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Does “never” implicate a larger reward than “possible”? : Risk–reward correlation in verbal probability phrases

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Does "never" implicate larger reward than "possible"?: Risk-reward correlation in verbal probability phrases

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Abstract

This study aimed to explore whether the risk-reward correlation would hold in verbal probability phrases. The risk-reward correlation refers to a tendency to infer inverse proportionality between probability and outcome magnitude and have been considered as reflecting the statistical structure of the environment. Existing studies have demonstrated this inverse proportionality in numerical probabilities. However, it is well known that verbal probability phrases can convey contextual information about uncertainty without numbers, and express contextual information that are not contained by numerical probabilities. Specifically, verbal probabilities have positive and negative directionality that make listener's attention to occurrence or non-occurrence of outcome and as a result affect listener's decision making. A purpose of this study is to examine whether the risk-reward correlation also hold in verbal probability phrases, To accomplish this, two empirical studies that required participants to estimate reward values and winning probability of gambles that were expressed by verbal probability phrases such as "certain" or "impossible" were performed. Results indicate that risk-reward correlation also hold in verbal probability phrases, and the directionality of the verbal probability phrases.

Keywords: verbal probability, directionality, risk-reward correlation

Introduction

Imagine that you hear certainty about your winning probability for gamble. Which phrase do you think indicate the highest rewards for winning the gamble?

"Quite certain"
"Impossible"
"Absolutely"

As you see, these phrases themselves do not contain information about the magnitude of reward value for the gamble. However, your impression for the reward values would differ among these phrases. A purpose of this study is to explore a quantitative relationship between these uncertainty expressions and the magnitudes of outcomes implicated by these expressions.

The above problem concerns how probability relate utility. In terms of normative utility theory, probability and utility are independent each other: It is assumed that value of probability does not connotate any magnitude of utility, and vice versa. However, many studies on judgment and decision making have demonstrated a dependency on probability judgments for future outcomes on their magnitudes or utilities (e.g., Hahn & Harris, 2014; Harris, Corner, & Hahn, 2009; Krizan & Windschitl, 2007). This proposition was suggested by early research on decision making (Crandall, Solomon, & Kellaway, 1955; Edwards, 1962; Marks, 1951; Morlock & Hertz, 1964). but controversy remains with regards to how valence of outcome/utility affects probability judgment (Edwards, 1962; Fischer & Jungermann, 1996; Harris & Corner, 2009; Weber & Hilton, 1990). For example, while Fischer and Jungermann (1990) found that, as a whole, the individuals' estimated probabilities for verbal probability phrases were lower for negative outcomes compared to positive outcomes in their study, Weber and Hilton (1990) reported the opposite tendency. To settle this controversy, Harris et al. (2009) examined the effect of utility on probability under experimentally controlled conditions and found that the seriousness of an event increases the estimated probabilities for the outcomes. Although the mechanism and direction of the effect are still unclear, previous studies suggest a relationship between probability judgments for outcomes and their utilities.

A recent theoretical development about the correlation between probability and utility is the study by Pleskac and Hertwig (2014). From examinations of real-world data such as gambling behaviors, finance or publications of scientific papers, Pleskac and Hertwig (2014) found a correlation between outcome desirability and their and likelihoods: large payoffs for the gambles are associated with lower winning probabilities; and the acceptance rate for scientific journals decreases as their values of impact factor increase. From these real-world examinations, they proposed that estimating the inverse proportionality between probability and outcome desirability is ecologically rational. In their study, participants were also required to estimate their winning probabilities for various gambles that had different payoff values. The results demonstrated a negative correlation between estimated probabilities and payoff values. From the results of both the real-world statistics and psychological experiments, Pleskac and Hertwig (2014) insisted that individuals' estimations of probabilities for outcomes from its utility are based on an ecologically rational strategy as it exploits the statistical structure of gambling environments to substitute the missing information of probability. Pleskac and Hertwig (2014) call this strategy "risk-reward heuristic", and several behavioral experiments supported people's use of heuristics (Hoffart et al., 2019; Skylark & Prabhu-Naik, 2018).

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Verbal probability phrases and risk-reward correlation

As state in the beginning of this paper, however, not the only numerical probabilities, but also verbal expression such as "possible" or "never" can also indicate degree of uncertainty information. This type of expression is called verbal probability, and many studies have demonstrated (e. g., Teigen, 1998; Teigen & Brun, 1995, 1999; Honda & Yamagishi, 2006, 2017) that verbal probability have several features that are not contained by numerical probabilities.

Specifically, it is known that verbal probabilities have positive and negative directionality (e. g., Teigen & Brun, 1995, 1999; Honda & Yamagishi, 2006, 2017; as a review, see Dhami & Mandel, 2022) that make listener's attention to occurrence or non-occurrence of outcome. For example, "possible" can be considered as the positive verbal probability phrase because it suggests the occurrence, whereas "never" can be considered as the negative probability phrase because it suggests the non-occurrence. This directionality is considered as having information other than probability because listener can infer sender's expectation for occurrence or non-occurrence of outcome. As a result, decision making may sometimes differ between positive and negative directionality even when implicated probabilities are the same (Teigen & Brun, 1999).

