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The Conjunction Effect: New Evidence for Robustness

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Abstract

Five studies with college students investigated variables affecting the frequency of the occurrence of the conjunction effect (or conjunction fallacy), in which individuals report that the conjunction of two events is more rather than less likely than one of the events alone. There was no evidence that either feedback or monetary reinforcement for correct answers affected students' performance on a series of conjunction problems. Under some circumstances the context in which the conjunction problem was presented (after questions emphasizing logic or questions emphasizing opinions) affected occurrence of the effect. Location of the conjunction among the statements being rated had a significant effect. The effect occurred with or without a "framing description" and whether the conjunction consisted of two or three simple statements. Statements representing the conjunction of three simple statements, however, were (appropriately) judged less likely than those representing the conjunction of two simple statements. The substantial incidence of the effect, even without the descriptive frame and even when incentive and feedback were provided for correct answers, argues for its robustness.

The Conjunction Effect: New Evidence for Robustness

A classic example of an apparent anomaly of human judgment and decision making is the conjunction effect (also called the conjunction fallacy), displayed when subjects report that the conjunction of two events is more rather than less likely to occur than one of the events alone (Tversky & Kahneman, 1982; 1983). For example, Stolarz-Fantino, Fantino, & Kulik (1996) administered a standard conjunction problem to students at their institution (University of California, San Diego [UCSD]) who were just completing a course in logic. They were asked to read a statement about "Ralph" in which he was described as "not especially creative" and "somewhat compulsive and dull". The students then rated the likelihood of simple statements, including "Ralph is a building inspector", and "Ralph plays in a heavy-metal band for a hobby", as well as the conjunction "Ralph is a building inspector who plays in a heavy-metal band for a hobby". Their logic professor, a celebrated philosopher, introduced the task as one involving reasoning. Despite this context, 43% of the students rated the conjunction as more likely than at least one of the components. A similar situation was observed by Arkes & Blumer (1985), who found that economics students enrolled in a course covering the sunk cost effect (an example of irrational economic decision making) were just as likely to display the effect as students not enrolled in the course. The robustness of the conjunction effect among educated, even academically elite, participants raises the more general issue of how humans react to compound stimuli such as the conjunctive statements of the conjunction problem. In a behavioral approach to this issue Fantino & Savastano (1996) and Zizzo (2001) found a significant tendency to respond more to compound stimuli than to individual stimuli, a tendency that may contribute to expression of the conjunction effect.

Another variable thought to have a major impact on expression of the effect is the framing description of the individual (for example, the description of Ralph as "compulsive and dull"). In the standard procedure, participants are given a framing description that is thought to bias them into finding the conjunction more "representative" or more likely than one of the component statements. Thus, if Ralph is described "as not especially creative" and "somewhat compulsive and dull", the conjunction "Ralph is a building inspector who plays in a heavy metal band for a hobby" is rated as more likely than the simple statement "Ralph plays in a heavy metal band for a hobby". But Stolarz-Fantino et al. (1996) also assessed the likelihood of the conjunction effect in the absence of a framing description and found that over 40% of their participants (their Experiments 1 and 4) still rated the conjunction as more likely. For example, in their Experiment 4, they assessed the likelihood of the effect in a between-subjects design with and without a descriptive (or "biasing") frame. These participants saw no other questions and had not participated in any of the prior work. Participants in the no-frame condition were given only the two sentences: "Ralph is 34 years old. You know nothing else about him." Of these participants, 41% displayed the conjunction effect. Although participants in the frame condition were significantly more likely to display the effect (78%), high incidence of the effect in the absence of the frame suggests a tendency to overestimate the likelihood of compound or conjunctive events that cannot be reduced entirely to their representativeness.

Indeed it is not at all clear how participants react to the conjunction problem in general, nor how they combine the likelihood of each of two simple events to arrive at a judgment of the likelihood of their conjunction. For example, Hertwig & Gigerenzer (1999) have argued that while the conjunction effect is a violation of probability theory, its occurrence is not necessarily irrational, in view of the diverse interpretations given to the word probability when it is used in colloquial speech. Likewise, Dulany & Hilton (1991), investigating Tversky & Kahneman's

(1983) “Linda” and “Bill” tasks, found that participants differed in their interpretations of component statements such as “Linda is a bank teller.” Unless, the authors point out, the statement is interpreted as an instance of logical possibility (“Linda is a bank teller—whether or not she is active in the feminist movement.”), it is not necessarily a logical violation to rate the conjunction of bank teller and feminist as more likely than bank teller alone. And recent work by Mellers, Hertwig, & Kahneman (2001) demonstrated that the wording of the conjunction phrase itself affects the tendency of participants to produce the effect. Nonetheless, the fact that the conjunction effect occurs over a remarkably broad range of presentation modes makes it an interesting phenomenon whether or not we believe that it is a logical fallacy. A substantial proportion of participants rate the conjunction as more likely than one of its component parts for a large array of problems tested, whether or not there is a framing description, across different populations of participants and experimenters and across different sets of instructions. For example, when Stolarz-Fantino & Fantino (1990) instructed students that their “judgments should be made in terms of their probability and not simply in terms of whatever intuitive appeal is generated by the description above,” the responses of 86% of their UCSD participants showed the conjunction effect. In another study (Stolarz-Fantino et al., 1996), some of the questions were presented in a qualitative format, to assess the view that allowing participants to approach the problem on a purely qualitative basis might reduce incidence of the effect. Indeed, there is evidence that this approach helps children avoid errors of class inclusion (Brainerd & Reyna, 1990). However, Stolarz-Fantino et al.’s attempt to minimize the conjunction effect by having participants make a simple choice between qualitative alternatives was unsuccessful. Students read that

