrm{TUR})$. The reason this inequality emerges is as follows. Let's take a standard recognition test. The retrieval of verbatim information is not description-dependent; that is, if the description at test asks if the cue is T (it was a target), R (it was a related distractor), or TUR (it was a target or a related distractor), a target cue is always correctly accepted as a target, correctly rejected as a related distractor, and correctly accepted as either a target or a related distractor. However, if the subject relies on gist traces, they are description-dependent. A target cue will be correctly accepted as a target with a T description, incorrectly accepted as a related distractor with an R description, and correctly accepted as either a target or a related distractor with a TUR description, which produces the inequality $P(\mathrm{T}) + P(\mathrm{R}) > P(\mathrm{TUR})$.

An advantage of FTT is that it not only explains probability judgment fallacies, but it also predicts new fallacies in the memory domain. In particular, because FTT's explanation of disjunction fallacies is solely a memory explanation, we can predict that we will see the same kind of illusions in episodic memory. Thus, if FTT's memory distinctions can explain fallacies in probability judgment, these same fallacies may be core properties of memory itself.

Disjunction and Conjunction Fallacies in Memory

In this section I will outline the research that has been done on disjunction and conjunction fallacies in memory. I will briefly sketch the methodologies that have been used, and the reasoning behind them. Then, I will review key findings from the studies of memory counterparts of disjunction and conjunction fallacies.

One reason why memory analogues of decision making fallacies have not been extensively explored is methodological. In memory research, the types of compound probes that are characteristic of research on conjunction and disjunction fallacies are rarely used. However compound probes are administered in the conjoint recognition design, which figures prominently in the false memory literature (e.g., Brainerd, Reyna, & Mojardin, 1999; Stahl & Klauer, 2009). Instead of only asking whether or not an item is a "target," the conjoint recognition procedure asks whether or not an item is a "target," "new but related to a target," or "a target, or new but related to a target." Notice that these instructions are identical to the instructions used in disjunction designs, except that rather than asking subjects to make probability estimates, they are asked memory questions. The simplicity of the conjoint recognition design makes it applicable to different kinds of stimuli, such as words in the Deese-Roediger-McDermott paradigm (DRM; Deese, 1959; Roediger & McDermott 1995), pictures, and videos. Additionally, it does not have to be restricted to old-new recognition designs, and can be used with source designs.

Because the conjoint recognition procedure parallels disjunction fallacy designs, it is simple to calculate subadditivity in episodic memory by comparing the relationship between the proportion where people say "yes" to each of the three types of descriptions. The disjunction fallacy occurs if the sum of the proportion of people who say "yes" to the description "target" and the proportion that say "yes" to the description "new but related to a target" is greater than the proportion that say "yes" to the description "a target, or new but related to a target." Based on FTT, we can also predict the kinds of memory manipulations that would increase subadditivity in conjoint recognition designs.

The first study to explore subadditivity in memory using conjoint recognition was by Brainerd and Reyna (2008). In this paper, the authors demonstrated that subadditivity falls out of FTT, and tested this hypothesis by analyzing datasets from 19 different research reports. There were a total of 116 datasets for disjunction fallacies in true memory and 165 datasets for disjunction fallacies in false memory. For true memory, the authors identified experiments with data for the probability that subjects indicated a target was a target, $P_v(T)$, the probability that a target was a related distractor, $P_G(T)$, and the probability that a target was either a target or a related distractor, $P_{VG}(T)$. Using bias corrected values for the three probabilities, the authors calculated $P_v(T)+P_G(T) - P_{VG}(T)$ for each data set and plotted it against $P_{VG}(T)$. Any data point above zero indicated the presence of the disjunction fallacy. The same procedure was used to determine disjunction fallacies in false memory, except the probabilities of interest were the probability that subjects indicated a related distractor was a target, $P_v(RD)$, the probability that a related distractor was a related distractor, $P_G(RD)$, and the probability that a related distractor was either a target or a related distractor, $P_{VG}(RD)$. In both cases, there was robust subadditivity; that is, $P(T) + P(R)>P(TUR)$. For true memory, 90% of the data sets showed the disjunction fallacy, and $P_v(T)+P_G(T) - P_{VG}(T)$ averaged across all data sets was reliably above zero. Similarly, 90% of the data sets for false memory also showed the disjunction fallacy, and $P_v(G)+P_G(G) - P_{VG}(G)$ averaged across all data sets was reliably above zero. Additionally, the authors hypothesized that gist processing encouraged disjunction fallacies, and tested this by plotting $P(T) + P(R) – P(TUR)$ for both true and false memory against the familiarity term derived from FTT. They found that disjunction fallacies increased as familiarity increased. Although this analysis provided tentative evidence for memory disjunction fallacies, it was a retrospective analysis of studies that were not designed for this purpose, and it did not measure disjunction fallacies within individual subjects.

Brainerd et al. (2010) addressed these limitations in some experiments in which within-subject analysis of disjunction fallacies was possible. In their experiment, the three descriptions were factorially varied within subjects instead of between subjects. The subjects were presented with a list of words, and then they were told that there were three types of cues in the test: presented, unpresented but related, and unpresented and unrelated. These cues were paired with one of the three conjoint recognition descriptions. Subjects then had to accept or reject one of the three descriptions for each test word. The disjunction fallacy was calculated by bias corrected acceptance probabilities $P(\mathrm{T})+P(\mathrm{R}) - P(\mathrm{TUR})$, and they were calculated for both targets and related distractors.

Several types of experimental manipulations were explored to see whether the data followed FTT's predictions on the disjunction fallacy. The manipulations included increasing processing of meaning content of the study items (DRM lists), delay between study and test, word frequency (based on how often the words appear in the English lexicon), and emotional valence. The authors found that disjunction fallacies appeared at the level of individual subjects. Additionally, as FTT predicts, it was found that manipulations that encourage gist processing increased the incidence of the disjunction fallacy. There was more disjunction fallacy when DRM lists were used and there was a time delay between study and test. Both of those manipulations are known to increase reliance on gist memory. Furthermore, there was less disjunction fallacy when there was no time delay between study and test, and when words were positively valenced. Both of those manipulations are known to encourage verbatim processing. The authors also found that the disjunction fallacy was greater for related distractors than for targets, which can be attributed to the fact that related distractors increase reliance on semantic gist compared to targets.

Another study investigated disjunction fallacies in another form of episodic memory: source memory (Brainerd et al., 2012). A source version of conjoint recognition can be configured by using two (or more) lists of words, rather than one, and asking subjects whether or not a cue was “presented on List 1,” “presented on List 2,” or “presented on List 1 or List 2.” Notice that this format is comparable to disjunction fallacy designs in probability judgment if the two presented lists are mutually exclusive, so that a target that was presented on List 1 was never presented on List 2 and vice versa. Subadditivity can be measured by calculating values for the acceptance values for descriptions “presented on List 1” *P*(L1), descriptions “presented on List 2” *P*(L2), and descriptions “presented on List 1 or List 2” *P*(L1UL2).

Like the prior study (Brainerd et al., 2010), this source design included manipulations that would affect the memory processes that FTT predicts will increase or decrease subadditivity. The manipulations were word frequency, concrete vs. abstract words, list order, individual differences in verbatim memory ability, and the number of source contexts. Subjects viewed two or three lists of words, depending on the number of source contexts they were assigned, and then they were asked to accept or reject one of the three conjoint recognition source descriptions attached to a cue word. Subjects were either from a University P or University Q, with one University scoring significantly higher in verbatim memory than the other, but with equal gist memory. All of the words were semantically unrelated to each other, so gist manipulations were not present in this particular study.

The memory disjunction fallacies were observed, and this phenomenon varied as a function of theoretically motivated manipulations. Because gist manipulations were not present in this study, the amount of disjunction fallacies depended on reliance on verbatim retrieval, and the results are summarized on Figure 1. Specifically, manipulations that increased verbatim memory decreased the disjunction fallacy as in earlier experiments, such as concrete targets, higher verbatim memory ability, and recent presentation. Manipulations that decreased verbatim memory, such as greater number of presentation contexts, increased disjunction fallacies. Additionally, manipulations such as low word frequency that increased item memory, but not recollection, also increased disjunction fallacies.

So far, I have discussed studies that have explored disjunction fallacies in episodic memory, but not studies that have explored memory analogues of conjunction fallacies. There is only a single article on that topic. Brainerd et al. (in press) conducted a conjunction fallacy follow-up of the 2012 source disjunction fallacy study. They found evidence of robust conjunction fallacies. The design was the same as the earlier source disjunction experiments, except that disjunctive probes were replaced by conjunctive probes so that the three descriptions were (a) “presented on List 1” (b) “presented on List 2” (c) “presented on List 1 and List 2.” Additionally, in order to prevent subjects from noticing that none of the words were repeated on both lists, some words at study which were never presented at test were repeated between lists. Notice that the conjunction fallacy occurs when the acceptance rate of the description “presented on List 1 and List 2” P(L1&L2) is greater than the acceptance rate of either “presented on List 1” P(L1) *or* “presented on List 2” P(L2). There were reliable conjunction fallacies observed in this study.

The authors also measured levels of conjunction illusions. A conjunction illusion occurs when subjects judge that an item had been presented on both List 1 and List 2, when it never appeared on both lists. For this study, the conjunction illusion is $P(\text{L1\&L2})>0$. While there are some decision studies (e.g. Wolfe & Reyna 2001), conjunction illusions are often difficult to study in decision studies because the relevant conjunctive probes have a nonzero probability of occurrence (e.g. in the Linda problem, the probability that Linda is both a bank teller and a feminist can be greater than zero). However, Brainerd et al. were able to observe conjunction illusions in their source design, because none of the targets were presented on both lists, and therefore $P(\text{L1\&L2})$ had to be zero. Low word frequency and recent lists showed greater conjunction illusions, and the results are summarized in Figure 2. Conjunction illusions were also robust, and appeared in all manipulations at significant levels.

Last, the authors compared the values from their experiment to Brainerd et al. (2012)'s $P(\text{L1})+P(\text{L2}) - P(\text{L1UL2})$ values to determine how well the disjunction fallacy can predict conjunction illusions. This was possible because the two were studied with comparable experimental designs that were done with the following two measures from basic probability theory for disjunction and conjunction illusions respectively:

$$P(\text{A})+P(\text{B}) - P(\text{AUB})$$

$$P(\text{A\&B})$$

Given the following equation from basic probability theory:

$$P(\text{AUB}) = P(\text{A})+P(\text{B}) - P(\text{A\&B})$$

The equation can be rearranged so that:

$$P(\text{A\&B})=P(\text{A})+P(\text{B}) - P(\text{AUB})$$

The authors can predict the amount of conjunction illusions if they know the amount of disjunction fallacy. By experimental design, it is impossible for *P*(A&B) to be a non-zero probability because none of the targets were presented on both lists. Also, *P*(A)+*P*(B) – *P*(AUB) must have zero probability if there is no disjunction fallacy. However, it is apparent from the above equations that if *P*(A&B) is a non-zero number, in other words there is a conjunction illusion, then the amount of disjunction fallacy is equal to that value. Using paired t-tests to compare *P*(A)+*P*(B) – *P*(AUB) and *P*(A&B), the authors found that the disjunction fallacy could predict conjunction illusions.

Present Experiment

What all of these studies suggest is that classic probability fallacies are also present in episodic memory, and hence, they have memory explanations. Not only do these fallacies appear in old/new false memory studies, but also for a second kind of episodic memory: source recognition. In this section I will sketch the motivation of the present experiments, the reasoning behind their designs, and what it adds to study of memory fallacies.

