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On the Conjunction Fallacy in Probability Judgment: New Experimental Evidence

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On the Conjunction Fallacy in Probability Judgment: New Experimental Evidence

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Abstract
This paper reports the results of a series of experiments designed to test whether and to what extent individuals succumb to the conjunction fallacy. Using an experimental design of Kahneman and Tversky (1983), it finds that given mild incentives, the proportion of individuals who violate the conjunction principle is significantly lower than that reported by Kahneman and Tversky. Moreover, when subjects are allowed to consult with other subjects, these proportions fall dramatically, particularly when the size of the group rises from two to three. These findings cast serious doubts about the importance and robustness of such violations for the understanding of real-life economic decisions.

Keywords: Conjunction fallacy, representativeness bias, group consultation, incentives

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Introduction

The conjunction rule—namely, the fact that the probability of the intersection of events (that is, their conjunction) cannot exceed the probabilities of the constituent events—is one of the simplest and most basic rules of probability. Abiding by this rule is therefore a basic tenet of any theory of rational choice in the face of uncertainty. Moreover, unlike other principles of choice, the simplicity of the conjunction rule makes it compelling, particularly in situations in which its applicability is transparent. To test whether decision-makers abide by the conjunction rule, Kahneman and Tversky (1983) asked subjects to rank the likelihoods of certain conclusions that can be drawn from hypothetical personality sketches of fictitious individuals. In one version of the experiment (the "transparent" test), subjects were given the following personality sketch and asked to identify which of the two alternatives below the sketch was more probable (Kahneman and Tversky, 1983, p. 297):

> Linda is 31 years old, single, outspoken, and very bright. She majored in philosophy. As a student, she was deeply concerned with issues of discrimination and social justice, and also participated in anti-nuclear demonstrations.
>
> (a) Linda is a bank teller.
>
> (b) Linda is a bank teller and is active in the feminist movement.

Kahneman and Tversky (1983) report that in this version of the experiment, 85 percent of respondents indicated that (b) is more likely than (a), thereby violating the conjunction rule. Moreover, they report similar rates of violations in several variations of the question, including injecting more alternatives and using a different fictitious character. They conclude that the conjunction fallacy (assigning higher probability to the conjunction than its constituents) is prevalent in situations in which likelihood judgments are mediated by intuitive heuristics such as *representativeness* and *availability*. In the example above, the conjunction fallacy may be accounted for by the impression that the conjunction is more representative of the personality

described than the constituent proposition "Linda is a bank teller." In such situations, representative bias may lead subjects to reverse the likelihood ranking of the events.

Camerer (1995, p. 598) offers an alternative explanation of the high rate of violations of the conjunction principle in terms of linguistic conventions. According to him:

> … some apparent biases might occur because the specific words used, or linguistic convention subjects assume the experimenter is following, convey more information than the experimenter intends. In other words, subjects may read between the lines. The potential linguistic problem is this: in the statement "Linda is a feminist bank teller," subjects might think that this statement "Linda is a bank teller" tacitly excludes feminists; they might think it actually means "Linda is a bank teller (and not feminist)." If subjects interpret the wording this way none of the statements are conjunctions of others and no probability rankings are wrong.

Even if these findings do indeed reflect the use of underlying intuitive heuristics, as suggested by Kahneman and Tversky, there is still an issue concerning their importance for understanding real-life decisions with significant consequences when individuals can discuss their options before deciding which course of action best serves their interests. Like most experimental studies of individual decision-making in the face of risk and uncertainty, the findings of Kahneman and Tversky indicate systematic errors committed by individuals acting in isolation and without monetary incentives, which is seldom the case in real life.

Thus, while we welcome the additional insights, realism, and enrichment coming from psychological studies, we also must guard against "jumping the gun" and changing the way economics model the world. By carefully replicating and retesting those findings we may find, as we did, that the significance of such "biases" for understanding economic behavior is minimal at best.