> Bill is 34 years old. He is intelligent but unimaginative, compulsive, and generally lifeless. In school, he was strong in mathematics but weak in social studies and humanities. Mark an "X" next to the alternative you think is more likely:
>
> _____ Bill plays jazz for a hobby
>
> _____ Bill is an accountant and plays jazz for a hobby.

Seventy-two per cent of the students placed their "X" next to the conjunction.

Several investigators have suggested that the conjunction effect may be understood in terms of an averaging model or variants thereof (e.g., Abelson, Leddo, & Gross, 1987; Fantino, Kulik, Stolarz-Fantino & Wright, 1997; Massaro, 1994; Zizzo, Stolarz-Fantino, Wen, & Fantino, 2000; Zizzo, 2001). Averaging implies that the conjoint probability is equal to or lies between the component probabilities, whereas the normative multiplicative model implies that the conjoint probability is equal to or lower than the component probabilities. Tversky & Kahneman (1983) note that "an averaging process...may be responsible for some conjunction errors, particularly when the constituent probabilities are given in numerical form" (p.306). It would not be surprising that participants make errors by misapplying strategies that work well for other tasks, and averaging is a strategy used in making many other types of decisions (e.g., Anderson, 1981).

The present experiments explore the effects of several additional variables that may have interesting effects on performance in the conjunction task. How does the decision-making context in which the conjunction problem is embedded affect incidence of the effect? In particular, is the tendency to display the conjunction effect affected by prior exposure to questions of attitude (which may facilitate reliance on the descriptive frame) as opposed to questions concerning logic (which may minimize incidence of the effect)? Does the conjunction effect persist over repeated trials and is its persistence influenced by feedback and by monetary

reward for correct answers? In particular, will a substantial payment for correct answers on conjunction problems (that is, for rating the conjunction as equally or less likely compared to the component statements) improve performance? It may be that the effect is less likely to occur when participants are sufficiently motivated. Another possibility, raised independently with the authors by two writers of fiction, is that the fallacy occurs because conjuncted statements are more informative and therefore more credible than simple statements. This possibility might be addressed by asking if the effect is more or less likely to occur when the conjunction consists of three rather than two components. These issues are introduced more substantively as the introductions to each of the five experiments comprising this article.

Experiment 1

If participants were told that the conjunction problem had a correct answer and that they might earn money by being correct would they be less likely to display the effect? It is possible that participants in past studies have not been sufficiently motivated to take the problem seriously. Indeed these studies have been typically carried out in a classroom with no incentive to pay careful attention to the task. By motivating participants we may affect the incidence of the effect. In this study we examined four groups. One group was studied in the typical manner with no information given beyond the conjunction problem itself. Participants in a second group were told that there was a correct way to answer, but were given no incentive for being correct. Participants in a third group were told that there was a correct way to answer and were also told that all participants would be entered in a lottery with a $35 prize for participating. Participants in the fourth group were treated in the same manner as those in the third group with the important exception that they were told that they would be entered in a lottery only if their answers were correct. Would this fourth group display the lowest incidence of the conjunction effect? And

would participants in Groups 2 and 3 do better than those in the first group who were not informed that there was a correct way to answer?

Method

Participants

Two hundred fifty-one students attending psychology classes at the University of California, San Diego (UCSD), participated.

Materials

The questions used in this experiment appear in Table 1. Group 1 saw the questions as they appear. The questionnaires filled out by Group 2 contained the additional statement "We are interested in seeing how many people can answer this questionnaire correctly." The questionnaire filled out by Group 3 contained the statement "We are interested in seeing how many people can answer this questionnaire correctly. All of the respondents, regardless of their answer, will be entered in a lottery for a prize of $35." And the questionnaire filled out by Group 4 contained the additional statement "We are interested in seeing how many people can answer this questionnaire correctly. Among those respondents whose answers are correct, we will enter their answer sheets in a lottery for a prize of $35."

Procedure

The data were collected in UCSD classrooms during psychology classes. Students were asked by their instructors to participate on a strictly voluntary basis. No extra credit was given for participating, nor was there any penalty for not participating. All versions of the questionnaire were handed out during the same sessions and each participant received only one version.

