

Cognitive Fallacies in Group Settings

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Abstract

Research in cognitive science has found that subjects regularly exhibit a conjunction fallacy in probability reasoning. Additionally, recent research has led to the finding of other fallacies in probability reasoning, including disjunction and conditional fallacies. Such analyzes of judgments are critical because of the substantial amount of probability judgment done in business organizational settings.

However, in each case, the previous research has been conducted in the environment of a single decision maker. Since the business environment also employs groups, it is important to determine the impact of groups on such cognitive fallacies. This paper finds that groups substantially mitigate the impact of cognitive fallacies in probability reasoning among the sample of subjects investigated.

1. Introduction

There has been substantial research in cognitive science regarding cognitive fallacies in probability reasoning. The classic work of Tversky and Kahneman [1983] found that, in contradiction to probability theory, on average, individuals rank the intersection of two events as more likely than one or both of the two events (the so-called "conjunction fallacy").

However, much business activity is performed in the context of group decisions. Thus, the concern is not only with individuals, but also with groups. As a result, the purpose of this paper is to investigate the impact of groups on the existence of cognitive fallacies in group decisions.

1.1 Probability Judgments in Business

Probability judgments are critical to business judgments. As noted in Ijiri [1975, p. 174]:

There are many areas ... where probability measurement is essential Insurance companies, for example, deal with risk and probability directly. Even in other businesses, risk is an integral part of every activity. Probability measurement is particularly important in areas such as research and development, new product introduction, exploration, economic obsolescence of properties and equipment, uncollectable receivables, pension cost, guarantees, warranties and other contingent liabilities.

In some aspects of business, probabilities are directly assessed and analyzed, e.g., auditing and insurance. The direct importance of probability to judgment has been stressed by a number of other researchers in those disciplines. For example, Stringer and Stewart [1985, p. 9] note "Auditor decisions ... involve, explicitly or implicitly, consideration of the probabilities of forming correct or incorrect conclusions from the evidence obtained from audit tests."

Such probability judgments are not made only by individuals. Often, much business work is done in a group environment. Typically, teams, directly or indirectly, make those judgments in pursuit of a common goal (e.g., Simon [1957]). Thus, a critical issue, in the analysis of the business decisions and organization is the impact of groups on probability assessments.

1.2 Findings

This paper finds that the use of groups has a substantial impact on mitigating the existence of cognitive fallacies in those situations where groups provide a single solution to a decision problem. Groups develop fewer fallacies on average. In addition, groups are more likely to develop a proper ordering to the probabilities of sets of events. Since much of business is a group activity this suggests that the use of groups can reduce some of the potential problems associated with cognitive fallacies in probability reasoning.

1.3 Outline of this Paper

This paper proceeds as follows. Section 2 briefly reviews some of the previous research. Section 3 develops the research hypotheses. Section 4 summarizes the methodology. Section 5 presents the findings. Section 6 discusses some contributions, extensions and implications of the current study.

2. Prior Research

The problem addressed in this paper brings together group research and cognitive science probability judgment fallacy research. This section reviews some aspects of both of those literatures.

2.1 "Group Behavior"

Throughout the group literature, and this paper, there is the notion of "group behavior" or group decisions (e.g., Simon [1957]). These terms are used since, as noted by Weick [1969, p. 32], "People in aggregates behave differently than do people in isolation."

This paper is concerned with a particular kind of group behavior. In particular, the concern is with those groups that must come to consensus with a common solution to a decision problem. For example, insurance companies

must issue a policy at a single rate; audits require that the audit team present a single financial statement opinion; firms must either invest or not invest. This is different than some other group environments where multiple decisions or recommendations can result from the group. For example, with the Supreme Court there is a "minority opinion."

2.2 Importance of Group Size

The number of group members can be a crucial variable, particularly in small groups (e.g., Simmel [1950] and Weick [1969] and others). The crucial transitions in group size are from one to two persons, from two to three, from three to four, from four to seven and from seven to nine (Weick [1969]). In particular, Weick [1969, p. 38] refers to triads as the basic unit of analysis in organization theory. The triad is particularly important since it is the smallest group size that allows for alliance of two group members against one. Triads allow for cooperation, control and competition.