In a different context, we find that when making decisions in isolation, a substantial number of subjects choose first-order stochastically dominated alternatives (see Charness, Karni, and Levin 2007). To find out the extent to which these errors persist when individuals are allowed to consult with others, we tested the hypothesis that merely deliberating the alternative courses of action with other subjects helps improve the understanding of the decision problem and, consequently, makes the subjects less likely to choose stochastically dominated alternatives. When social interaction is allowed, the number of such violations tends to decrease dramatically with the size of the group (Charness, Karni, and Levin 2007).[1]

This paper applies the same approach to test whether the violations of the conjunction rule persist in an environment in which mild monetary incentives are offered and consultation with others permitted. To establish a baseline against which the social-interaction effects may be evaluated, we report our attempt to replicate the results of Kahneman and Tversky (1983), using the transparent test described above as the main experiment. In the first variant of the experiment, small monetary incentives were introduced but individuals were not permitted to communicate. In the second variant subjects were allowed to consult with one or two other subjects, with and without monetary incentives.

This paper spans two distinct research areas. The first is the study of the specific issue of the conjunction fallacy, the second the study of the effects of social interaction on individual decision-making.

Critiques of the use of heuristics to explain cognitive illusions include Gigerenzer (1991, 1997, 2005, and in press), who claims that the heuristics or biases that arise in synthetic experimental environments often do not represent how people make decisions in natural environments with natural stimuli. Cosmides and Tooby (1996) and Catrin et al. (1999) suggest

[1] In that study the observed choices were group decisions; in this study the observations are individual choices.

that people may be reasonably good intuitive statisticians when problems are presented in terms of frequencies rather than probabilities. Inhelder and Piaget (1964) report an experiment in which 82 percent of eight-year-olds gave responses consistent with set inclusion. Fiedler (1988) finds that while more than 80 percent of undergraduate subjects commit the conjunction fallacy when asked for the probability of single events, only 20 percent do so when asked for relative frequencies.

While it appears that the conjunction fallacy is less prevalent when the representation takes a more natural form, there is still an issue concerning its robustness in the presence of incentives and the ability to consult others. Most important economic decisions—including decisions whose consequences affect individual decision units, such as buying a home or choosing a health insurance plan—are taken after some consultations with others. But not much is known about the effect of social interaction on the quality of such decision-making. [2]

The literature distinguishes between situations in which decisions involve judgment (that is, there is no "correct decision") and situations involving finding the correct solution to a decision problem. The tasks in the experiments reported here are of the second type. Consequently, the measure of success is the ability of decision-makers to arrive at the correct response. When assessing the improvement, if any, afforded by consultation with other members of a group, it should be kept in mind that some improvement is due to a pure order-statistic effect. Intuitively, a team should be at least as likely to solve a problem as its most able members

[2] A large body of experimental psychology literature deals with group versus individual decision-making (see, for example, Heath and Gonzalez [1995] and references therein) and, in economics an entire field is devoted to the study of collective decision-making. This literature should not be confused with the social interaction studied here. In particular, we are not concerned with the issue of aggregation of individual preferences that is at the heart of social choice theory. Our focus is on individual decisions and how their quality may be affected following consultation with others.

acting alone. Thus, by comparing the performance of freely interacting teams with this norm, it is possible to identify the presence and nature of synergies resulting from social interaction.[3]

The evidence on groups versus individuals' performance on decision tasks in which there is a correct decision is inconclusive, and it seems that psychologists and economists often reach opposite conclusions. Generally speaking, the conclusion that emerges from the psychology literature dealing with teams versus individuals is that teams typically fall well short of the truth wins norm (see Davis [1992] and references therein).[4] In contrast, Cooper and Kagel (2005) and Blinder and Morgan (2005), find that groups consistently play more strategically than individuals and generate positive synergies in more difficult games.

The next section describes the experiment and the results. Section 3 describes another set of results, obtained when the word *single* is omitted from the description of Linda. Section 4 presents an analysis of the combined data set. Additional remarks and discussion appear in section 5. Section 6 presents the main conclusions.

2. The Experiment and the Findings

2.1 The experiment

The main part of this study focuses on the version of Kahneman and Tversky's (1983) experiment referred to as the "transparent" test. Accordingly, in our experiment sheets of paper were distributed with the Linda scenario found in the introduction to their paper. To neutralize

[3] Suppose each individual has a 50 percent chance of seeing the solution to a problem, which is obvious ex post, and that this likelihood is not correlated across individuals. The expected error rate is 50 percent individuals, 25 percent for pairs, and 12.5 percent for trios. This constitutes the "truth wins" norm against which actual performance is evaluated.