Results and Discussion

The data were analyzed to determine whether a significant conjunction effect was evident in the responses of each group of participants. The results appear in Table 2. In Experiment 1, participants in all four groups rated the conjunction as significantly more likely than they rated the less-likely of the component statements (as determined by each participant's response). In addition, the data were evaluated to determine whether or not each participant's response represented an instance of the conjunction effect. This was done in the following way: A participant's ratings of the statements "Ralph is a building inspector" and "Ralph plays in a heavy-metal band for a hobby" were compared with that participant's rating of the conjunction "Ralph is a building inspector who plays in a heavy-metal band for a hobby." If the likelihood rating of the conjunction was higher than the ratings of either (or both) of the component statements, the response was counted as an instance of the conjunction effect.

The percentages of participants in each group whose responses showed the conjunction effect were as follows: Group 1 (n = 55), 43.6%; Group 2 (n = 46), 24%; Group 3 (n = 75), 45.3%; and Group 4 (n = 75), 37.3%. A X^2 test showed that these differences are not statistically significant [X^2 (3, $\underline{N}$ = 251) = 6.26, $\underline{p}$ > .05]. Overall, the effect was evident in the responses of 39% of participants.

There was no evidence that the possibility of monetary reward enhanced performance nor was there a trend in that direction. Of course the promise of being entered in a lottery may provide a low subjective likelihood of reward. We resorted to a more expensive solution to this issue in Experiment 5. Thus, either we failed to motivate our participants to attend more closely to the problem or enhanced motivation does not improve performance on the conjunction problem. Merely telling participants that there was a correct answer (Group 2) appeared to produce more correct answers. This possibility was explored further in Experiment 2.

Experiment 2

This experiment employed a 2 x 2 design to focus on two variables that may influence incidence of the conjunction effect. One variable was whether or not participants were told that there "is a correct answer", following up the suggestive results of Group 2 participants in Experiment 1. The second variable involves placement of the conjunction statement. In Experiment 1 the conjunction statement was always the last to be judged. Thus, participants could consult the likelihood ratings that they had assigned the simple statements before rating the likelihood of the conjunction. Perhaps this feature helped the majority of participants in all groups of Experiment 1 to avoid the effect. This was evaluated in the present experiment by comparing the arrangement used in Experiment 1 with an arrangement in which the conjunction rating was instead made first; if order is important, participants in the latter condition should be more likely to display the conjunction effect.

Method

Participants

Two hundred eleven UCSD students attending psychology classes participated.

Materials

The questions shown in Table 1 were used, with modifications. Group 1 saw the questionnaire as it appears in Table 1. Group 2 received questionnaires that contained the statement "We are interested in seeing how many people can answer this questionnaire correctly," as in Experiment 1. Groups 3 and 4 received questionnaires that were modified by having the conjunction appear at the top of the list of statements, rather than on the bottom as it appears in Table 1. Group 3 received no additional information; Group 4 received the same additional statement as Group 2.

Procedure

The procedure was the same as that used in Experiment 1.

Results and Discussion

Responses were examined for the conjunction effect, using the criteria described in Experiment 1. Overall, the conjunction effect occurred among 44% of participants. The percentages of participants demonstrating the effect in each of the four conditions were as follows: Group 1 (n = 58), 31%; Group 2 (n = 49), 30.6%; Group 3 (n = 41), 58.5%; and Group 4 (n = 63), 55.5%. According to a X^2 test, the differences among groups are statistically significant [X^2 (3, $\underline{N}$ = 211) = 15.7, $\underline{p} < .01$]. Ryan's Procedure was performed, showing that participants in Group 4 (knowing that there is a correct answer, conjunction presented on top) and Group 3 (not knowing that there is a correct answer, conjunction presented on top) showed the effect significantly more often than participants in Group 2 (knowing that there is a correct answer, conjunction presented on bottom); Group 1 did not differ significantly from the other groups. The main effect, therefore, is the difference between the groups who received the conjunction statement on the top and those who received it on the bottom; the effect of knowing that there is a correct answer is quite small—only a few percentage points. As shown in Table 2, not only were there fewer conjunction errors in Groups 1 and 2, but the differences in ratings between the conjunction and the least-likely component statement were also quite small.

These results confirm the statistical ones of Experiment 1 in showing that merely informing participants that there is a correct answer does not significantly affect incidence of the conjunction effect. However there was a clear effect of where the conjunction question was placed. Participants were much more prone to show the effect when they were asked to rate the likelihood of the conjunction prior to rating the likelihood of its components (57% showed the effect) than when the rating of the conjunction came last (31%). In one sense this finding is unsurprising: if participants are trying to be logically consistent in rating the likelihood of the conjunction, they may find it easier to be so if they have the ratings they assessed the simple

statements readily available. But this methodological point underscores the fact that there is no "single" explanation of the conjunction effect. In addition to the factors discussed in the introduction that are believed to affect the conjunction effect (including representativeness; mode of presentation, i.e., frequencies versus probabilities; averaging), the present results demonstrate that large differences in incidence of the effect (here 25%) may result from procedural variables such as placement of the conjunction question. In any event, this point should be considered when comparing results across studies.