In any group of size four or larger, a group size of three can be a subgroup. Thus, in larger groups, we also need to consider groups of size three. Since the triad is one of most critical group sizes and because of its use in groups of other sizes, it will be the focus of this paper.

2.3 Perceptual Sets

The notion of perceptual sets argues that individuals "see" what they are attuned to see, based on past experience. Subjects carry their perceptual sets from situation to situation. The perceptual sets change as experiences change. Thus, if the subjects have had training in probability theory we might expect that training to become part of their perceptual set.

The perceptual sets of the group and the individuals in the group are closely related, depending on the dynamics. Assuming static (or limited changes to) perceptual sets, the

perceptual set of the group is limited, at its maximum, to the union of the perceptual sets of the group members. Assuming a completely dominant group member, the perceptual set of the group would be limited to the perceptual set of that individual.

The notion of perceptual sets has received much application in cognitive science and artificial intelligence (e.g., Simon [1981]). In addition, it is not unusual for the developers of computer systems (e.g., decision support systems) to assume that the use of a computer program will increase the perceptual set of the user. Effectively, those developers assume that the augmented human and computer system can function with a perceptual set limited by the union of the two perceptual sets.

2.4 Conjunction Fallacy Research

Tversky and Kahneman [1983] provided evidence that people assess the probability of the intersection of two events to be greater than the probability of at least one of the events. As an example, Tversky and Kahneman [1983] used the "predicting Wimbledon" case. Given a brief scenario, subjects were asked to rank the probability of four different sets of events: a. Borg will win the match b. Borg will lose the first set c. Borg will lose the first set but win the match d. Borg will win the first set but lose the match It was found that subjects, on average, assigned a greater probability to c than to b. Thus, there was a conjunction fallacy in the average of the subjects reasoning.

There are some explanations for the existence of such cognitive fallacies. For example, in some cases the temporal sequence of events does not match the sequence of causation (Einhorn and Hogarth [1986]). Disease (cause) results in a positive test result (effect), yet it is by the test that we determine the existence of the disease. In those situations, causation and temporal order reversal can confuse probability reasoning.

2.5 Disjunction and Conditional Fallacies

Recently, Favere and O'Leary [1991] found additional fallacies in the probability reasoning of subjects. It was found that subjects often estimated that the probability of the union of two events was less than the probability of at least one of the events. In addition, it also was found that subjects generally estimated the probability of one event conditioned on another lower than the probability of the intersection of those two events. These two cases of fallacious probability reasoning were referred to as the Disjunction Hypothesis and the Conditional Hypothesis. In addition, in what was referred to as Conjunction/Disjunction fallacy, subjects estimated the probability of the intersection of two events as larger than the probability of the union of those same two events.

2.6 Fallacy Research in a Group Context

Unfortunately, it appears that there has been limited research involving the impact of groups on fallacy research. Thus, this paper is designed to mitigate that gap in the literature.

3. Hypotheses

The hypotheses of subject and group performance are based on both probability theory and the group theory discussed in the previous section. A comparative basis of analysis is used: individual subjects are compared to groups of subjects.

3.1 Probability Theory and Research Hypotheses

Probability theory provides a number of relationships between different sets of events. Let $Pr(A)$ be the probability of A. Let the union of two events be denoted " \vee " and the intersection of two events be denoted " \wedge ." If subjects use reasoning consistent with probability theory, then we would have the following. Conjunction Hypothesis Subjects will estimate $Pr(A \wedge B) < Pr(A)$ and

$\Pr(A \wedge B) < \Pr(B)$. Disjunction Hypothesis Subjects will estimate $\Pr(A \vee B) > \Pr(A)$ and $\Pr(A \vee B) > \Pr(B)$. Conjunction/Disjunction Hypothesis Subjects will estimate $\Pr(A \wedge B) < \Pr(A \vee B)$. Conditional Hypothesis Subjects will estimate $\Pr(A|B) > \Pr(A \wedge B)$.