For episodic source memory we have yet to manipulate semantic gist in connection with disjunction and conjunction fallacies. In decision making, there is often a gist-based explanation for these fallacies, and FTT posits that this is also true for memory fallacies (i.e. Bar-Hillel & Neter, 1993; Fisk, 2002; Stolarz-Fantino et al., 2003). Furthermore, compound memory questions in day-to-day life are often source questions: “Did you meet her on Monday or Sunday? Did you go to the mall and the movies?”. Because of this, determining whether or not accuracy is compromised because of these fallacies for source designs is important, as well as identifying how verbatim and gist retrieval affects them. Prior studies have already determined that gist memory plays a crucial role in elevating fallacies in decision-making and false memory studies, and the crucial next step is to see if it affects episodic source memory as well. In other words, does gist and verbatim retrieval operate under a similar framework for all three realms of fallacy studies? Including semantically related targets and semantic orienting tasks can elevate the amount of gist processing that is used at retrieval. In the present experiment, we manipulated semantic relatedness among study items to compare the effects of gist on disjunction and conjunction fallacies.

There were two main experiments. The first explored disjunction fallacies in episodic source memory, and was similar to Brainerd et al.'s (2012) design. Subjects studied two lists of words and answered conjoint recognition questions with a disjunctive probe so that the three descriptions were (a) "presented on List 1" (b) "presented on List 2" and (c) "presented on List 1 or List 2." The key difference was the inclusion of gist manipulation, specifically the inclusion of taxonomic categories in the lists. For instance, a category might be "trees," and the words within that category may be "oak," "maple," "birch," and "spruce." Within the two lists of study words, some categories appeared on both lists, some categories appeared on just one list, and some of the words on each list belonged in no category at all (Figure 3). For manipulations of verbatim memory, word frequency and list order manipulations were included. The second experiment was a comparable conjunction fallacy experiment. All of the materials were identical to the disjunction fallacy experiment, except that a conjunctive description replaced the disjunctive description so that the three descriptions were (a) "presented on List 1" (b) "presented on List 2" (c) "presented on List 1 and List 2." The advantage of using the same design, except for the change in the test questions, is that it allowed for a direct comparison between the behavior of disjunction and conjunction fallacies with respect to the different manipulations. Based on FTT, I hypothesized that the gist manipulation would affect both disjunction and conjunction fallacies, elevating both. Additionally, I hypothesized that the verbatim manipulations would drive down these fallacies.

I also examined the relation between conjunction illusions and disjunction fallacies. Because the design for the disjunction and conjunction experiments was the same except for the type of probe, it was possible to determine whether or not disjunction fallacies are able to predict conjunction illusions. A similar comparison was done by Brainerd et al. (in press), but their comparison did not include any semantic gist manipulations.

EXPERIMENT 1

The main goal of Experiment 1 was to look at the effects of semantic relatedness on the incidence of disjunction fallacies. More gist processing should mean larger disjunction fallacies. In order to manipulate gist, I introduced taxonomic relatedness between the studied words. The format of the experiment was similar to the format used in Brainerd et al. (2012). Subjects studied two lists of words varying in frequency, with each list differing in presentation context and appearance (e.g. List 1 had a yellow background and Arial font, List 2 had a white background and Stencil font). Some of the taxonomic categories appeared on both List 1 and List 2, some appeared on just one of the lists, and some of the study words belonged in no discernible category.

I predicted that items belonging in taxonomic categories would show greater disjunction fallacies than those that were not categorized, due to greater gist processing for the former. When target words are grouped into recognizable categories, it encourages the meaning-based gist processing during encoding and retrieval. Furthermore, because list recency is a verbatim manipulation, I predicted larger disjunction fallacies for List 1 items than for List 2 items.

Subjects. The subjects in Experiment 1 were 67 undergraduate students who participated in the experiment to fulfill a course requirement. One subject was dropped from analysis because they skipped too many answer choices in the memory task.

Materials. 12 categories were chosen from the Uyeda and Mandler prototypicality norms (Uyeda & Mandler, 1980). All of the words were concrete nouns, and word frequency was counterbalanced between lists and categories, and was determined with both the updated Battig and Montague norms (Van Overschelde et al. 2004) and the Kucera and Francis norms (Kucera & Francis, 1967). Words with the highest prototypicality ratings were chosen to be used for the experiment.

8 of these categories were chosen to appear at study, with 4 categories being unique to either List 1 or List 2, and the remaining 4 categories being repeated in both lists. During presentation, these categorized words were shown in blocks of 4 words to further emphasize the fact that all of the words belonged to a specific category. In order to keep the number of target items per category equal between unique categories and shared categories, 8 targets were shown in two separate but consecutive blocks for targets in List unique categories, while 8 targets were shown in two separate blocks of words, one block in each list, for targets in shared categories. None of the words that appeared on List 1 appeared on List 2 and vice versa, even though same categories were shared between lists. For example, *trees* might be a category on both lists, and List 1 might have the word *oak* and List 2 may have the word *maple*, but there were no instances in which *oak* appeared on both Lists 1 and 2. There was a frequency manipulation, with half of the words in each category being high frequency (i.e. appearing frequently in the English

lexicon) and half being low frequency (i.e. appearing infrequently in the English lexicon). Each categorical block was separated by two uncategorized words that did not belong in any category for a total of 14 presented uncategorized words in each list. Each list began with a two-word opening buffer and ended with a two-word closing buffer. These uncategorized words were fillers that did not appear on the later memory test (Figure 3).

As in previous studies of disjunction and conjunction fallacies, each list was presented with distinct visual cues by presenting all of the words in a distinct font (e.g., Arial, Stencil) against a different background color (e.g., yellow, white). Therefore, each list was identified by a specific combination of font and background color. Because List 1 was always presented before List 2, temporal order was another list-specific cue (Figure 3).

During the test phase, 168 probes were presented in random order. The probes consisted of a cue word paired with an episodic description of the word. There were 12 different types of cue words, which consisted of the following. 24 categorized targets whose categories were unique to one list (12 high frequency/12 low frequency), 24 categorized targets whose categories were shared between both lists (12 high frequency/12 low frequency), 24 related distractors from a category unique to one list (12 high frequency/12 low frequency), 24 related distractors from a category shared between both lists (12 high frequency/12 low frequency), 24 uncategorized targets (12 high frequency/12 low frequency), 24 unrelated categorized distractors belonging in categories that were not presented at study (12 high frequency/12 low frequency), and 24 unrelated and uncategorized distractors (12 high frequency/12 low frequency). Each of the cue words was paired with one of the following three episodic descriptions of the word: presented on List 1, presented on List 2, and presented on List 1 or List 2. The descriptions were varied factorially across the 12 possible types of cue words. The subjects accepted or rejected each probe depending on whether or not they judged the episodic description to be true or false.

Procedure. At the start of the experiment, participants were informed that they were participating in a source recognition task, and that they will be given two lists of words to study. Then, they were presented the two lists in succession on a computer screen. The words were presented at a rate of 3 seconds, centered on the screen and printed in 72-point font. After the first list was completed, there was a 15 second pause before the presentation of the second list. Once the subject finished studying the second list, they were given instructions for the upcoming memory test. The instructions informed the subjects that while they would have to make source judgments for words that appeared on the list, they would also have to make source judgments for words that never appeared on the list. They were specifically instructed to only accept the test probes where they thought the episodic description for the cue word to be true. Examples for the three episodic descriptions paired with sample cue words were provided so that the subjects understood how to answer the upcoming memory test. Additionally the instructions emphasized the fact that the two lists did not overlap, and that if the subject clearly remembered a word as having been on one of the lists, then it could not have been on the other list. The 168 probes were then presented in a random order, and the subjects completed the test in a self-paced manner.

RESULTS

Disjunction Fallacy

The analysis was done on bias corrected values for both targets and related distractors. Bias was corrected with the two-high threshold method, by subtracting acceptance probabilities for unrelated distractors from acceptance probabilities for targets (Table 1, Table 2). A 2 (list) x 3 (category) x 2 (frequency) ANOVA was conducted on the disjunction fallacy index $P(\text{L1})+P(\text{L2}) - P(\text{L1UL2})$. For targets, there was a main effect of list, $F(1, 65)=28.30$, $p<0.001$, partial $\eta^2=0.30$, with List 1 targets showing a greater disjunction fallacy than List 2 targets (mean difference=0.21, SE=0.04, $p<0.001$). There was also a main effect of category, $F(2, 130)=14.67$, $p<0.001$, partial $\eta^2=0.18$, with targets whose categories were on only one list showing a greater disjunction fallacy than uncategorized targets (mean difference=0.23, SE=0.06, $p<0.001$), and targets whose categories were on both lists showing a greater disjunction fallacy than uncategorized targets (mean difference=0.28, SE=0.06, $p<0.001$). There was a significant interaction effect for list by category, $F(2, 130)=5.66$, $p=0.004$, partial $\eta^2=0.08$. The plots for the descriptive statistics for these analyses are presented in Figure 4. Frequency did not have an effect and was therefore removed from the figure. No disjunction fallacies were observed for related distractors, so ANOVAs were not run.

A one-sample t-test with a test value of zero was done to check which factors produced a disjunction fallacy for targets. If the P(L1)+P(L2) - P(L1UL2) is not significantly different from zero, then we do not have a disjunction fallacy. The results indicated that only targets on List 1 that were categorized on just List 1, $t(65)=4.25$, $p<0.001$, $d=1.05$, and List 1 targets categorized on both lists, $t(65)=6.44$, $p<0.001$, $d=1.60$, resulted in the disjunction fallacy. Thus the disjunction fallacy was strongly affected by both the gist manipulation and one of the verbatim manipulations.

Acceptance Rates

Additionally, ANOVAs were run on bias corrected acceptance probabilities for the different kinds of test probes for both targets and related distractors. For the targets, there were a total of four main effects. There was a main effect of list, $F(1, 65)=37.70$, $p<0.001$, partial $\eta^2=0.37$, with List 1 targets showing a greater acceptance rate than List 2 targets. There was a main effect of frequency, $F(1, 65)=4.47$, $p=0.038$, partial $\eta^2=0.06$, with low frequency words showing a greater acceptance rate than high frequency words. This replicates a finding in Brainerd et al.'s (2012) experiment. There was a main effect of categories, $F(2, 130)=6.03$, $p=0.003$ partial $\eta^2=0.09$, with targets whose categories appeared in both lists showing a greater acceptance rate than targets whose categories only appeared in one list, but with no significant difference with targets that were uncategorized. Last, there was a main effect of question type, $F(2, 130)=25.26$, $p<0.001$, partial $\eta^2=0.28$, with the greatest acceptance rate for "was it on List 1 or List 2" questions, the second greatest for "was it on List 2" questions, and the least for "was it on List 1" questions.

There was also a three way list by categories by question interaction for the target acceptance rate, $F(4, 260)=7.14$, $p<0.001$, partial $\eta^2=0.55$. List 1 targets had no significant difference in acceptance rates between the three categorical classes when asked "was it on List 1," but List 1 targets whose categories belonged in both lists had greater acceptance rates than the other two categorical classifications when asked "was it on List 2" or the disjunctive probe "was it on List 1 or List 2." List 2 targets, however, only showed a slight significant difference between uncategorized words and words whose categories belonged on only one list for the question "was it on List 1," with uncategorized words showing a higher acceptance rate. For the other question types, there were no significant differences in acceptance rates between the different categorical classifications. This shows that categorical gist depended heavily on whether verbatim traces were likely to be accessible (e.g. List 2 vs. List 1).