Experiment 3

Performance on the conjunction problem may be influenced by the context in which the problem is presented. Perhaps participants would be more likely to emphasize the framing description, and show the effect, if they were presented with the problem after answering a series of questions engaging their attitudes and opinions. Similarly participants exposed to a series of questions about probability and logic immediately before the conjunction problem may be less likely to show the effect. There is indirect evidence of this in the results of Stolarz-Fantino et al. (1996). They found that students enrolled in an abnormal psychology class were much more likely to show the conjunction effect (when personality frames were included) than were students in a physiological psychology class (63% versus 23%, respectively). Of course, that large difference is also attributable to the possible effects of self-selection: students who elect to take physiological psychology may tend to respond in a more logical manner than students electing to take abnormal psychology. The present study avoids the problem of self-selection by randomly assigning participants in a two-by-two design in which the context is one of attitude or logic and in which half of the participants receive the standard conjunction problem with the descriptive frame and half receive the problem without the frame. Two questions are of central interest: (1) Will fewer students show the conjunction effect when the problem is embedded in a logical

context? (2) Will students show the effect even in the conditions without a frame, albeit at a lower incidence?

Method

Participants

One hundred thirty-two UCSD students attending psychology classes participated.

Materials

The questionnaire given to Group 1 (logic with frame description) contained the following conjunction question:

> Bill is 34 years old. He is intelligent, but unimaginative, compulsive and generally lifeless. In school, he was strong in mathematics but weak in social studies and humanities. You are told that there is an 80% likelihood that Bill is an accountant and that there is a 20% likelihood that he plays jazz for a hobby. What is your estimate of the likelihood that he is both an accountant and that he plays jazz for a hobby?
>
> 0 (virtually impossible)----------100 (virtually certain)

This question was preceded by six questions that were intended to remind participants of the rules of logic and probability. Group 2 (logic without frame description) participants were given a questionnaire that was the same except that Question 7 did not contain the description of Bill; instead, it began with the words "You are told that there is an 80% likelihood..." The questionnaire given to the Group 3 (opinion with frame description) participants contained the same conjunction question shown above, but also contained six questions assessing participants' opinions. Group 4 (opinion without frame description) participants were given a questionnaire that was the same as that of Group 3 except that it did not contain the description of Bill. The logic and opinion questions used in this study appear in the Appendix.

Procedure

The procedure was the same as that used in Experiment 1.

Results and Discussion

In this study, participants did not rate the component statements of the conjunctions; they were told that there was an 80% likelihood that Bill was an accountant and a 20% likelihood that he played jazz for a hobby. Therefore, any response in which the likelihood of the conjunction was rated as higher than 20 was classified as an instance of the conjunction effect.

Over all conditions, the conjunction effect occurred in 53% of participants' responses. The percentages of participants who showed the conjunction effect in each of the four conditions was as follows: Group 1 (n = 28), 60.7%; Group 2 (n = 34), 32.3%; Group 3 (n = 33), 63.6%, and Group 4 (n = 33), 57.5%. A X^2 test showed the groups to be significantly different [X^2 (3, $\underline{N}$ = 128) = 8.26, $\underline{p} < .05$]. Ryan's Procedure shows that participants in Group 2 (logic without frame description) committed significantly fewer conjunction errors than those in the other three conditions; the other groups did not differ significantly from one another. As shown in Table 2, Group 2 also had the smallest difference in mean ratings of the conjunction and the less-likely component statement.

These results support those of Stolarz-Fantino et al. (1996) in showing that the conjunction effect occurs even when the problem is presented without a framing description (45% of participants in the no-frame conditions showed the effect) although the incidence of the effect is less than when the framing description is included (62% of participants in the frame conditions showed the effect). This is a significant difference [X^2 (1, $\underline{N}$ = 128) = 3.9, $\underline{p} < .05$]. The present results also implicate the role of context. Participants presented with the conjunction problem after answering questions with a logical nuance were least likely to show the effect if no frame was presented (32% showed the effect in Group 2). However, in the present study the

logical context had no effect if a framing description was included. Thus, while context may affect the incidence of the conjunction effect it does not necessarily do so. The role of context is explored further in Experiment 4.

Experiment 4

We repeated Experiment 3 on the effects of context and on the effects of the framing description but with two additional groups and with an additional manipulation. Participants in the two new groups did not receive a context (opinion or logic). For one of these two groups the conjunction problem was presented with a framing description; for the other group, without a framing description. Participants in each of the six groups studied in this experiment received two conjunction problems, one in which the conjunction consisted of two simple statements (as usual) and the other in which the conjunction consisted of three simple statements. Since from a logical perspective it is even less likely that a conjunction comprising three events is more probable than any of the single events, the conjunction effect might occur less frequently when three rather than two statements are conjoined. However, if the conjunction effect occurs because a combination of two statements seems more informative than a single statement, adding an additional statement could drive up the incidence of the effect. This possibility had been suggested to us by two different writers (a playwright who is also a scientific researcher and a television screenwriter); both independently predicted that with more information, statements would become more "credible" and therefore be judged more likely (a "writer's trick"). The present study assessed that possibility.