3.2 Group and Individual Perceptual Sets

If we were to be able to compare the perceptual sets of an individual, to the perceptual sets of a group, we would expect the probability of the union of perceptual sets of group members to encompass a larger set of events and knowledge. Thus, given similar training in probability and the business context, we would expect that groups would more likely include the appropriate probability theory in their perceptual sets. That is, in general, we would expect more expertise to be present in any arbitrary group, of equally trained subjects, than an arbitrary individual. As a result, we have the following hypothesis: Group Hypothesis Groups will exhibit fewer probability theory-based cognitive fallacies than individuals.

4. Methodology

The study employed a questionnaire that was given to both individual and groups of student subjects. Subjects were given the questionnaire and limited to one-half hour to complete the questionnaire. The questionnaire was administered in a closed classroom. In the case of the groups, roughly one half the groups met in the room at a time, in order to complete the questionnaire. The completion of the questionnaire by both the individuals and the groups was treated as an "in-class" homework assignment which would contribute to the student's class grade. As a result, there was incentive for students to perform the task.

4.1 Questionnaire

The questionnaire was designed in a manner similar to Tversky and Kahneman's

"Predicting Wimbledon." The questionnaire contained three such case studies designed to have the individual and groups rank relationships between $\Pr(A)$, $\Pr(B)$, $\Pr(A \wedge B)$, $\Pr(A \vee B)$ and $\Pr(A|B)$. In particular, subjects were presented with various orderings of those events and asked to "... rank order the following outcomes ...," with the most probable event given a "1."

4.2 Cases

Three cases were presented to the subjects. The first was a variation of the Tversky and Kahneman [1983] "Predicting Wimbledon" case using "Michael Chang," rather than "Bjorn Borg." This case was used to establish direct comparability between the current study and the Tversky and Kahneman study. The remaining two cases were drawn from a business environment. In particular, the cases were couched in an auditing environment, that employed concepts discussed in the class. In the second case, event A was "The company's bank renews a substantial line of credit" and event B was "The company losses a major customer." In the third case, event A was "The system of internal controls is strong" and event B was "Initial testing reveals some errors."

For each case, sets to be ranked were preceded by a one paragraph discussion. In case 2 subjects were told "You are in charge of the Laser audit. In the past year, the company has experienced some difficulties with the design of a new product line. Production problems have affected the quality of this line which in turn, has resulted in slow sales. In addition, throughout the year, the company has been late in making its loan payments." In case 3, subjects were told "You are planning a review of Electra's internal controls. Although the company has not emphasized a strong network of detailed control procedures, top management closely monitors the operations and overall management controls serve as an adequate substitute for detailed controls."

4.3 Subjects

The subjects were junior accounting majors. As a prerequisite to the class, students were required to take a class in probability theory. In addition, class lectures took place regarding the theoretical content of the cases. The subjects were from one of three different sections of the same accounting class. Each subject was treated as either an individual or a member of a group. The questionnaire was given to the subjects near the end of the term, so the groups had the opportunity to work on a number of projects together.

4.4 Groups

In order to normalize the impact of group size, all groups in the study had three members. The triad group size was chosen for reasons discussed above.

The groups were formed in an in-class setting. The group members self selected themselves.

The groups were not formed only with the purpose of the research project. Instead, those subjects in groups had participated in three group projects for class credit prior to being presented with the questionnaire. This was done to simulate the multi-day work environment associated with a typical business environment.

4.5 Data Analysis

The data analysis took two different forms. First, the rankings were analyzed as in Tversky and Kahneman [1983]. The average ranking for each category was analyzed for the behavior of the average ranking.

Second, the individual rankings were analyzed to determine the extent to which the two populations of groups and individuals developed rankings that had violations in them. A violation was defined as a ranking that was

inconsistent with probability theory. For example, if $\Pr(A \wedge B)$ was ranked as more likely than $\Pr(A)$, then there was a violation.