The related distractors were distractors that belonged to a category presented during study, but were not actually presented. A 2 (frequency) x 3 (categorization) x 3 (question) ANOVA was run for the acceptance probabilities of bias corrected related distractors. There were two main effects. There was a main effect of category, $F(2, 130)=37.25$, $p<0.001$, partial $\eta^2=0.10$, where items that belonged to categories presented on List 1 were accepted more often than items that belonged to categories presented on both lists, and items that belonged to categories presented on both lists were accepted more often than items that belonged to categories presented only on List 2. This could be due to the fact that there is greater verbatim processing for List 2, which produces verbatim-based rejection and, hence, lower acceptance rates. There was a main effect of question type, $F(2, 130)=8.28$, $p<0.001$, partial $\eta^2=0.11$, with acceptance being greater for the disjunctive probe “was it on List 1 or List 2” than for the question “was it on List 2.”

Last, there was one notable interaction between categories and questions, $F(4, 260)=18.03$, $p<0.001$, partial $\eta^2=0.22$. For the questions “was it on List 1” and “was it on List 1 or List 2,” the acceptance probabilities were highest for words from List 1 categories, second highest for words that were on categories from both lists, and least for words that were from List 2 categories. This is in the predicted direction, because decreased verbatim-based rejection for List 1 words but persistent gist processing of the categories would increase the acceptance rate for distractors belonging in categories that were presented on List 1. For the question “was it on List 2,” words that were from categories from both lists were accepted at higher rates than words from List 1 categories, but not words from List 2 categories.

Discussion

If disjunction fallacies in episodic source memory behave similarly to disjunction fallacies in probability judgment, then increasing gist processing should increase the occurrence of these fallacies. This is the pattern that emerged in this experiment. When words are categorized, they encourage gist processing due to the accessibility of meaning-based information. Unlike verbatim processing, which retrieves surface-level cues that allow subjects to distinguish the source of the target item (e.g. I can see in my mind's eye that the word was presented in a white background in Stencil font, therefore it must have been on List 2), gist processing encourages meaning processing (e.g. I remember a lot of animals were presented). A test probe that allows retrieval of meaning without context, for instance a test probe supported by congruent gist information, will support acceptance of its appearance in either list. As we saw, regardless of whether or not the target words were categorized on just one of the lists or both lists, the disjunction fallacy was greater than when words belonged in no category at all. With greater gist processing, we see more disjunction fallacies, just as in false memory studies. At the same time, verbatim processing suppresses disjunction fallacies. This effect can be seen by the fact that there are no reliable disjunction fallacies for List 2, where verbatim memory is still strong.

The results from the disjunction fallacy experiment fit the predictions derived from FTT, and provide some evidence that increasing gist processing will enhance disjunction fallacies in episodic source memory, as it does disjunction fallacies in probability judgment and false memory.

EXPERIMENT 2

The second experiment focuses on not only the conjunction fallacy, but the conjunction illusion. A conjunction illusion occurs simply when the probability that a subject accepts the impossible conjunctive probe is a value greater than zero. In probability judgment studies, it is generally impossible to observe the conjunction illusion because the conjunctive probe (e.g. Lisa is a bank teller and a feminist) has some probability of being true. In an episodic memory experiment, however, we are able to design the experiment so that the conjunctive probe cannot be true. For instance, in a source design where none of the target words were presented on both lists, a target would have a zero probability of having been on both lists. Thus, a conjunction illusion occurs whenever the acceptance probability for the probe “it was on List 1 and List 2” is greater than zero. Paralleling the previous studies by Brainerd et al. (in press), manipulations that I predict would result in the greatest conjunction illusions are conditions with greatest verbatim retrieval, such as low frequency targets and for targets that appeared on List 2. In the disjunction experiment, gist and verbatim retrieval worked against each other: gist increased the disjunction fallacy, but verbatim decreased it. For the conjunction experiment, gist and verbatim work together. The reason why high verbatim retrieval would actually increase the conjunction illusion but not the disjunction fallacy is because of the nature of the two-list source design. Low frequency List 2 targets have the greatest verbatim retrieval, and have clear memory representations that they had been presented on List 2. However, verbatim-rejection would be weak when asked whether these targets were presented on List 1 because of lower verbatim retrieval for List 1 words, resulting in a greater likelihood of accepting the conjunctive probe.

Additionally, I hypothesize that items that belong to taxonomic categories would produce greater illusions than items that are uncategorized. This is because there will again be higher gist retrieval for categorized words, which will support memory for the word having been presented but not for the context in which it was presented. For instance, being exposed to many words in a category “animal” would support the probe “cat” as having been presented, but it would not specify the context in which it had been presented. Some conjunction illusions may rise to the level of conjunction fallacies if P(L1&L2)>P(L1) or P(L1&L2)>P(L2), and thus memory conjunction fallacies are simply a special case of conjunction illusions.

The format of Experiment 2 was identical to the format of Experiment 1, except that there was a change in the conjoint recognition instructions. Rather than asking if an item was presented on either List 1 or List 2, subjects were asked if a probe was on List 1 AND List 2. For this experiment, I included the same manipulations as those that were studied with the disjunction fallacy in Experiment 1.

Subjects. The subjects in Experiment 2 were 67 undergraduate students who participated in the experiment to fulfill a course requirement.

Materials. Materials for Experiment 2 were largely the same as the materials in Experiment 1. The two lists were presented with the same visual format (same colors and font), and the words and categories that appeared in List 1 and List 2 were the same as Experiment 1. The first difference between the experiments is that 3 of the words that were not presented at test and did not belong to any category were repeated on List 1 and List 2. The reason for this is to preclude subjects using a metacognitive strategy that *none* of the words were repeated, which therefore would result in nonmemorial 'No' answers to all conjunctive memory probes. Repeating some words across lists thus ensured that the subjects would know that indeed some of the words appeared in both lists. The instructions that told subjects that there was no overlap between the two lists were removed in the conjunction design. A second difference between the experiments was that the disjunctive description "presented on List 1 or List 2," was replaced by the conjunctive probe "presented on List 1 and List 2."

Procedure. The procedure for Experiment 2 was mostly the same as that for Experiment 1 except for a few small differences. At the start of the experiment, participants were informed that they were participating in a source recognition task, and that they would be given two lists of words to study. Then, the lists were presented in succession on a computer screen at a rate of 3 seconds, centered on the screen and printed in 72-point font. After the first list was completed, there was a 15 second pause before the presentation of the second list. Once the subject finished studying the second list, instructions were given for the upcoming memory test. The instructions informed the subjects that while they would have to make source judgments for words that appeared on the list, they would also have to make source judgments for words that never appeared on the list. They were specifically instructed to only accept the test probes for which they thought the episodic description for the cue word was true. Examples for the three episodic descriptions, paired with sample cue words, were provided so that the subjects understood how to respond. Unlike Experiment 1, subjects were not told that the targets in the two lists did not overlap and they were given examples of overlapping study items that were not actually tested. The 168 probes were then presented in a random order, and the subjects completed the test in a self-paced manner.

RESULTS

Conjunction Illusion

These analyses were done on bias corrected values for both targets and related distractors. Bias was corrected with the two-high threshold method, by subtracting the acceptance probabilities for unrelated distractors from the acceptance probabilities for targets. A 2 (list) x 3 (category) x 2(frequency) ANOVA was conducted on the degree of conjunction illusion statistic *P*(L1&L2). Because none of the cue words that the subjects were tested on appeared on both lists, and because the values are all corrected for bias, any value for the probability that subjects said “Yes” to the description “it was on List 1 and List 2”, or P(L1&L2), was greater than zero indicated a conjunction illusion. For targets, there were no main effects, but there was a significant interaction effect for list by category, $F(2, 132)=24.50$, $p<0.001$, partial $\eta^2=0.27$. The plots of the descriptive statistics for this interaction are presented in Figure 5. A one-sample t-test indicated that all conditions were significantly above zero, and therefore every condition resulted in the conjunction illusion, in which subjects judged that a target that was never on both lists had appeared on both lists (Table 8). Because there was no effect of frequency, it was removed from the tables and figures.

A conjunction illusion was observed only for related distractors whose categories appeared in List 1, $t(66)=5.66$, $p<0.001$, $d=1.39$. ANOVAs for related distractors revealed one main effect for category, $F(2, 132)=32.13$, $p<0.001$, partial $\eta^2=0.33$. Related distractors whose categories appeared in List 1 had greater conjunction illusions than both related distractors whose categories appeared in List 2, and related distractors whose categories appeared in both lists.

Conjunction Fallacy

Going beyond the conjunction illusion, the conjunction *fallacy* occurs when subjects judge the probability of an impossible compound event (a target appeared on List 1 and List 2) as greater than the probability of a singular event (a target appeared on List 1). A paired t-test compared P(L1&L2) and P(L1), and P(L1&L2) and P(L2). Results indicate that there is a significant conjunction *fallacy* for List 2 targets that were categorized on only one list, $t(66)=3.20$, $p=0.002$, $d=0.79$, and for List 2 targets that were categorized on both lists, $t(66)=7.92$, $p<0.001$, $d=1.95$. This means that when targets were in categories that were unique to the list or shared between both lists, subjects judged that a List 2 target that couldn't have been on both List 1 and List 2 had been on both List 1 and List 2, and they rated this probability as being higher (which is an impossibility) than the probability that it had only been on one list (in this case List 1). This is analogous to the conjunction fallacy that is often studied in probability judgment. A paired t-test was also done for related distractors to see if there were any conjunction fallacies, but results indicated there were none.

The occurrence of the conjunction fallacy was list dependent, much like in the disjunction fallacy, and only appeared for List 2 items (Figure 6 and Figure 7). There appeared to be no effect of frequency, and the only dependency seems to be for inclusion of categories. It did not seem to matter whether or not the category appeared on both lists or just one– the presence of categories alone determined whether or not there was a conjunction fallacy. When items were from List 2 and belonged to categories that are shared between both lists, subjects would be able to retrieve the same categorical gist for both List 1 and List 2, as well as verbatim information from List 2, increasing the likelihood that they will say the word had appeared on both lists because of the availability of verbatim and gist information for both lists. The degree of conjunction fallacy is significantly less for items whose categories were unique to one list than items whose categories were shared between lists, and this might be due to the fact that metacognitive strategies (i.e. "I only saw this category on one list") can be used. However, for List 2 items, there is still a significant conjunction fallacy for both items that were in unique categories and items that were in shared categories.

Acceptance Rates

ANOVAs were run for the bias corrected acceptance probabilities for targets and related distractors. The acceptance probabilities are available on Table 7. There were two main effects for targets. There was a main effect of list, $F(1, 66)=22.22$, $p<0.001$, partial $\eta^2=0.25$, with List 1 targets having a greater acceptance rate than List 2 targets as it was for the disjunction experiment. Another main effect was found for question type, $F(2, 132)=28.17$, $p<0.001$, partial $\eta^2=0.27$, with "was it on List 2" having a greater acceptance rate than both "was it on List 1" and the conjunctive probe "was it on List 1 and List 2."