[4] The Heath and Gonzalez (1995) study is also closer to this type of problem, where decision makers interact with others before making a final decision alone. Although they find less improvement than the truth wins norm would predict, they conjecture that interaction forces people to explain their choices to others, thereby increasing their confidence.

possible order effects, the statement "Linda is a bank teller" was placed first in some scenarios and second in other scenarios. The instructions can be found in Appendix A.

Our experiments were conducted at the University of California, Santa Barbara (UCSB). The 361 participants were recruited from the general student population that had expressed interest in participating in such experiments. To reduce the chance that psychology majors who may have seen this experiment before contaminate the results, no psychology majors were included in the sample and no subject was allowed to participate in the experiment more than once.[5]

As this experiment is short, it was added as an exercise at the conclusion of other experiments, so that participants could mark their responses while payoffs were being calculated for the other experiments. The other experiments (a public goods experiment, an experiment on a generalized winner's curse, and an experiment on hidden information and communication) were quite different from this experiment. There seem to be no reason to suspect that the earlier experiment affected the decisions made, as there was no difference in behavior across these different experiments (and in two cases, there was no earlier experiment, because of software crashes).

Experiments were conducted either with or without incentives. In both cases, the sheets of paper were distributed, the scenario was read aloud, and no questions were taken. In the treatment with incentives, participants were informed that there was a correct answer and that anyone who chose this correct answer would receive $4. In the treatment without incentives, participants were told that they would receive $2 for filling out the questionnaire. When no other experiment was conducted, participants also received a $5 show-up fee.

[5]After the instructions were read, participants were also asked if they had seen this question before. In the rare event that they had, they were excluded from the experiment.

These experiments were conducted with individuals, pairs, and trios of participants. In the second and third treatments, participants formed groups of two or three based on group numbers written on the (shuffled) decision sheets. They were told that they could (quietly) discuss the scenario with their partner or partners before making their choices; it was not required that responses be the same for all members of the group. After this period of consultation, each subject made his or her own choice. Subjects (or groups) were seated apart, so that they did not observe one another's answers. In the case of pairs or trios, the subjects were also asked to speak softly, so that members of other groups could not hear their discussion. No time constraint was imposed.

2.2 The findings

Several interesting findings emerged from this experiment (figure 1 and table 1). First, we were unable to confirm the findings of Kahneman and Tversky (1983), who found a violation rate of the conjunction rule of more than 85 percent. Our results show a much lower rate of such violations. In this study 58 percent of participants committed the conjunction fallacy, a highly significant difference, with the test of the difference in proportions (Glasnapp and Poggio 1986) yielding $Z = 4.58$, $p = 0.000$. Second, the mere addition of small incentives reduced this rate to 33 percent. This is less than 40 percent of the rate Kahneman and Tversky report.

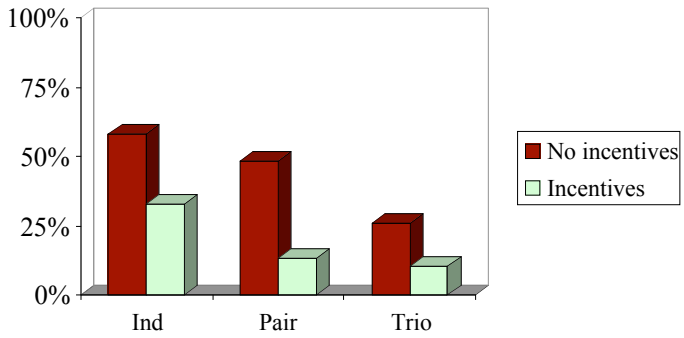

Figure 1. Error rates for individuals, pairs, and trios, with and without incentives

Table 1. Violations of the Conjunction Rule

Study	***Details***	*Incorrect answers/total sample*	*Error rate (percent)*
Individuals			
T&K, 1983	UBC undergrads, no incentives	121/142	85.2
CKL, 2008	UCSB students, singles, no incentives	50/86	58.1
CKL, 2008	UCSB students, singles, incentives	31/94	33.0
CKL, 2008	UCSB students, with and without incentives	**81/180**	**45.0**
Pairs			
CKL, 2008	UCSB students, pairs, no incentives	27/56	48.2
CKL, 2008	UCSB students, pairs, incentives	5/38	13.2
CKL, 2008	UCSB students, with and without incentives	**32/94**	**34.0**
Trios			
CKL, 2008	UCSB students, trios, no incentives	10/39	25.6
CKL, 2008	UCSB students, trios, incentives	5/48	10.4
CKL, 2008	UCSB students, with and without incentives	**15/87**	**17.2**