Method

Participants

Four hundred fifty UCSD students attending psychology classes participated.

Materials

The questionnaires used were the same as in Experiment 3 except for two changes. First, two groups of participants received questionnaires that included only conjunction questions and had no logic or opinion questions. Second, each of the six different questionnaires contained two conjunction questions — the question about Bill used in Experiment 3, and the three-component conjunction question that follows:

> Bill is 34 years old. He is intelligent, but unimaginative, compulsive and generally lifeless. In school, he was strong in mathematics but weak in social studies and humanities. You are told that there is an 80% likelihood that Bill is an accountant, that there is a 20% likelihood that he plays jazz for a hobby, and that there is a 10% likelihood that he surfs for a hobby. What is your estimate of the likelihood that he is an accountant and that he plays jazz and surfs for a hobby?

Procedure

The procedure was the same as that used in Experiment 1.

Results and Discussion

Participants did not rate the individual components of the conjunctions, but were given the likelihoods, as in Experiment 3. Ratings of greater than 20 for the two-component conjunction and greater than 10 for the three-component conjunction were classified as instances of the conjunction effect.

As shown in Table 2, a significant conjunction effect was evident for both the two-component and three-component conjunction questions in all six conditions. In all cases, the likelihood of the conjunction was rated more than 10 percentage points higher than that of the least-likely component statement. The percentages of participants in each condition whose responses showed the conjunction effect on the two-component conjunctions and the three-

component conjunctions are shown in Figure 1. For the two-component conjunctions, there was a significant effect of the framing description [X^2 (1, $\underline{N}$ = 450) = 4.07, $\underline{p}$ < .05]. In all three context conditions, a greater percentage of participants showed the conjunction effect when the framing description of Bill was included. There was no significant effect of context itself [X^2 (2, $\underline{N}$ = 450) = 3.11, $\underline{p}$ > .05]. However, much as the "logic without framing description" participants in Experiment 3 had committed fewer conjunction errors than other groups, in Experiment 4, participants in the "opinion with framing description" condition — the opposite of the "logic without framing description" condition — had the highest rate of conjunction errors (66%). Analyses of the three-component conjunctions also revealed a significant effect of framing description [X^2 (1, $\underline{N}$ = 450) = 11.87, $\underline{p}$ < .01) and no significant effect of context (X^2 (2, $\underline{N}$ = 450) = 2.73, $\underline{p}$ > .05). Interestingly, while there is essentially no difference between context conditions for participants who did not receive the framing description, there is a marginally significant effect of context among participants who did receive the framing description [X^2 (2, $\underline{N}$ = 212) = 5.99, $\underline{p}$ = .05]. This effect is due to differences between the Logic condition (with a 49% conjunction effect rate) and the Opinion and Control conditions (68% and 62% rates respectively).

An innovation of this study was the ability to compare participants' ratings of two- and three-component conjunctions. What was the relationship between participants' performance on the two types of conjunction problem? Fifty-two percent of participants showed the effect on the three-component conjunction, compared to a rate of 55% for the same participants when the conjunctions consisted of the typical two events. There was a strong association between participants' performance on the two-component conjunction and their performance on the three-component conjunction, as shown in Table 3 (ϕ = .77). But despite the finding that participants

who showed (or did not show) the conjunction effect on one conjunction problem were likely to perform similarly on the other, participants did not rate the three-component conjunctions as more likely than the two-component conjunctions. Instead, over context and frame conditions, the mean rating for a two-component conjunction was 36.25, while the mean rating of a three-component conjunction was 23.75. A paired, two-tailed t-test showed this difference to be statistically significant [t (449) = 16.13, p < .001]. The percentages of participants in each condition who rated the three-component conjunction as less likely than the two-component conjunction appear in Table 4. Note that, with the exception of the Opinion/Frame Group, fewer than 10% of participants in each group failed to rate the three-component conjunction as less likely. This finding is consistent with participants' use of an averaging rule (e.g., Fantino et al, 1997): Since the average of the two likelihoods comprising the two-component conjunction (80% and 20%) is 50% whereas the average of the three likelihoods comprising the three-component conjunction (80%, 20%, and 10%) is only 37%, participants implicitly following an averaging rule would rate the three-component conjunction as less likely. The result is also consistent with the possibility that participants were demonstrating understanding of the rules of probability, even as they demonstrated the conjunction effect. In any event, the present results provide no support for the suggestion that statements consisting of more events would be judged more likely, at least when assessed with the conjunction effect problem.