There was also a significant three way interaction between list, categories, and questions, $F(4, 264)=6.22$, $p<0.001$, partial $\eta^2=0.09$. For List 1 targets, all three types of questions "was it on List 1," "was it on List 2," "was it on List 1 and List 2," resulted in higher acceptance rates for words that were only categorized on List 1 than words whose categories appeared on both lists. Also, there were significant differences between the three categorizations within the three question types for List 2 targets, and the only significant difference for List 2 targets was for the conjunctive probe "was it on List 1 and List 2," where targets whose categories appeared on both lists, were accepted at a higher rate than targets whose categories appeared on only one list and targets that were not categorized.

Last, for the ANOVAs for the acceptance probabilities for related distractors, there was one main effect and one interaction. There was a main effect of categories, $F(2, 132)=26.46$, $p<0.001$, partial $\eta^2=0.29$, where distractors whose categories were on List 1 were accepted more often than distractors whose categories were on both lists, and distractors whose categories were on both lists were accepted more often than distractors whose categories were on List 2.

There was a significant interaction of categories by questions, $F(4, 264)=12.47$, $p<0.001$, partial $\eta^2=0.16$. For questions that asked "was it on List 1," both distractors whose categories were presented on List 1 and distractors whose categories appeared on both lists were accepted more often than distractors whose categories appeared on List 2. For questions that asked "was it on List 2," there were no significant differences, and for the conjunctive probe "was it on List 1 and List 2," distractors whose categories were on List 1 were greater than the other two categorizations.

Predicting Conjunction Illusions with Disjunction Fallacies

We can predict the values of the conjunction illusion where P(A&B) > 0 from the values obtained for the disjunction fallacy in the corresponding conditions of Experiment 2. The amount of disjunction fallacy P(A) + P(B) – P(AUB) predicts the value of P(A&B) because the experimental design makes it such that logically, P(A&B) must equal zero unless there is subadditivity. A t-test comparing the means of the degree of disjunction fallacy and the conjunction illusion was performed, and the results are shown on Table 8. For targets, aside from two comparisons, the values from the disjunction fallacy experiment failed to predict the values from the conjunction experiment, and the differences were all highly significant. Furthermore, most of the comparisons between the observed direct measure of P(A&B) were greater than the subadditivity measure of P(A) + P(B) – P(AUB). For related distractors, one out of three cells had conjunction illusions that were significantly different than the values predicted by the disjunction fallacy. The observed direct measure of P(A&B) for related distractors were less than the subadditivity measure.

Discussion

The results demonstrate that the conjunction illusion is a reliable phenomenon in episodic memory, with all types of targets showing the illusion. Although this is difficult to study in probability judgment because the usual experimental design does not allow the conjunctive probe to have zero probability, an episodic source memory design is able to do this. Prior research shows that the conjunction illusion will occur in cases where there is high item memory, when subjects are likely to judge a probe as having appeared on the list, but with low source memory (Brainerd et al., in press). The results were replicated in this experiment. Manipulations that are expected to have higher item memory are List 1 items based on prior research (e.g. Brainerd et al. 2012), and items that were categorized due to greater gist support. At the same time, there should be a difference between words that were categorized on both lists and words that were categorized on just one list, because words whose categories appeared on only one list would allow subjects to use the metacognitive strategy that a category "A" only appeared on List 1, increasing source memory for these items.

Looking at List 2 targets, items that were categorized on just List 2 had the smallest conjunction illusions. Based on prior research (Brainerd et al. 2012), List 2 targets have the greatest context recollection; that is, subjects are able to identify contextual cues such as presentation context of the target, leading to greater source discrimination. List 2 targets categorized on just List 2 would therefore have the greatest source discrimination because subjects would remember the category as having been presented only on List 2, and the data shows this to be the case, with conjunction illusions being the lowest for List 2 targets whose categories appeared on just List 2. On the other hand, List 2 targets categorized on both lists would result in source confusion because of interfering contextual information from List 1 targets that were in the same category: that is, subjects would remember that category as having been on List 1 and List 2, and would therefore be likely to accept the description "it was on List 1 and List 2."

For List 1 targets, however, items that were categorized on just List 1 had the largest conjunction illusions. List 1 targets do not encourage retrieval of their presentation contexts as well as List 2 targets. However, List 1 targets have better target recollection where subjects can recall that a word had been presented somewhere in the test, but not exactly where (Brainerd et al. 2012). Because of this increased target recollection but decreased context recollection for List 1 targets compared to List 2 targets, we do not see the same decrease in conjunction illusions for categories only presented on one list, and the level of conjunction illusions for List 1 targets presented only on one list remains high.

Conjunction fallacies, rather than conjunction illusions, were present for List 2 items that were categorized either on just one list or both lists. This is similar to results reported in probability judgment, where gist processing promotes the conjunction fallacy (e.g. Tentori et al., 2013). It should be noted, however, that the conjunction fallacy did not emerge for List 1 targets even though there were conjunction illusions. Gist processing promotes the conjunction fallacy, but only for List 2 targets.

In terms of predicting conjunction illusions from the disjunction experiment, the disjunction fallacy did not predict conjunction illusions well. This is curious, because prior research indicated that the disjunction fallacy, while not entirely perfect, could predict the average values of conjunction illusions across several conditions (Brainerd et al., in press).

GENERAL DISCUSSION

Similar to prior research on probability fallacies, the level of gist appears to influence fallacies in episodic memory. In the case of both the disjunction and conjunction fallacies, verbatim and gist manipulations affected them in theoretically motivated directions. Processes that encouraged verbatim retrieval reduced the amount of fallacies, while processes that encouraged gist retrieval increased it. The findings parallel the effect of gist and verbatim retrieval in semantic false memory designs, suggesting that these ideas can extend to source memory designs.

Furthermore, this study provides evidence that probability fallacies can extend to basic areas such as memory. FTT first suggested that disjunction fallacies fall out of memory processes, and the results of this study follow the theory's predictions about certain manipulations. In this section I will briefly go over the findings from the disjunction and conjunction experiments, and an alternative explanation to the results in contrast to FTT's interpretation of them.

Dual-Retrieval and Memory Fallacies

There were two goals for this study, 1.) to replicate earlier studies to provide evidence that fallacies occur in episodic memory and 2.) determine if semantic gist manipulations affect memory fallacies in the same way that they affect probability fallacies. The disjunction fallacy appeared reliably in Experiment 1. Furthermore, manipulations that increase verbatim retrieval, such as recency, decreased it, and the fallacy was only observed in List 1 targets. Categorization, which encourages gist processing, increased the fallacy.

Experiment 2 demonstrated that conjunction illusions are prevalent in episodic source memory. Gist manipulation caused the conjunction illusion to move in predicted directions. In prior studies, item memory without source memory encouraged conjunction fallacies (Brainerd et al., in press). Introducing semantic gist into study lists supports item memory, but not necessarily source memory unless a category appeared only on one list. Replicating earlier experiments from Brainerd et al. (in press), conjunction illusions were greatest for List 2 targets, and they were greatest for words whose categories belonged in both lists. However, when words were categorized in just one of the lists, subjects may have used metacognitive strategies that they otherwise would not have been able to use compared to words categorized in both lists, thus decreasing the conjunction illusion.

The addition of metacognitive judgments may also have affected the predictive power of the disjunction fallacy for conjunction illusions. In the current study, the disjunction fallacy did not predict the conjunction illusion well, whereas the disjunction fallacy could predict the conjunction illusion in prior studies that did not use semantic gist manipulations (Brainerd, in press). The relationship between the disjunction fallacy and the conjunction illusion is $P(\mathrm{A}) + P(\mathrm{B}) - P(\mathrm{AUB}) = P(\mathrm{A\&B})$. This relationship is based on memory processes, but metacognitive strategies that can be used for conjunctive probes in Experiment 2 are nonmemorial and require no memory to answer accurately.

For example, in the case of the disjunction fallacy, a subject may be uncertain whether or not a word was presented, but they may be certain that a category only appeared on one list. If the subjects can recall that the category appeared only on one list, then they will be more likely to say that it was not on the other list. This idea is supported by the fact that there was no significant disjunction fallacy in Experiment 1 in the List 2 condition, although there has been in prior research with unrelated lists (Brainerd et al., 2012).

Another explanation is that some words were repeated across lists in Experiment 2. None of these words was categorized, and thus, it is possible that subjects could have used the metacognitive strategy that the categorized words were never repeated. However, this strategy would cause conjunction illusions to decrease, but in fact, disjunction fallacies underpredicted conjunction illusions.

Brainerd et al. (in press) found that in cells where the disjunction fallacy did not predict the conjunction illusion, the direction of the difference was opposite to what would be predicted by a retrieval effectiveness hypothesis. This hypothesis states that the reason why disjunction fallacies occur is because disjunctive probes are less effective at retrieving memory support than nondisjunctive probes, resulting in disjunctive probes being under-remembered. While this is hypothesized by other studies, (Fisk, 2002; Rottenstreich & Tversky, 1997; Tversky & Koehler, 1994), it does not predict that the direct estimates would be greater than the disjunctive estimates. In fact, if the disjunction fallacy is partially due to the reduced retrieval effectiveness of disjunctive probes, then the direct estimates should be smaller than the predicted values. This was not the case in Experiment 2, and therefore we can rule out retrieval effectiveness as being the reason for disjunction fallacies. In conclusion, disjunction and conjunction fallacies manifested in episodic source memory, and the data followed predictions from FTT.

Pure Ignorance Model

It is important to consider whether a different model can be used to explain conjunction and disjunction fallacies in memory; that is, a model other than FTT. One such model is the pure ignorance model, which assumes that all responses are a result of guessing when memory of a target item P_{L1} is incomplete. It may be the case that the appearance of disjunction and conjunction fallacies in memory can be explained by that model.

If we look at the disjunction fallacy, we see that the pure ignorance model can account for disjunction fallacies in Experiment 1. The acceptance probability of P(L1) for a L1 target is some probability P_{L1} where there is some memory of the target, plus a guessing probability $(1 - P_{L1})0.5$. The rejection probability of P(L2) for a L1 target is some probability $P_{L1} + (1 - P_{L1})0.5$. Therefore, the acceptance probability for an L1 target of P(L1UL2) is $P_{L1} + 2(1 - P_{L1})0.5$. Table

10 includes the calculations for *P*(L1), *P*(L2), and *P*(L1UL2) for L1 targets for various levels of memory trace P_{L1} and P_{L2}. The sum of *P*(L1) and *P*(L2) is greater than *P*(L1UL2) for cases where memory of the target P_{L1} is both small and large, leading to the disjunction fallacy. The pure ignorance model is able to account for disjunction fallacies in Experiment 1.

The pure ignorance model can also account for conjunction illusions in Experiment 2. Recall that conjunction illusions occur when subjects judge that the conjunctive probe *P*(L1&L2) has a positive probability when it is impossible for both events to have occurred. The acceptance probability of *P*(L1&L2) in a pure ignorance model is greater than zero for all cases, and thus the conjunction illusion in Experiment 2 can be accounted for by this model.

However, the pure ignorance model fails when we come to conjunction fallacies. In Experiment 2, we observed conjunction fallacies for List 2 targets, where *P*(L1&L2) > *P*(L1). In a pure ignorance model, *P*(L1&L2) can never exceed the values for either *P*(L1) or *P*(L2), for either the scenario in which subjects rely completely on guessing or the scenario in which they rely partly on memory and partly on guessing. FTT's memory explanation, however, does predict conjunction fallacies. The pure ignorance model is not sufficient to explain the complete package of distortions that were observed in the present experiments.