Third, and most important, the violation rate falls significantly when communication between—and particularly among—participants is allowed. Without incentives a majority of

participants acting alone—that is, without communicating with others—commit the conjunction fallacy. When participants interact with one other, the decline in the violation rate is significant at the 5 percent level ($Z = 1.75$, $p = 0.040$, one-tailed test). When participants interact with two other subjects, the error rate declines dramatically, falling to less than half that observed for individuals acting alone without incentives and to less than a third of that observed when incentives are introduced. When moving from pairs to trios, the decline is even more pronounced than when moving from individuals to pairs. This decline is significant at the 1 percent level ($Z = 2.58$, $p = 0.005$, one-tailed test). As indicated in Table 3, the decline in the violation rate when going from individuals to pairs becomes statistically insignificant when interaction with the incentives is taken into account, while the decline in the violation rate associated with the increase ingroup size from two to three subjects remains statistically significant at the 1 percent level.

Fourth, the violation rate of the conjunction rule declines across all group sizes as a result of incentives, suggesting that subjects put more effort into the task and, as a result, made fewer errors, when coming up with the right answer was rewarded. Using pair wise one-tailed tests, we find that the incentive effect is statistically significant for individuals ($Z = 2.58$, $p = 0.005$), pairs ($Z = 3.52$, $p = 0.000$), and trios ($Z = 1.87$, $p = 0.031$).

3. The Importance of Being Single

3.1 A single-word difference

In experiments that included 433 participants, the word *single* was inadvertently omitted from the description of Linda's personality sketch. Presumably, the omission of the word from Linda's personality sketch affects the representativeness of the conjunction relative to the constituent proposition "Linda is a bank teller," resulting in a lower violation rate of the conjunction rule.

Insofar as the main issue with which this study is concerned, the question is the robustness of the results to the variation in the representativeness.

The findings are displayed in Figure 2 and summarized in Table 2 below. The rates of violation that appear in the last column of Table 2 is calculated twice, because in the sessions without the word *single*, the subjects may have included psychology majors (and perhaps a few others) who may have been exposed to this question before.[6]

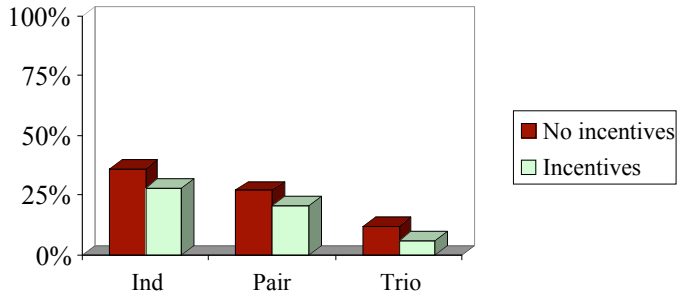

Figure 2. Error rates for individuals, pairs, and trios, with and without incentives, with omission of word *single*

[6] To correct for this potential contamination of the sample, we applied a 10 percent correction factor in the "Corrected"' column, lowering the number of participants by 10 percent and presuming that all such people would answer the question correctly. Given that the participant database has 2,398 subjects, 206 (8.6 percent) of which are psychology majors, this appears to be a conservative correction.