Experiment 5

Although there was no evidence that the monetary incentive provided in Experiment 1 minimized incidence of the conjunction effect, it is not clear that the promise of being entered into a lottery, if the conjunction problem was answered correctly, increased participants' motivation. This is for at least two reasons: (a) the expected monetary reward was small; (b) the experiment was performed in a classroom, which may not be an ideal recruitment method (Eckel

and Grossman, 2000). Further, no opportunity for learning from past experience was allowed. In the present experiment we introduced several potentially important innovations: (1) the experiment was done individually in the company of an experimenter; (2) all participants received six conjunction problems; (3) participants in some groups were paid for each correct answer; (4) participants in some groups received feedback after each problem on whether their answer was correct or incorrect. In all, six groups participated: (1) a standard ("control") group which received six standard conjunction problems with no feedback, monetary reward, or "hints"; (2) a group given a hint for correct solution but no feedback or reward; (3) a group given both a hint and feedback after each problem; (4) a group receiving feedback only; (5) a group given feedback after each trial and also earning $3 for each correct answer, payable at the end of the participant's participation; (6) a group identical to group (5) except that the $3 reward for each correct answer was distributed as soon as the correct answer was made. The final group was included to eliminate any possibility that subjects did not really anticipate being paid $3 for each correct answer (permitting the possibility of earning $18 in just a few minutes). In fact, for participants in this group the experimenter sat with the participant while holding a stack of $1 bills. Clearly, if participants understand the conjunction problem but merely require incentive and feedback to respond in a logical fashion, then those in groups (5) and (6) should not show the effect or should cease to do so over trials.

Method

Participants

Seventy-two UCSD students attending psychology classes participated. Participants received credit for experimental participation in partial fulfillment of a course requirement.

Materials

Four of the conjunction questions used in this study are like the "Ralph" question shown in Table 1. However, instead of rating the likelihood of eight different single statements and a conjunction, participants rated only two single statements and the conjunction of those two statements. Thus, they completed four "Ralph" questions, each with a different combination of two statements about Ralph's possible job and hobby. Participants also answered the "Bill" and "Linda" questions used in much previous conjunction fallacy research (Tversky and Kahneman, 1982). Again, likelihood numbers were assigned to two single statements ("Bill plays jazz for a hobby" and "Bill is an accountant" in the Bill question, and "Linda is a bank teller" and "Linda is active in the feminist movement" in the Linda question) and to their conjunctions. All six questions contained descriptive frames, and participants in all conditions answered all six questions.

Procedure

Participants completed the task individually in the company of an experimenter. Each student was assigned to one of the following conditions: 1) Control, in which participants were given no additional information or incentives; 2) Hint only, in which participants were given a hint but were not given feedback or other incentives (" Hint: Probability that someone has both brown hair and is wearing brown shoes equals the probability that the person has brown hair multiplied by the probability that he is wearing brown shoes)"; 3) Feedback + hint, in which participants were told, after each question was answered, whether the answer was correct (but were not offered payment for correct answers) and were also given the hint described above to help them answer correctly; 4) Feedback only, in which participants were told by the experimenter after each question was answered, whether that answer was correct ("correct" meant that the rating of the conjunction was less than or equal to those of the ratings of the

components); 5) Feedback + $3, in which the participant was given feedback and was offered $3.00 for each correct answer, payable at the end of the session; and 6) Feedback + immediate $3, which was like Group 5, except that payment was made immediately after each correct answer.

Results and Discussion

On four of the six conjunction questions, participants' mean ratings of the conjunctions were significantly higher than their ratings of the less-likely component statements. The mean percent of responses showing the conjunction effect made by participants in each group were as follows: Control, 46%; Hint, 53%; Feedback + hint, 42%; Feedback only, 51%; Feedback + $3, 43%; and Feedback + Immediate $3, 56%. An analysis of variance showed no significant differences among the means. Participants committed the conjunction fallacy at about the same rate whether or not they were given hints and/or feedback and whether or not they received monetary rewards for correct answers. Overall, 48% of participants' responses showed the conjunction effect. Moreover, there was no suggestion of improvement over the six trials of the experiment. The results support the contention of Epstein, Donovan, and Denes-Raj (1999) that participants' strategies on the conjunction problem tend to be "self-maintaining." The results do not support the possibility that participants are aware of the logically correct answer on the conjunction problem but prefer to respond in an alternative manner since, in that event, it would be expected that they would have come to respond correctly under the conditions of the present experiment.

Summary and Conclusions

The present results attest to the robustness of the conjunction effect. As measured by a significant difference between ratings of conjunctions and those of the least-likely component, it occurred in nearly all of the many settings assessed in the present five experiments. It occurred

even when there were monetary incentives for making the correct answer (that is, for avoiding the effect), when a logical context was provided for the correct answer, over repeated trials (even with feedback and monetary incentives), with and without a framing description, and with conjunctions comprised of either two or three simple statements.