Future Directions

Episodic memory is not immune to disjunction and conjunction fallacies. This can be problematic because compound questions in memory can occur in interview settings, including those involving criminal investigations ("Did you buy a soda and a hamburger?" "Did you go to the mall or the grocery store?"). It is also interesting to consider what it means for subjects to commit the conjunction illusion. When subjects judge that two mutually exclusive events have some probability *P*(L1&L2), what does it indicate? Brainerd et al. (2012) described the value

P(L1&L2) as a situation where items are in contradictory episodic states at retrieval, such that the item is remembered to have been on both List 1 and List 2, and the source to which it is eventually assigned depends entirely on the type of probe. This is the overdistribution error.

A question relevant to forensic interviewing is whether or not it also appears in false memory paradigms. Suggestive interviewing is similar to the types of probes that were used in this study (e.g. "Was it on List 1?") in the sense that neither use open-ended questions, and findings of increased false memory in suggestive interviewing indicates that overdistribution may be relevant here as well (Wade & Garry, 2005). Overdistribution errors propose that not only do they increase the likelihood that a false probe is accepted, but they also increase the likelihood that a true probe is accepted after a false probe is accepted.

To date there is only one study that explored overdistribution errors in false memory within individual subjects. Brainerd et al. (2010) found evidence of overdistribution in the form of disjunction fallacies in a standard old-new conjoint recognition design. In this experiment, subjects studied a list of words with various manipulations that increased or decreased gist and verbatim processing. The level of the disjunction fallacy was calculated from the response probabilities to the conjoint recognition probes.

While there is evidence for the significance of overdistribution errors in false memory, very few studies look at overdistribution errors in repeated testing. Would overdistribution increase the likelihood that previously made answers are changed at later testing? Because overdistribution assumes that episodic memory is in mutually exclusive states at the time of retrieval, and that the memory that it is ultimately assigned is dependent on the description paired with the test probe, then it should be the case that some subject responses will be inconsistent at the time of test. The inconsistency should also be affected in predictable ways in the same pattern we see in prior experiments, where increasing gist and decreasing verbatim processing would increase it. There is some suggestion that this may be the case. Brainerd et al. 2010 included a repeated testing manipulation where subjects studied and were tested on 12 DRM lists, and were tested again a week later on the same lists. The authors found that overdistribution increased for targets, critical distractors, and related distractors for the delayed repeated test. It is unclear whether the consistency of responses was maintained between the first and second test, but the elevated levels of overdistribution on the second test suggest that the effect of overdistribution-related inconsistency may be present. Whether or not overdistribution can play a role in self-correcting memories is an interesting topic for future studies.

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Appendix 1: Test Words

Test Word	Target or Distractor?	Categorized or Unrelated?	Presented on: List 1(yellow) or List 2(white) or Neither	Test Question: List 1? List 2? List 1 or List 2?	Word freq: High or Low?
CANADA	target	Categorized	Yellow	Yellow?	High
RUSSIA	target	Categorized	Yellow	Yellow or White?	High
ITALY	target	Categorized	Yellow	Yellow or White?	High
SWITZERLAND	target	Categorized	Yellow	Yellow?	Low
SKYSCRAPER	target	Unrelated	Yellow	Yellow or White?	Low
BELL	target	Unrelated	Yellow	Yellow or White?	High
SHIRT	target	Categorized	Yellow	Yellow?	High
BRA	target	Categorized	Yellow	Yellow?	Low
MUSTARD	target	Unrelated	Yellow	White?	Low
CHILD	target	Unrelated	Yellow	Yellow?	High
SOCKS	target	Categorized	Yellow	White?	High
T-SHIRT	target	Categorized	Yellow	Yellow or White?	Low
SHOES	target	Categorized	Yellow	Yellow or White?	High
DRESS	target	Categorized	Yellow	White?	Low
CIGARETTE	target	Unrelated	Yellow	Yellow?	High
FORK	target	Categorized	Yellow	Yellow or White?	High
PAN	target	Categorized	Yellow	Yellow or White?	High
DOCTOR	target	Unrelated	Yellow	White?	High
TELESCOPE	target	Unrelated	Yellow	Yellow?	Low
HORSE	target	Categorized	Yellow	Yellow or White?	High
TIGER	target	Categorized	Yellow	Yellow or White?	High
KEROSENE	target	Unrelated	Yellow	White?	Low
NEEDLE	target	Unrelated	Yellow	Yellow or White?	High
CHAIR	target	Categorized	Yellow	Yellow?	High
BUREAU	target	Categorized	Yellow	Yellow?	Low
PIPE	target	Unrelated	Yellow	White?	High
DIME	target	Unrelated	Yellow	Yellow or White?	Low
COUCH	target	Categorized	Yellow	White?	High

BOOKCASE	target	Categorized	Yellow	Yellow or White?	Low
DESK	target	Categorized	Yellow	Yellow or White?	High
STOOL	target	Categorized	Yellow	White?	Low
JELLO	target	Unrelated	Yellow	Yellow?	Low
APPLE	target	Categorized	Yellow	Yellow?	High
PLUM	target	Categorized	Yellow	Yellow or White?	Low
PINEAPPLE	target	Categorized	Yellow	Yellow or White?	High
CANTALOUPE	target	Categorized	Yellow	Yellow?	Low
KNIFE	target	Categorized	White	Yellow?	High
BOWL	target	Categorized	White	White?	Low
POT	target	Categorized	White	White?	High
DISH	target	Categorized	White	Yellow?	Low
WOOD	target	Unrelated	White	Yellow?	High
BLUE	target	Categorized	White	Yellow or White?	High
BROWN	target	Categorized	White	Yellow or White?	Low
PURPLE	target	Categorized	White	Yellow?	High
TULIP	target	Unrelated	White	White?	Low
GREEN	target	Categorized	White	White?	High
TURQUOISE	target	Categorized	White	Yellow?	Low
VIOLET	target	Categorized	White	White?	Low
PUDDLE	target	Unrelated	White	Yellow or White?	Low
TELEPHONE	target	Unrelated	White	Yellow?	High
MEXICO	target	Categorized	White	White?	High
ENGLAND	target	Categorized	White	White	High
LANTERN	target	Unrelated	White	Yellow or White?	High
CHICKENPOX	target	Unrelated	White	Yellow or White?	Low
GRAPE	target	Categorized	White	White?	High
PEACH	target	Categorized	White	White?	High
INK	target	Unrelated	White	Yellow or White?	High
DAGGER	target	Unrelated	White	Yellow?	Low
EAGLE	target	Categorized	White	Yellow or White?	High
SPARROW	target	Categorized	White	Yellow or White?	Low
HAWK	target	Categorized	White	Yellow?	High
CINNAMON	target	Unrelated	White	Yellow?	Low
STREET	target	Unrelated	White	White?	High
BLUEJAY	target	Categorized	White	White?	High
PARAKEET	target	Categorized	White	Yellow?	Low
SEAGULL	target	Categorized	White	White?	Low
PENNY	target	Unrelated	White	White?	High
ONION	target	Unrelated	White	White?	Low
DOG	target	Categorized	White	Yellow?	High
PIG	target	Categorized	White	White?	Low
ELEPHANT	target	Categorized	White	White?	High

FOX	target	Categorized	White	Yellow?	Low
UNDERWEAR	distractor	Categorized	Neither	White?	High
IRON	distractor	Categorized	Neither	White?	High
GRAY	distractor	Categorized	Neither	Yellow?	Low
STEEL	distractor	Categorized	Neither	Yellow?	High
DONKEY	distractor	Categorized	Neither	Yellow?	Low
MAROON	distractor	Categorized	Neither	Yellow or White?	Low
BED	distractor	Categorized	Neither	White?	High
GRAPEFRUIT	distractor	Categorized	Neither	White?	Low
BRONZE	distractor	Categorized	Neither	White?	Low
BOOK	distractor	Unrelated	Neither	Yellow or White?	High
RASPBERRY	distractor	Categorized	Neither	Yellow?	Low
TABLE	distractor	Categorized	Neither	Yellow or White?	High
SOFA	distractor	Categorized	Neither	Yellow?	High
LADLE	distractor	Categorized	Neither	Yellow or White?	High
DOVE	distractor	Categorized	Neither	White?	Low
UMPIRE	distractor	Unrelated	Neither	White?	Low
OAK	distractor	Categorized	Neither	Yellow?	High
ARMS	distractor	Categorized	Neither	White?	High
BRANDY	distractor	Unrelated	Neither	White?	High
PIGEON	distractor	Categorized	Neither	Yellow?	Low
SKIRT	distractor	Categorized	Neither	Yellow or White?	Low
SHORTS	distractor	Categorized	Neither	Yellow?	High
LAMP	distractor	Categorized	Neither	Yellow or White?	Low
SPOON	distractor	Categorized	Neither	Yellow?	High
PANTS	distractor	Categorized	Neither	Yellow or White?	High
FRANCE	distractor	Categorized	Neither	Yellow?	High
FLAG	distractor	Unrelated	Neither	Yellow?	High
GUN	distractor	Unrelated	Neither	White?	High
BLUEBIRD	distractor	Categorized	Neither	Yellow or White?	High
GUITAR	distractor	Categorized	Neither	White?	High
MINISTER	distractor	Unrelated	Neither	Yellow or White?	High
MORPHINE	distractor	Unrelated	Neither	Yellow?	Low
NICKEL	distractor	Categorized	Neither	Yellow or White?	Low
PEAR	distractor	Categorized	Neither	Yellow or White?	High
FILM	distractor	Unrelated	Neither	White?	High
MARSHMALLOWS	distractor	Unrelated	Neither	Yellow?	Low
BLENDER	distractor	Categorized	Neither	Yellow or White?	Low
BENCH	distractor	Categorized	Neither	White?	Low
LION	distractor	Categorized	Neither	White?	High
CABINET	distractor	Categorized	Neither	Yellow?	Low
MOUTH	distractor	Categorized	Neither	Yellow or White?	Low
FOOT	distractor	Categorized	Neither	Yellow or White?	High