Table 2: Conjunction rule violations without the word *single*: Individuals and groups

Study	*Details*	*Incorrect answer/ total sample*	*Error rate (raw)*	*Error rate (corrected)*
Individuals				
CKL, 2008	UCSB students, singles, no incentives	28/87	32.2	35.8
CKL, 2008	UCSB students, singles, incentives	20/79	25.3	28.1
CKL, 2008	UCSB students, with and without incentives	**48/166**	**28.9**	**32.1**
Pairs				
CKL, 2008	UCSB students, pairs, no incentives	17/70	24.3	27.0
CKL, 2008	UCSB students, pairs, incentives	15/80	18.8	20.8
CKL, 2008	UCSB students, with and without incentives	**32/150**	**21.3**	**23.7**
Trios				
CKL, 2008	UCSB students, trios, no incentives	5/45	11.1	12.3
CKL, 2008	UCSB students, trios, incentives	4/72	5.6	6.2
CKL, 2008	UCSB students, with and without incentives	**9/117**	**7.7**	**8.5**

3.2 Analysis

These findings strongly suggest that the word *single* plays an important role in producing the conjunction fallacy in this instance. Without it, the violation rates of the conjunction rule by individuals is reduced from about 58 percent to 36 percent (a decline of nearly 40 percent) when there were no incentives and from 33 percent to 27 percent (a decline of more than 15 percent) when incentives are present. Overall, the violation rate for individuals is less then half of that obtained when the word *single* is included as part of the description of Linda.

These findings indicate that the conclusions regarding the social interaction effects of the preceding section are robust. As in the case in which the word *single* was part of Linda's description, the violation rate declines as the size of the group increases whether or not incentives were included. The decrease when going from individuals to pairs is not quite significant in the aggregate data ($Z = 1.55$, $p = 0.061$, one-tailed test), but the decrease when

going from pairs to trios is highly significant (Z = 3.07, p = 0.001, one-tailed test). While a substantial minority of the subjects committed the conjunction fallacy when acting in isolation, by the time they interact with two other subjects the aggregate error rate falls to below 10 percent. The violation rate committed is lower when incentives are provided. However, the incentive effect is statistically insignificant in all cases (Z = 0.97 for individuals, Z = 0.83 for pairs, and Z = 1.10 for trios).

4. Regression Analysis

This section estimates probit models using the data from the treatments with and without the word *single* in the description of Linda. It captures the difference in treatments with a dummy variable. The discussion below focuses on the corrected data in Table 3 below, which provide a more accurate comparison. The omitted (baseline) category is an individual in the treatment without the word *singl*e.

Table 3. Probit results on determinants of violation rate of the conjunction rule, combined corrected data

Variable	(1)	(2)	(3)	(4)	(5)
Single	0.329*** [0.102]	0.326*** [0.102]	0.554*** [0.139]	0.554*** [0.139]	0.557*** [0.139]
Incentive	-0.488*** [0.101]	-0.455*** [0.142]	-0.240* [0.145]	-0.242* [0.145]	-0.240* [0.145]
Pair	-0.292** [0.115]	-0.259* [0.154]	-0.316*** [0.116]	-0.275** [0.127]	-0.245* [0.129]
Trio	-0.846*** [0.139]	-0.821*** [0.191]	-0.864*** [0.139]	-0.814*** [0.152]	-0.872*** [0.160]
Incentive*pair		-0.075 [0.232]			
Incentive*trio		-0.054 [0.278]			
Single*incentive	-	-	-0.488** [0.204]	-0.403* [0.229]	-0.407* [0.229]
Single*incentive*mult	-	-		-0.206 [0.252]	-
Single*incentive*pair	-	-	-	-	-0.434 [0.317]
Single*incentive*trio	-	-	-	-	-0.005 [0.321]
Constant	-0.219** [0.104]	-0.234** [0.113]	-0.327*** [0.114]	-0.349*** [0.117]	-0.355*** [0.124]
Log-likelihood	-410.79	-410.74	-407.92	-407.59	-406.81

*, **, and *** means significant at the 10 percent, 5 percent, and 1 percent levels, respectively
Note: Standard errors are in brackets. $N = 750$.

The regression analysis of the aggregate data strengthens the general conclusions arrived at based on the analysis of the behavior in the subsamples. First, and most important, the phenomenon known as the conjunction fallacy is less prevalent when social interaction is allowed. This decline is monotonic with respect to the number of interacting subjects and statistically significant at the 1 percent level. Moreover, it is more pronounced when subjects are allowed to discuss the problem with two other subjects than when they interact with only one

other subject. In conjunction with our previous work, these results suggest that an emerging and perhaps robust phenomenon is that "three heads are better than one." The former effect remains statistically significant at the 1 percent level even when incentive group–size interaction terms are included in the regression. Interestingly, this is not the case when a subject is allowed to interact with one other subject. Second (and perhaps not surprisingly), the conjunction fallacy is sensitive to the language used, as there is a strong and robust effect (statistically significant at the 1 percent level) from the presence of the word *single* in the description of Linda. Third, violations of the conjunction rule tend to decline when fairly small monetary incentives are introduced. However, there is a substantial interaction of incentives with the presence of the word *single*. The incentive effect is statistically significant at the 1 percent level when *single* is omitted; it is only marginally significant otherwise.