Some of the variables studied produced statistically significant effects on the incidence of the conjunction effect. Thus, requiring participants to rate the likelihood of the conjunction before rating the likelihood of the simple statements comprising the conjunction increased its occurrence (Experiment 2), a finding with methodological implications. Presenting the conjunction problem following a series of logical problems decreased incidence of the effect in Experiment 3. In Experiment 4 there was a trend in the same direction; however, the results were not statistically significant. Thus, while context may affect incidence of the conjunction effect, it certainly does not do so impressively. When conjunctions comprised of three simple statements were used in the conjunction problem the conjunction effect continued to occur at only a very slightly reduced rate from that with conjunctions comprised of only two statements. However, student participants rated the three-component conjunctions as less likely than the two-component conjunctions, consistent with both the averaging hypothesis and with the possible application of the principles of probability to the task. Perhaps the most striking finding of the present experiments, however, was the complete lack of an effect of incentive and of feedback on incidence of the conjunction effect (Experiments 1 and 5). Even when presented with six conjunction problems with a reward of $3 for each correct answer, participants did no better than controls without money and feedback nor did they improve over trials. It appears that most participants did not approach the conjunction problem as a problem in logic. As noted in the Introduction, they may approach the problem as an averaging task or in some other manner. If so, the present results suggest that their approach is held with some tenacity. In any event, the high

incidence, even without the descriptive frame, and even when incentives and feedback were provided for correct answers, supports the conclusion that, whether or not it represents a true logical fallacy, the conjunction effect is a robust phenomenon at least among college students.

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Appendix

Logic Questions from the Experiment 3 Questionnaire

_____ 1) If it is raining outside, the floor is wet. 2) It is raining outside. Assuming the two statements above are true, how much confidence do you have that the floor is wet?

0 (no confidence) ----------100 (complete confidence)

_____ 2) Suppose you have an ordinary deck of 52 cards. You are to draw one card. Assume that each card is equally likely to be drawn. What is the probability that you will draw a black card?

0 (virtually impossible) ----------100 (virtually certain)

_____ 3) Suppose two fair dice are rolled once. What is the probability that there is at least one 6?

0 (virtually impossible) ----------100 (virtually certain)

_____ 4) What is the likelihood that a given person was born on a Sunday morning?

0 (virtually impossible) ----------100 (virtually certain)

_____ 5) Suppose two fair dice are rolled once. What is the probability that there is one 6 and one 2?

0 (virtually impossible) ----------100 (virtually certain)

_____ 6) How much confidence do you have that there are more people than primates?

0 (no confidence) ----------100 (complete confidence)

Opinion Questions from the Experiment 3 Questionnaire

_____ 1) People who are more sociable get better grades.

0 (completely disagree)----------100 (completely agree)

_____ 2) How much human intelligence is inherited?

0 (virtually none)----------100 (virtually all)

_____ 3) People with a religious upbringing are more likely to be sensitive to the needs of their friends.

0 (completely disagree)----------100 (completely agree)

_____ 4) True leadership is the ability to detect the public will and to follow it.

0 (completely disagree)----------100 (completely agree)

_____ 5) Professors who are strong in both research and teaching are more common than those who are strong in research.

0 (virtually impossible)----------100 (virtually certain)

_____ 6) Women are more likely than men to vote for Tom Cruise as best actor for the Oscar award.

0 (completely disagree)----------100 (completely agree)

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Table 1

Example of the Statements Rated by Participants in Experiments 1 and 2

Ralph is 34 years old. He is intelligent though not especially creative, and his friends describe him as somewhat compulsive and dull. In college, he did well in the physical sciences but was weak in the humanities and social sciences.

Please indicate the likelihood of each of the following statements about Ralph by entering a percentage on the line to the left of the statement—for example, "0" would be virtually impossible, and "100" virtually certain. You can think of the continuum of likelihood as looking like this:

0	100
virtually impossible	virtually certain

Since the statements are not mutually exclusive, the numbers (each from 1 to 100) need not sum to 100.

_____ Ralph is a disc jockey.

_____ Ralph builds radio-controlled gliders for a hobby.

_____ Ralph is a building inspector.

_____ Ralph collects stamps for a hobby.

_____ Ralph plays in a heavy-metal band for a hobby.

_____ Ralph is a park ranger.

_____ Ralph is a kindergarten teacher.

_____ Ralph scuba dives for a hobby.

_____ Ralph is a building inspector who plays in a heavy-metal band for a hobby.

Table 2

Average ratings of conjunctions and least-likely component statements

Experiment 1

Condition	Rating of Least-likely component	Conjunction rating	df	t (1-tailed)
1	12.5	19.3	54	2.85**
2	12.3	16.7	45	1.71*
3	9.5	19.1	74	4.2**
4	11.7	20.4	74	3.79**

Experiment 2

1	15.4	16.7	57	.55 ns
2	12.4	16.3	48	1.63 ns
3	19.1	25.4	40	2.79**
4	16.8	26.3	62	4.26**

Experiment 3

1	20	36.9	27	3.75**
2	20	25.5	33	1.58 ns
3	20	38.9	32	4.28**
4	20	37.4	32	4.32**

Table 2, continued

Experiment 4	(Three-component conjunction data in parentheses)			
1	20 (10)	36.8 (26.8)	49	5.04** (5.24**)
2	20 (10)	35.0 (23.1)	44	3.77** (3.45**)
3	20 (10)	38.6 (29.3)	90	7.56** (7.71**)
4	20 (10)	35.8 (22.3)	87	5.96** (4.81**)
5	20 (10)	35.9 (20.6)	70	5.11** (4.43**)
6	20 (100	34.3 (21.6)	104	6.14** (5.48**)

*= $\underline{p} < .05$

** = $\underline{p} < .01$

Table 3

Number of Participants Who Showed the Conjunction Effect in Rating Two- and Three-component Conjunctions

		Three-component Conjunction	
		Effect	No Effect
Two-component Conjunction	Effect	214	33
	No Effect	19	184

N = 450

Note. Each participant rated both a two-component and a three-component conjunction.