The analysis used the concept of violation to analyze the average rankings and individual rankings. A violation of probability theory in the average rankings is referred to as an average violation. Violations in individual rankings led to the notion of violation rate. The total number of violations in a set of rankings, divided by the total number in the set was referred to as a violation rate.

5. Findings

The results indicate that groups in this research project were able to order the event sets, so that far fewer cognitive fallacies appeared in the group solutions, rather than with individual's solutions.

The average rankings, for each case, by the two different subject groups are summarized in Table 1. In each case, there were far fewer average violations by the groups compared to the individuals.

TABLE 1
Average Ranking Value*

Individuals (n=31)			
	Case 1	Case 2	Case 3
Pr(A)	2.93	3.41	3.70
Pr(B)	2.16	1.93	2.00
Pr(A \wedge B)	2.90	4.25	4.61
Pr(A \vee B)	2.48	2.51	3.09
Pr(A B)	4.09	4.42	5.19
Groups (n=17)			
	Case 1	Case 2	Case 3
Pr(A)	2.32	2.33	2.89
Pr(B)	2.14	1.93	1.67
Pr(A \wedge B)	3.82	3.77	4.00
Pr(A \vee B)	1.41	1.51	1.77
Pr(A B)	3.52	3.38	4.55

* (1 is highest ranking)

An analysis of the number of individual violations of the probability hypotheses is contained in Table 2. In each possible situation, the group had a substantially lower level of violation rate than the individuals.

TABLE 2
Violation Percentages*

Individuals (n=31)	Case 1	Case 2	Case 3
Pr(A) : Pr(A ∧ B)	.45	.45	.48
Pr(B) : Pr(A ∧ B)	.29	.13	.16

Pr(A) : Pr(A ∨ B)	.32	.42	.45
Pr(B) : Pr(A ∨ B)	.55	.68	.77

Pr(A ∧ B) : Pr(A B)	.74	.58	.68

Pr(A ∧ B) : Pr(A ∨ B)	.52	.39	.32
Groups (n=17)			
	Case 1	Case 2	Case 3
Pr(A) : Pr(A ∧ B)	.06	.06	.11
Pr(B) : Pr(A ∧ B)	.00	.06	.00

Pr(A) : Pr(A ∨ B)	.12	.18	.18
Pr(B) : Pr(A ∨ B)	.18	.24	.29

Pr(A ∧ B) : Pr(A B)	.41	.29	.58

Pr(A ∧ B) : Pr(A ∨ B)	.12	.12	.17

* A violation occurs when the rankings attributed to the sets of events are inconsistent with probability theory.

5.1 Conjunction Hypothesis

Individuals. The individual subjects exhibited an average violation of the conjunction hypothesis only in the first case. In both of the business-based cases the subjects did not develop an average violation of the conjunction hypothesis. However, in each of the cases the maximum violation rate (for both Pr(A) and

Pr(B)) ranged from 45% to 48%. Further, the minimum violation rate for individuals exceeded the maximum violation rate for groups. Thus, individually and compared to the groups, there was a substantial amount of violation of the conjunction rule.

Groups. The groups developed no average violation of the conjunction hypothesis. In addition, the violation rate was substantially lower, ranging from 0% to 11% for these cases. The violation rate for groups was substantially lower than the violation rate for individuals in all six conjunction situations.

5.2 Disjunction Hypothesis

Individuals. The individual subjects exhibited an average violation of the disjunction hypothesis in all three cases. Average ranking differences in those three violations ranged from .32 in case 1 to 1.09 in case 3.

The violation rates were substantial in some cases. In particular, the violations of the disjunction hypothesis ranged from roughly one-third to over three-quarters of the subjects. The smallest violation rate for individuals (.32) exceeded the largest violation rate for groups (.29).

Groups. The groups exhibited only one average violation of the disjunction hypothesis, occurring in case 3. In that case, the difference was only .10, substantially smaller than the differences that occurred with the individuals.

In addition, the violation rate for the three cases ranged from .12 to .29. This was substantially less than the violation rate rate for individuals.