In addition to the single-incentive interaction effect, a variety of possible interaction effects are considered in the regression specifications. In specification (2), the interaction of incentives with group size is inconsequential in the aggregate data.[7] In specifications (4) and (5), the interaction effect of incentives and group size in the "single" population were isolated. No statistically significant effects were found, although the coefficient on the single*incentive* pair variable is fairly large.

5. Discussion

New experimental evidence suggests that the rate of violation of the conjunction rule by individuals acting in isolation is much lower than reported in Tversky and Kahneman (1983). Furthermore, when subjects are given the opportunity to consult with others before choosing their responses, the error rate declines dramatically. Not surprisingly, financial incentives for

[7] In another specification (not shown), we added the single*incentive dummy to specification (2). The results were essentially the same.

providing the correct answer are effective in inducing individuals to make efforts to find the correct answer. The weight of this evidence suggests that the conjunction fallacy is a phenomenon of no serious concern for economics.

A subsidiary finding (also found in Charness, Karni, and Levin [2007]) is that there is a substantially larger drop in the error rate when the group size is increased from two to three than when it is increased from one to two: "three heads are better than one." This result is perhaps even more surprising in the Linda problem than in our earlier study, where the error reflected a failure to recognize first-order stochastic dominance. To the extent that these problems are "*eureka* problems" (that is, problems that have a correct answer that, once discovered is easy to explain), one would expect the truth-wins norm to be applicable (assuming that the insight regarding the conjunction principle is i.i.d across the subject population). The Linda problem seems to be a clear-cut eureka problem. The finding that the truth-wins norm fails to describe the data is surprising, and the particular way in which this norm fails suggests the presence of a significant positive synergy with trios but not with pairs. The presence of a third person in a group may create a "cascading effect," in which the person who finds the correct answer has a better chance of persuading one other member of the group and the weight of the two may be sufficient to make the third member accept their conclusion even if not persuaded.

6. Conclusions

Individuals rarely make important decisions in a vacuum: before changing jobs, buying homes, or investing in a mutual fund, they consult others (friends, colleagues, parents, spouses, experts). Moreover, in facing important decisions they recognize that the choice they make has consequences. Experimental environments in which subjects are not allowed to consult with

others and not rewarded for making the right decision therefore seem far removed from those in which actual economic agents operate.

The results presented here suggest that the phenomenon described by Kahneman and Tversky (1983) as the conjunction fallacy in individual decision-making is much less prevalent than their findings suggest. More important, to the extent it exists, the conjunction fallacy is a psychological phenomenon of little consequence for economic analysis.

Some critics cite experimental evidence to fault economics for its reliance on the assumption that economic agents act rationally. Whether or not rational behavior is a useful premise, the results presented here suggest that observing individuals making decisions in isolation is not always a good guide for understanding the conduct of economic agents in real-world environments.

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Appendix A – Instructions

[The following instructions were handed out in the 'no-single' treatment, with the alternatives listed either in this order or the reverse order. No questions were taken]

Linda is 31 years old, outspoken and very bright. She majored in philosophy. As a student, she was deeply concerned with issues of discrimination and social justice, and also participated in anti-nuclear demonstrations.

Which of these two alternatives do you think is more probable?

Linda is a bank teller _____

Linda is a bank teller and is active in the feminist movement _____

[The following instructions were handed out in the 'single' treatment, with the alternatives listed either in this order or the reverse order. No questions were taken]

Linda is 31 years old, single, outspoken and very bright. She majored in philosophy. As a student, she was deeply concerned with issues of discrimination and social justice, and also participated in anti-nuclear demonstrations.

Which of these two alternatives do you think is more probable?

Linda is a bank teller _____

Linda is a bank teller and is active in the feminist movement _____