LEGS	distractor	Categorized	Neither	Yellow?	High
TUBA	distractor	Categorized	Neither	White?	Low
CANARY	distractor	Categorized	Neither	Yellow or White?	Low
CHINA	distractor	Categorized	Neither	White?	High
CAT	distractor	Categorized	Neither	Yellow?	High
CHURCH	distractor	Unrelated	Neither	Yellow?	High
COAT	distractor	Categorized	Neither	White?	Low
GOAT	distractor	Categorized	Neither	Yellow or White?	Low
KITE	distractor	Unrelated	Neither	Yellow or White?	Low
STRAWBERRY	distractor	Categorized	Neither	Yellow or White?	High
PETAL	distractor	Unrelated	Neither	Yellow or White?	Low
PEDAL	distractor	Unrelated	Neither	Yellow?	Low
SKILLET	distractor	Categorized	Neither	White?	High
ROCK	distractor	Unrelated	Neither	Yellow?	High
JAPAN	distractor	Categorized	Neither	White?	Low
INDIGO	distractor	Categorized	Neither	White?	Low
FLUTE	distractor	Categorized	Neither	Yellow or White?	High
YELLOW	distractor	Categorized	Neither	White?	High
ELM	distractor	Categorized	Neither	Yellow?	Low
EAR	distractor	Categorized	Neither	White?	Low
BANANA	distractor	Categorized	Neither	Yellow?	High
CELLO	distractor	Categorized	Neither	Yellow or White?	Low
SODA	distractor	Unrelated	Neither	Yellow?	Low
TROMBONE	distractor	Categorized	Neither	Yellow?	Low
WATERMELON	distractor	Categorized	Neither	White?	High
DEER	distractor	Categorized	Neither	Yellow or White?	High
GERMANY	distractor	Categorized	Neither	Yellow or White?	High
BROOM	distractor	Unrelated	Neither	White?	Low
BALLOON	distractor	Unrelated	Neither	White?	High
PINE	distractor	Categorized	Neither	White?	High
SWEDEN	distractor	Categorized	Neither	Yellow?	Low
PIMPLE	distractor	Unrelated	Neither	Yellow or White?	Low
CANDY	distractor	Unrelated	Neither	Yellow or White?	Low
HAILSTONE	distractor	Unrelated	Neither	White?	Low
DRUM	distractor	Categorized	Neither	Yellow?	High
HONEY	distractor	Unrelated	Neither	Yellow or White?	High
CEDAR	distractor	Categorized	Neither	Yellow or White?	Low
BEECH	distractor	Categorized	Neither	White?	Low
RAIN	distractor	Unrelated	Neither	Yellow or White?	High
COW	distractor	Categorized	Neither	White?	High
SILVER	distractor	Categorized	Neither	Yellow or White?	High
MAPLE	distractor	Categorized	Neither	Yellow or White?	High
NOSE	distractor	Categorized	Neither	Yellow?	Low

STOVE	distractor	Categorized	Neither	Yellow?	Low
TIN	distractor	Categorized	Neither	Yellow?	Low
SEA	distractor	Unrelated	Neither	Yellow?	High
SPAIN	distractor	Categorized	Neither	Yellow or White?	High
BLOUSE	distractor	Categorized	Neither	Yellow?	Low
CARDINAL	distractor	Categorized	Neither	White?	High
BLACK	distractor	Categorized	Neither	Yellow or White?	High
MOUTHPIECE	distractor	Unrelated	Neither	White?	Low
SPATULA	distractor	Categorized	Neither	White?	High
RED	distractor	Categorized	Neither	Yellow?	High
ROBIN	distractor	Categorized	Neither	Yellow?	High

Appendix 2: Instructions

This is a memory experiment that involves 2 parts. In the first part, you will view 2 lists of vocabulary words that will be presented as Power Point slides. To keep the lists separate, the slides for the first list will be yellow and the slides for the second list will be white. Pay close attention to the slides because there will be a memory test later. As each word comes up on the screen, read it silently to yourself.
The second part of the experiment is the memory test. You will receive detailed instructions for the memory test when we get to it. However, it is what we call a list identification test because your task will be to identify words that appeared on the first list versus words that appeared on the second list. Do you have any questions?

We are ready to present the 2 lists now.

Table 1
Target and Related Distractor Acceptance Probabilities for Taxonomic Disjunction Experiment

Word content		List-context/statistic		
		p(L1)	*p*(L2)	*p*(L1UL2)
		Targets		
List 1				
	High Frequency Categorized One	.73(.28)	.45(.34)	.80(.30)
	Low Frequency Categorized One	.73(.32)	.38(.35)	.72(.33)
	High Frequency Categorized Both	.77(.28)	.71(.26)	.83(.27)
	Low Frequency Categorized Both	.57(.36)	.60(.34)	.86(.26)
	High Frequency Uncategorized	.55(.38)	.42(.37)	.75(.32)
	Low Frequency Uncategorized	.65(.33)	.39(.40)	.80(.32)
List 2				
	High Frequency Categorized One	.22(.32)	.59(.36)	.74(.32)
	Low Frequency Categorized One	.21(.33)	.72(.32)	.73(.29)
	High Frequency Categorized Both	.27(.34)	.70(.34)	.83(.27)
	Low Frequency Categorized Both	.30(.35)	.61(.38)	.79(.30)
	High Frequency Uncategorized	.36(.37)	.61(.37)	.76(.33)
	Low Frequency Uncategorized	.30(.35)	.61(.37)	.73(.32)
		Related Distractors		
	High Frequency Categorized on L1	.45(.39)	.14(.24)	.57(.38)

Low Frequency Categorized on L1	.35(.36)	.23(.34)	.58(.35)
High Frequency Categorized on L2	.17(.27)	.31(.37)	.25(.31)
Low Frequency Categorized on L2	.14(.27)	.22(.33)	.30(.34)
High Frequency Categorized Both	.28(.29)	.29(.17)	.42(.32)
Low Frequency Categorized Both	.23(.24)	.26(.26)	.31(.29)

Table 2
Unrelated Distractor Acceptance Probabilities for Taxonomic Disjunction Experiment

Word content	List-context/statistic		
	p(L1)	*p*(L2)	*p*(L1UL2)
High Frequency Distractor Only Category	.22(.27)	.26(.25)	.30(.30)
Low Frequency Distractor Only Category	.16(.20)	.17(.26)	.26(.28)
High Frequency Uncategorized	.18(.26)	.20(.25)	.29(.29)
Low Frequency Uncategorized	.14(.23)	.11(.18)	.26(.28)

Table 3
Bias-Corrected Acceptance Probabilities for Taxonomic Disjunction Experiment

Targets

List-context/statistic	Word content					
	Hi Frequency Categorized One	Hi Frequency Categorized Both	Hi Frequency Uncategorized	Lo Frequency Categorized One	Lo Frequency Categorized Both	Lo Frequency Uncategorized
List 1:						
p(L1)	.50(.35)	.55(.36)	.36(.48)	.57(.40)	.41(.40)	.51(.43)
p(L2)	.19(.40)	.45(.36)	.23(.41)	.21(.39)	.43(.40)	.27(.42)
p(L1UL2)	.50(.39)	.53(.39)	.46(.50)	.46(.42)	.60(.40)	.53(.46)
List 2:						
p(L1)	.00(.38)	.04(.38)	.18(.41)	.05(.35)	.14(.39)	.16(.38)
p(L2)	.33(.43)	.44(.47)	.41(.48)	.55(.40)	.45(.45)	.50(.41)
p(L1UL2)	.45(.45)	.54(.41)	.47(.43)	.47(.42)	.53(.44)	.47(.48)

Related Distractors

List-context/statistic	Word content					
	Hi Frequency Categorized L1	Hi Frequency Categorized L2	Hi Frequency Categorized Both	Lo Frequency Categorized L1	Lo Frequency Categorized L2	Lo Frequency Uncategorized Both
Related Distractor:						
p(L1)	.23(.41)	-.06(.35)	.06(.28)	.19(.30)	-.02(.24)	.07(.28)
p(L2)	-.13(.26)	.05(.38)	.03(.25)	.06(.27)	.05(.33)	.09(.27)
p(L1UL2)	.27(.32)	-.05(.38)	.12(.33)	.32(.35)	.04(.30)	.05(.25)

Note. Bias was corrected by subtracting the raw acceptance values of Categorized (One and Both) targets and related distractors by Unrelated Categorized distractors, and subtracting the raw acceptance values of Uncategorized targets and related distractors by Unrelated Uncategorized distractors.

Table 4
Bias-Corrected Target Disjunction fallacy estimates [P(L1)+P(L2)] – P(L1UL2)

List-context/statistic	Word content		
	Categorized One	Categorized Both	Uncategorized
List 1:			
	.26	.35	-.08
t	4.25***	6.44***	1.41
List 2:			
	.01	.00	-.12
t	.15	.00	1.69

Note. Test value=0
*$p < .02$
**$p < .008$
***$p < .0001$

Table 5
Target and Related Distractor Acceptance Probabilities for Taxonomic Conjunction Experiment

Word content		List-context/statistic		
		p(L1)	*p*(L2)	*p*(L1∩L2)
		Targets		
List 1				
	High Frequency Categorized One	.78(.29)	.60(.35)	.44(.37)
	Low Frequency Categorized One	.67(.35)	.55(.34)	.36(.36)
	High Frequency Categorized Both	.69(.29)	.37(.33)	.29(.39)
	Low Frequency Categorized Both	.56(.37)	.54(.36)	.25(.34)
	High Frequency Uncategorized	.54(.37)	.57(.36)	.38(.39)
	Low Frequency Uncategorized	.66(.34)	.44(.37)	.27(.34)
List 2				
	High Frequency Categorized One	.34(.39)	.65(.36)	.25(.33)
	Low Frequency Categorized One	.22(.33)	.75(.31)	.24(.34)
	High Frequency Categorized Both	.34(.35)	.69(.38)	.40(.36)
	Low Frequency Categorized Both	.29(.35)	.69(.34)	.51(.22)
	High Frequency Uncategorized	.38(.35)	.60(.35)	.28(.35)
	Low Frequency Uncategorized	.30(.37)	.68(.37)	.25(.33)
		Related Distractors		
	High Frequency Categorized on L1	.48(.39)	.31(.37)	.36(.39)

Low Frequency Categorized on L1	.42(.39)	.36(.36)	.31(.35)
High Frequency Categorized on L2	.22(.32)	.40(.35)	.13(.25)
Low Frequency Categorized on L2	.21(.30)	.36(.38)	.12(.21)
High Frequency Categorized Both	.43(.30)	.36(.31)	.14(.21)
Low Frequency Categorized Both	.34(.23)	.31(.28)	.10(.18)

Table 6

Unrelated Distractor Acceptance Probabilities for Taxonomic Conjunction Experiment

Word content	List-context/statistic		
	p(L1)	*p*(L2)	*p*(L1∩L2)
High Frequency Distractor Only Category	.35(.31)	.25(.26)	.15(.22)
Low Frequency Distractor Only Category	.24(.26)	.23(.26)	.12(.18)
High Frequency Uncategorized	.28(.28)	.22(.22)	.12(.19)
Low Frequency Uncategorized	.21(.26)	.16(.20)	.08(.18)

Table 7

Bias-Corrected Acceptance Probabilities for Taxonomic Conjunction Experiment

Targets

List-context/statistic	Word content					
	Hi Frequency Categorized One	Hi Frequency Categorized Both	Hi Frequency Uncategorized	Lo Frequency Categorized One	Lo Frequency Categorized Both	Lo Frequency Uncategorized
List 1:						
p(L1)	.42(.38)	.34(.39)	.26(.48)	.43(.49)	.32(.44)	.46(.43)
p(L2)	.35(.38)	.13(.39)	.35(.42)	.32(.40)	.31(.41)	.28(.39)
p(L1∩L2)	.29(.37)	.15(.40)	.26(.40)	.24(.35)	.13(.37)	.19(.37)
List 2:						
p(L1)	-.02(.40)	-.02(.38)	.10(.39)	-.01(.38)	.05(.35)	.09(.38)
p(L2)	.40(.44)	.45(.46)	.39(.44)	.51(.38)	.46(.46)	.52(.44)
p(L1∩L2)	.11(.34)	.26(.37)	.16(.34)	.12(.36)	.39(.29)	.17(.37)

Related Distractors

List-context/statistic	Word content					
	Hi Frequency Categorized L1	Hi Frequency Categorized L2	Hi Frequency Categorized Both	Lo Frequency Categorized L1	Lo Frequency Categorized L2	Lo Frequency Uncategorized Both
Related Distractor:						
p(L1)	.12(.37)	-.14(.39)	.07(.34)	.18(.41)	-.03(.36)	.10(.27)
p(L2)	.07(.39)	.15(.36)	.11(.34)	.13(.42)	.13(.37)	.08(.33)
p(L1∩L2)	.21(.36)	-.01(.24)	.00(.21)	.19(.38)	.00(.26)	-.02(.19)

Note. Bias was corrected by subtracting the raw acceptance values of Categorized (One and Both) targets and related distractors by Unrelated Categorized distractors, and subtracting the raw acceptance values of Uncategorized targets and related distractors by Unrelated Uncategorized distractors.