5.3 Disjunction/Conjunction Hypothesis

Individuals. There was no violation of this hypothesis on average. However, individual violation rates ranged from .32 to .52. The largest violation rate for the groups

was almost one-half the smallest violation rate for the individuals. Thus, in many cases, individual raters had comparative difficulty establishing rankings in the likelihood of the intersection of two events and the union of two events.

Groups. The groups also had no average violation of the hypothesis. In addition, the group rates of violation were substantially less than those of the individuals. In particular, violation rates ranged from only .12 to .17.

5.4 Conditional Hypothesis

Individuals. On average this hypothesis was violated in each of the three cases. Ranking differences between $\Pr(A|B)$ and $\Pr(A \wedge B)$ ranged from .17 to 1.19. The distance was greatest in the non-business case.

The rates of violations in the rankings ranged from .58 to .74 for the three cases. The smallest rate of violation for individuals was equal to the largest rate for the groups. The average violation rate was the highest for this hypothesis.

Groups. On average, only in case three, was there a violation of this hypothesis by the groups. In addition, the violation rate was the highest of any of the hypotheses by the groups. However, performance by the groups was superior that of the individuals for each case.

5.5 Discussion

Case 3 gave the groups their only average violations and the highest rates of violations, for each of the hypotheses. It is unclear why the violations took place to the extent that they did. However, case 3 exhibited the highest average ranking for $\Pr(B)$ (1.67) and the lowest average ranking for $\Pr(A)$ (2.89), thus, yielding the largest distance between rankings (1.22). This disparity may have had an impact on the existence of the appearance of the fallacies.

Across each of the cases and each of the measures of performance, the groups outperformed the individuals. It appears that groups can provide an environment that can substantially mitigate the impact of cognitive fallacies.

6. Contributions, Implications and Extensions

This paper has presented a research study designed to study the impact of groups on cognitive fallacy reasoning. The paper used the methodology developed in Tversky and Kahneman [1983] for the development of the data. The data was then analyzed using the approach in Tversky and Kahneman [1983] and Favere and O'Leary [1991].

6.1 Contributions

The primary contribution of this paper is that it demonstrates that groups can have an impact on the potential for mitigating fallacies in probability reasoning. Since the study used groups that had worked together on different projects prior to the research study, it is analogous to many business environments where the team works together on a number of projects.

6.2 Implications

There are a number of implications resulting from this study. First, the study found that groups mitigate the impact of cognitive fallacies. Thus, particularly in those situations where probability thinking is critical, the use of groups can be helpful. Second, group performance was not perfect. Thus, it appears that groups also should be provided with other tools that might mitigate the impact of fallacies in reasoning. For example, decision support tools might provide the ability to mitigate fallacies in reasoning.

6.3 Extensions

There are a number of extensions of the research in this paper. First, this paper employed student subjects. As a result, one extension would be to extend the study to another population, such as professional auditors or underwriters. However, based on the comparison between students and professionals in Favere and O'Leary [1991], it is expected the use of professional auditors would result in similar findings.

Second, the theory presented suggests that triads are a particularly important group size. Thus, this study used groups of three. Further research could be extended to groups of other sizes.

Third, this research discussed a study using 17 groups and 31 individuals. Additional research could use larger populations of groups and individuals. However, the responses of the individuals are similar to the findings reported in Favere and O'Leary [1991]. As a result, we would not anticipate substantial changes in the findings by increasing the population. It is particularly difficult to extend the sample size of groups, since the groups discussed in this paper were groups that had worked together on a number of different projects prior to the research study.

Fourth, this research found that although groups improve performance in probability reasoning, groups still make errors. Thus, additional research could analyze the impact of providing tools designed to further mitigate reasoning fallacies, such as decision support systems or expert systems.

Fifth, this paper used groups that had been involved in a number of projects together, before they were given the cases to analyze. Future research might examine the impact of groups only put together for the purposes of solving the specific decision problem. However, the approach used in this paper of

employing established groups is more likely to mirror a business environment.

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