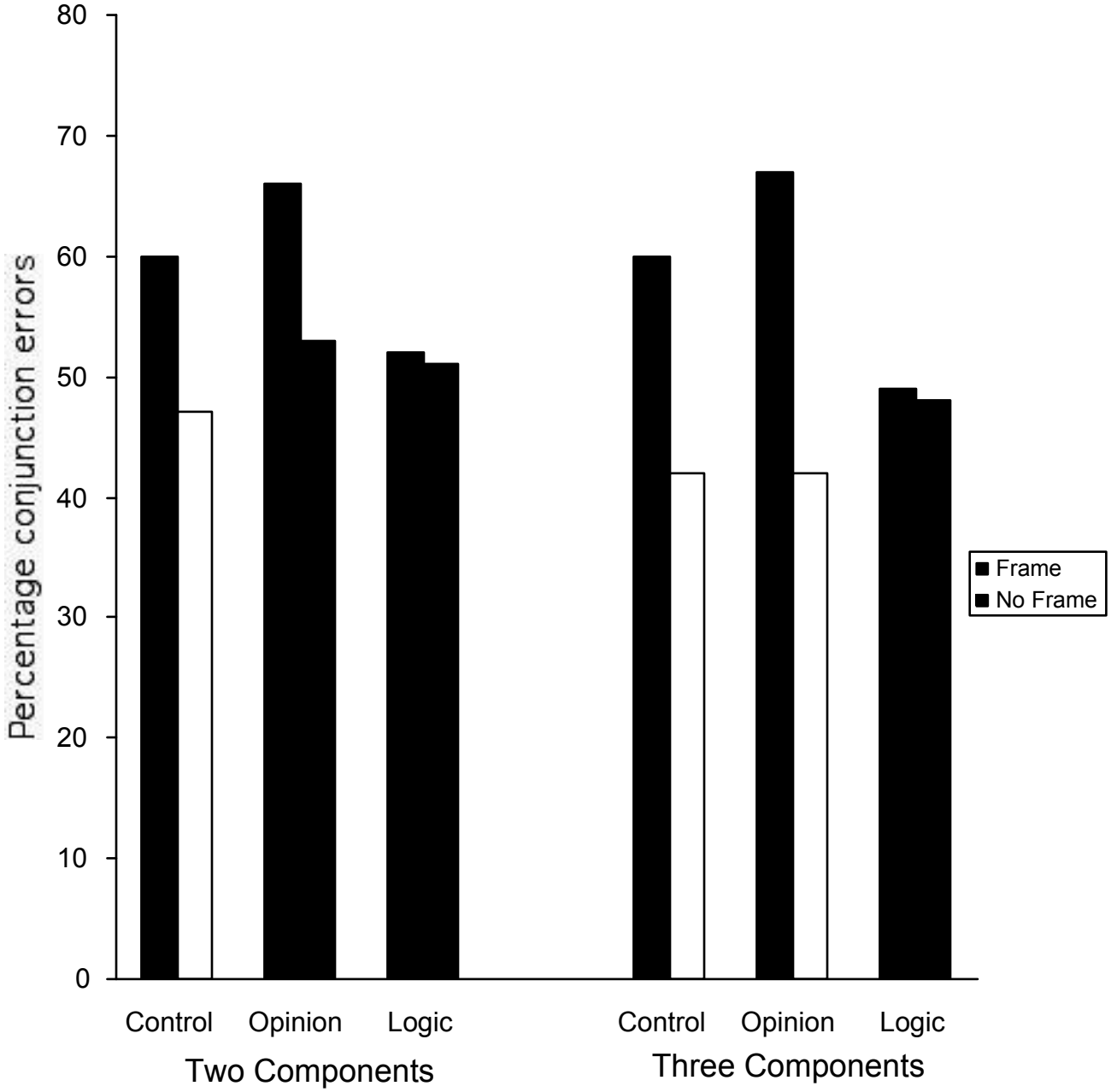
Table 4

Percentage of Participants in Each Condition Rating the Three-component Conjunction Less Likely than the Two-component Conjunction

	No Context		Logic		Opinion	
	Frame	No frame	Frame	No frame	Frame	No frame
	92%	96%	97%	93%	76%	96%
N	(50)	(45)	(39)	(71)	(54)	(50)

Figure Caption

Figure 1. Mean percentage of participants making conjunction errors on two- and three-component conjunction questions as a function of context and the presence or absence of a descriptive frame.


80
70
60
50
40
30
20
10
0
Percentage conjunction errors
Frame
No Frame
Control
Opinion
Logic
Two Components
Control
Opinion
Logic
Three Components