Table 8
Bias-Corrected Acceptance Subadditivity Comparisons between Disjunction and Conjunction Experiments

Targets

List-context/statistic	Word content			
	Categorized One	Categorized Both	Uncategorized	Grand Mean
List 1:				
p(L1)	.43	.33	.36	.37
p(L2)	.34	.22	.32	.29
p(L1∩L2)				
Observed	.27	.14	.22	.21
Predicted	.26	.35	-.08	.18
t	.14	3.30**	4.45***	.74
List 2:				
p(L1)	-.02	.02	.09	.03
p(L2)	.46	.46	.46	.46
p(L1∩L2)				
Observed	.11	.32	.16	.20
Predicted	.01	.00	-.12	-.04
t	1.82	5.93***	3.66***	5.47***

Related Distractors

List-context/statistic	Word content			
	Categorized List 1	Categorized List 2	Categorized Both	Grand Mean
p(L1)	.15	-.08	.14	.07
p(L2)	.10	.14	.09	.11
p(L1∩L2)				
Observed	.20	-.01	-.01	.06
Predicted	-.12	.02	.04	-.02
t	5.56***	.47	1.29	2.32

Note. Observed = bias-corrected response probabilities from Conjunction and Predicted = bias-corrected response probabilities from Disjunction
*p < .02
**p < .008
***p < .0001

Table 9
Bias-Corrected Conjunction fallacy estimates

List-context/statistic		Word content		
		Categorized One	Categorized Both	Uncategorized
$p(L1 \cap L2) - p(L1)$	List 1:			
		-.16	-.19	-.13
	t	3.08**	3.93***	2.55*
	List 2:			
		.13	.31	.07
	t	3.20**	7.92***	1.70
$p(L1 \cap L2) - p(L2)$	List 1:			
		-.07	-.08	-.09
	t	1.62	1.87	2.08
	List 2:			
		-.35	-.13	-.29
	t	7.37***	3.24**	5.65***

Note. Test value=0
*$p < .02$
**$p < .008$
***$p < .0001$

Table 10

Pure Ignorance Model for an L1 Target

P_{L1}	P_{L2}	P(L1)	P(L2)	P(L1UL2)	P(L1∩L2)
1	0	1	0.5	1	0.50
0.8	0.2	0.9	0.6	1	0.54
0.6	0.4	0.8	0.7	1	0.56
0.4	0.6	0.7	0.8	1	0.56
0.2	0.8	0.6	0.9	1	0.54
0	1	0.5	1	1	0.50

Note. P_{L1} is the amount of accurate memory that an item was on List 1. P_{L2} is the amount of accurate memory that an item was on List 2. P(L1) and P(L2) are the probabilities that the subject answers that the item had been on List 1 and that the item had been on List 2 respectively. While the model predicts disjunction fallacies and the conjunction illusion, it does not predict conjunction fallacies.

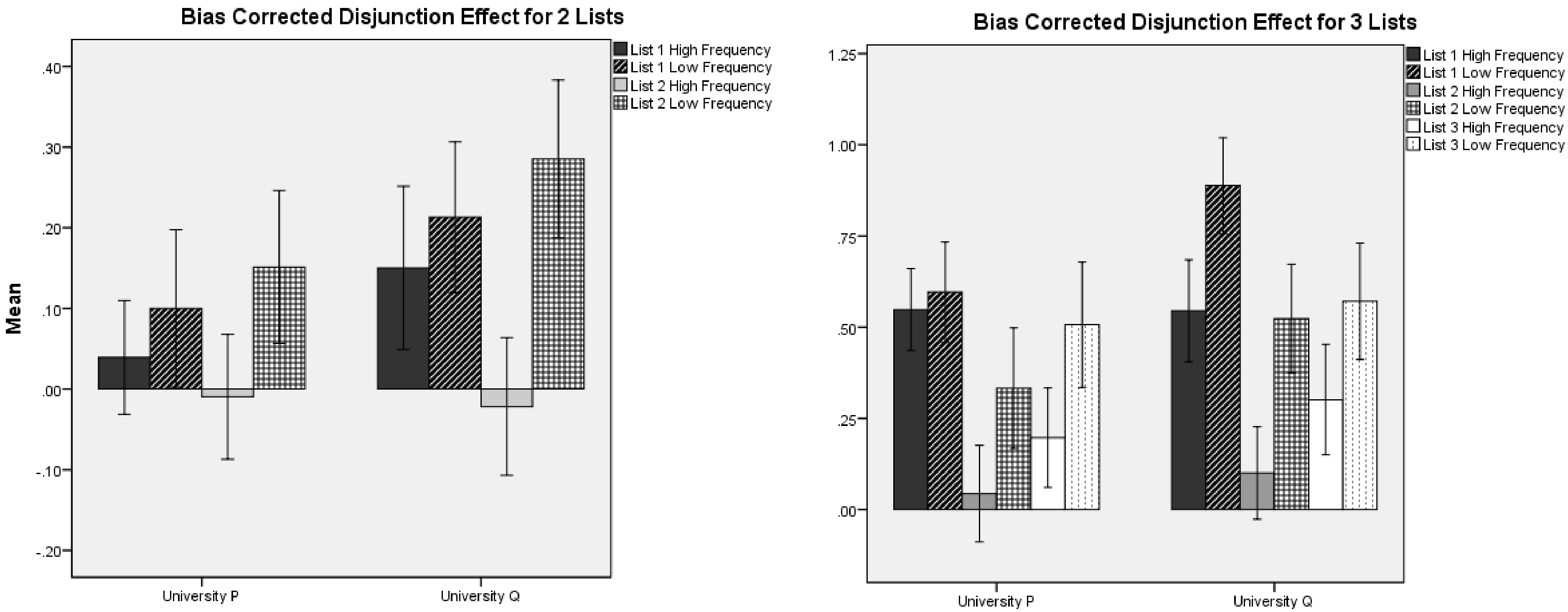

Figure 1. Average bias corrected values of the disjunction fallacy for targets from Brainerd et al. (2012). Error bars are +/- 2 standard error. University P students had higher verbatim ability than University Q students. The disjunction fallacy was lower for manipulations that encouraged verbatim processing, such as low frequency words, lower number of presentation contexts, and individual verbatim memory ability.

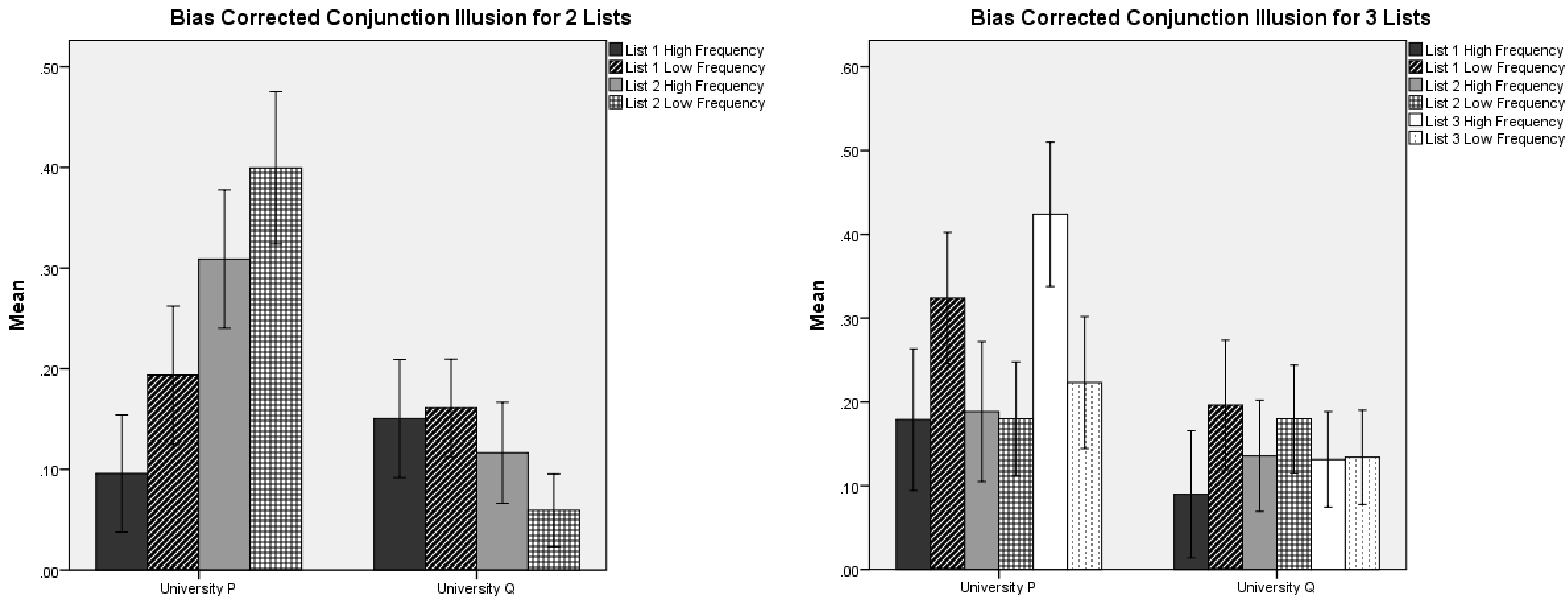

Figure 2. Average bias corrected values of the conjunction illusion for targets from Brainerd et al. (in press). Error bars are +/- 2 standard error. University P students had higher verbatim ability than University Q students. All manipulations showed robust conjunction illusions.

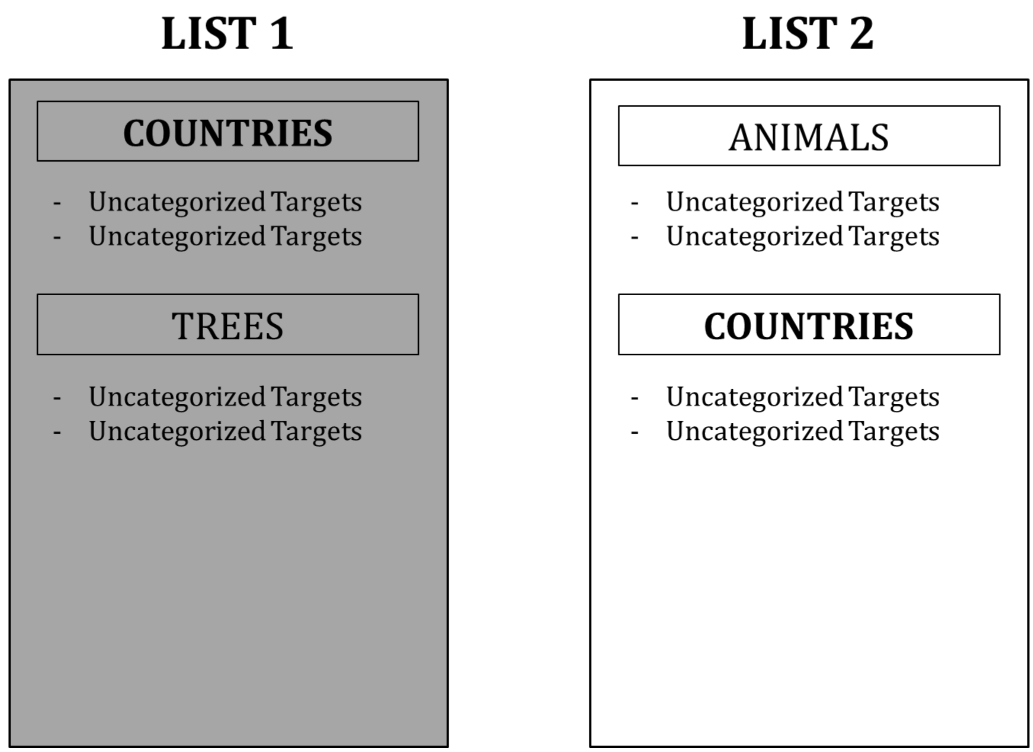

Figure 3. Study words were always presented in the order List 1 first, List 2 second. Study words either belonged in a category that appeared on just one of the lists (e.g. "Trees" in List 1, "Animals" in List 2), a category that appeared on both lists (e.g. "Countries"), or in no category.

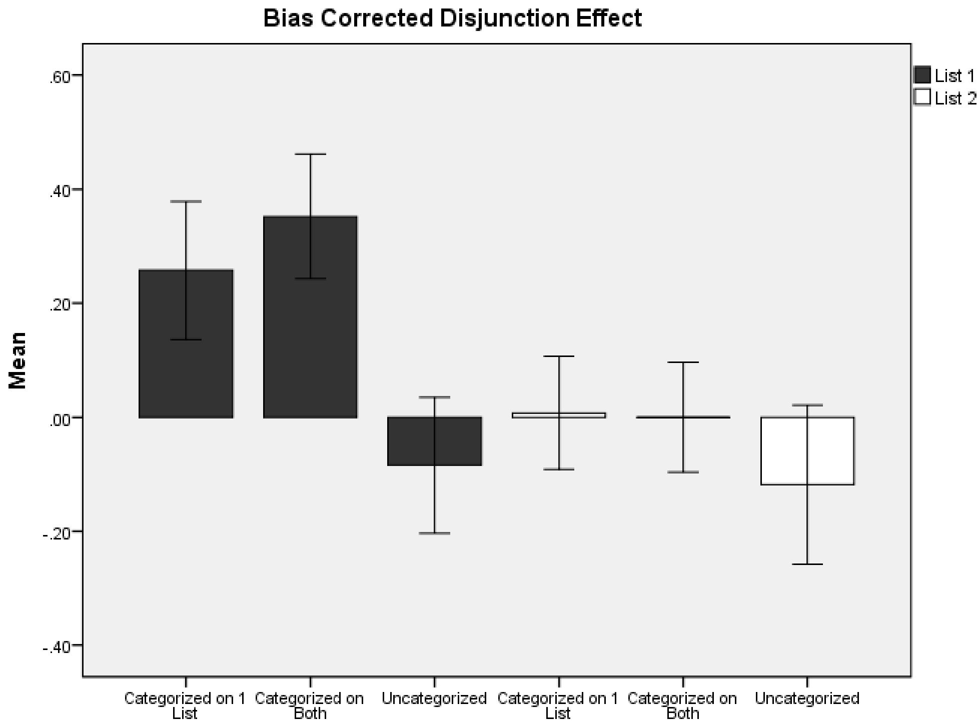

Figure 4. Average bias corrected values for the disjunction effect in Experiment 1. Error bars are +/- 2 standard error. The effect was only observed for categorized targets on List 1, and the values were reliably above zero.

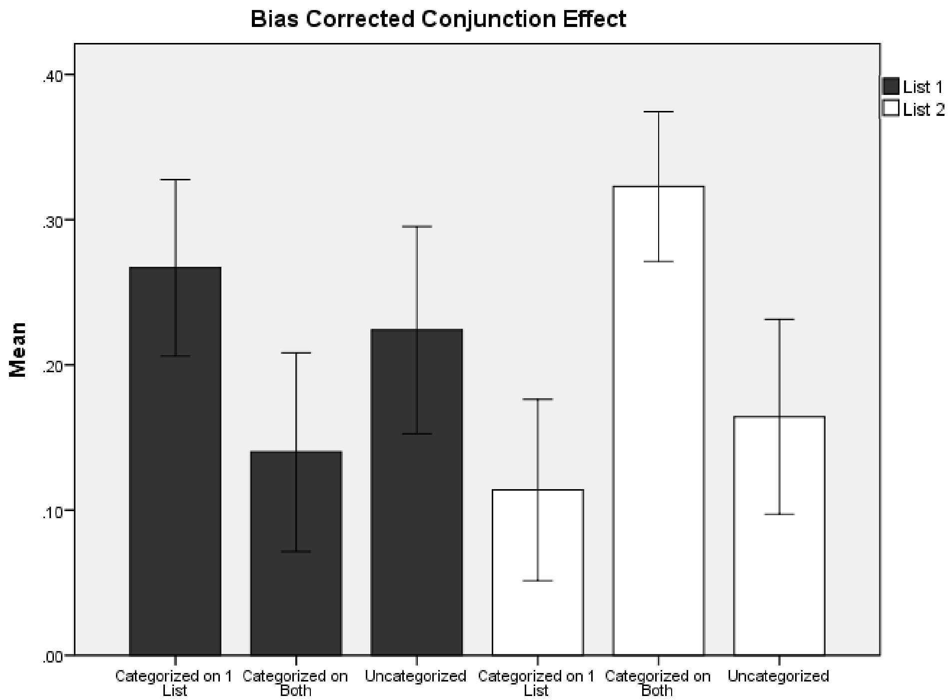

Figure 5. Average bias corrected values for the conjunction illusion in Experiment 2. Error bars are +/- 2 standard error. All cases were reliably above zero. When words were categorized on only one list, there was a downward trend going between lists. When categories were shared, there was an upward trend. There was no significant difference between List 1 and List 2 for uncategorized targets.

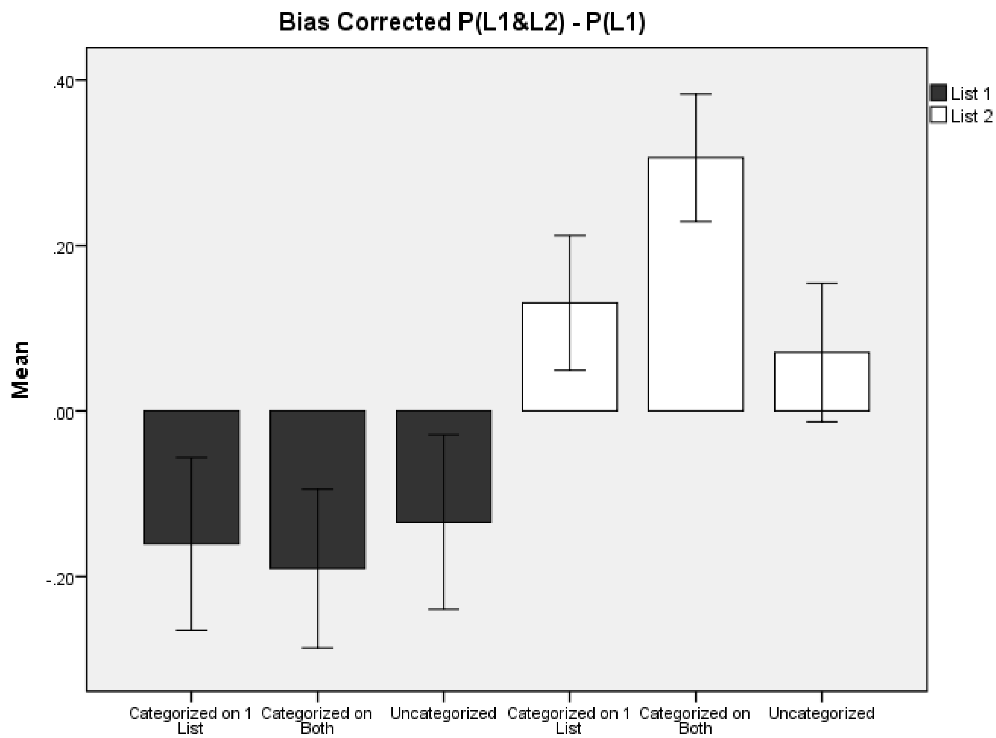

Figure 6. Bias corrected difference between the conjunctive description $P(L1 \cap L2)$ and the nonconjunctive description $P(L1)$. Error bars are +/- 2 standard error. Conjunction illusions rose to the level of conjunction fallacies for targets that were on List 2, but only for words that were categorized.

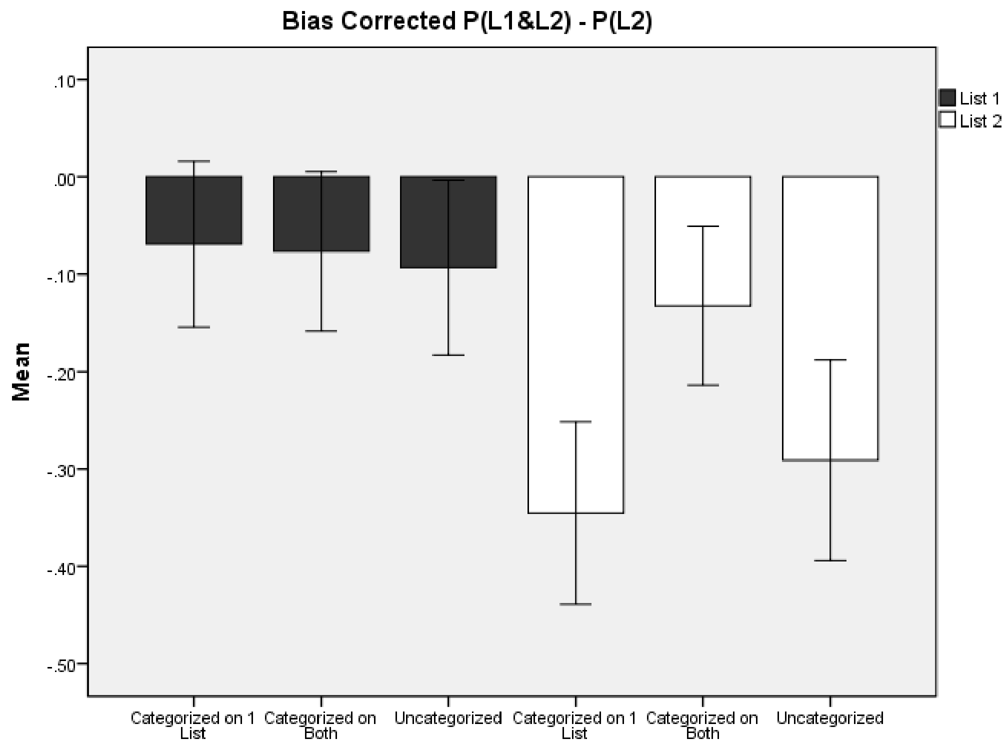

Figure 7. Bias corrected difference between the conjunctive description *P*(L1∩L2) and the nonconjunctive description *P*(L2). Error bars are +/- 2 standard error. There were no conjunction fallacies for List 1 targets and only remained at the level of conjunction illusions: the responses that List 1 targets were on List 1 and List 2, or on List 2 only, were not significantly different.