The findings from the studies on the verbal probability suggest that that the risk reward correlation for verbal probability phrases might differ from that for numerical probability. Specifically, the directionality of verbal probability would play important role in reflecting the risk-reward correlation. The existing studies on risk-reward correlation have employed numerical values as expression for probability. As far as the author knows, no study has explored the risk-reward correlation in verbal probabilities.

A main purpose of this study is to explore the risk reward correlation between verbal probabilities and reward values. This paper is organized as follows. Study 1 required participants to answer both winning probabilities and reward values of gambles whose uncertainties about winning were expressed by verbal probability phrases, and explored relation between them. Additionally, Study 1 also required participants to estimate the reward values of the gambles with numerical probabilities, and compared the risk-reward correlations between the numerical and verbal probabilities.

Study 2 employed almost the same procedure as Study 1 except that it explored what determine the directionality of the verbal probability phrases. Although the directionality of the verbal probabilities can be easily interpreted, what aspect of the verbal probability determine positive and negative directionality? Although many studies have explored a nature of the verbal probability phrases, a few studies have explored this point. To accomplish this, Study 2 paid attention to anonym expression, ("high-low") prefix negation, ("possible-impossible") and their lexical negations ("not high", "not impossible") and examined how these features would affect the risk-reward correlation.

Study 1

Study 1 is conducted as a first trial that examined the risk-reward correlation in the verbal probability phrases. In doing so, Study 1 adopted the verbal probability phrases from the existing studies (Honda & Yamagshi, 2006; Nakamura, 2007) and examined how the estimated probabilities and rewards for these verbal probability phrases were related.

Participants and procedure

One hundred and three Japanese undergraduates participated Study 1 by answering the questions presented in Google form. Participants were required to estimate the reward values for gambles by Japanese yen considering uncertainties expressed by numerical or verbal probabilities. For example, participants were shown the following questions and answered by entering number that expresses price for the reward:

> There is a gamble whose winning probability is expressed as "99%." What amount of reward value do you think will be given when you really win this gamble?

The numerical probability values used in Study 1were 1%, 17%, 33%, 50%, 67%, 83%, and 99%. In addition to the numerical probabilities, Study 1 also used a total of fifteen types of the verbal probabilities chosen from Nakamura (2007) that contained both the positive and negative phrases (Table 1). Both the numerical and verbal probability phrases were shown by exchanging the word between double quotation in the above example. After the estimation for the reward values, participants also estimated probabilities for verbal probabilities by percentage.

Result and discussion

Following Sylark & Prabhu-Naik (2018), Study 1 transformed the estimated reward values to logarithmic values (log 10 (x+1)). Figure 1 demonstrates scatterplots for averages of the estimated values for verbal probabilities and the transformed reward values. This graph indicates the inverse relationship between probabilities and reward values both in numerical and verbal probability expressions. All of simple correlations between the average estimated reward values and the numerical probability values, the estimated probability values of the positive phrases, and the negative phrases were statistically significant (-0.95, - 0.92, and -0.93; the numerical, positive, and negative phrase, respectively, all *p*s<.001) indicating that the risk-reward correlations at the group level were found both in the numerical and verbal probabilities. Additionally, visual inspection of Figure 1 also suggests that the estimated reward values for the negative phrases were higher than those for the positive and numerical probabilities.

To explore the risk-reward correlation in these results considering the individual difference, Study 1 performed hierarchical linear model. In this model, the estimated reward

Table 1. Verbal probability phrases used in Study 1 (Japanese translations in parentheses)

Positive	Negative
Faint possibility (かすかな可能性)	Never (ない)
Slight possibility (わずかな可能性)	Almost impossible (ほぼ不可能)
Slight chance (少しだけ考えられる)	Not likely (あまりない)
A possibility (考えられる)	Not very likely (それほどでない)
Possible (可能)	Uncertain (確信がない)
Quite possible (十分に考えられる)	A little uncertain (やや疑わしい)
Quite certain (ほぼ確実である)	Not certain (確実ではない)
	Slightly uncertain (多少の不安がある)

Figure 1 Scatterplots for the estimated rewards and probabilities in Study 1

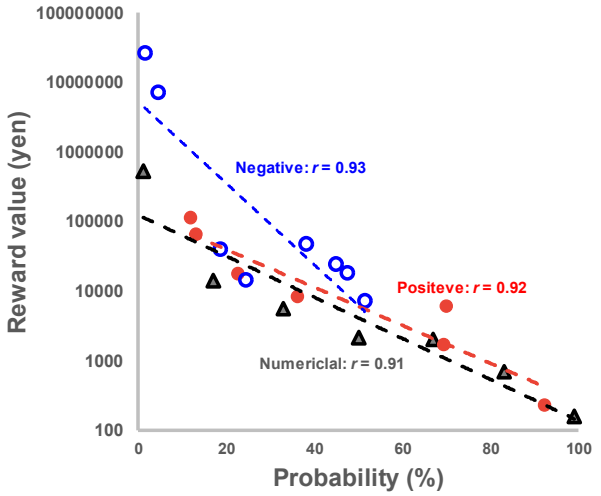


Table 2. Results of the multilevel regression analyses in Study 1 and 2 (standard error in parentheses)

	Study 1		Study 2	
Regression coefficeint (fixed effect)				
Intercept	5.31***	(0.12)	4.96***	(0.15)
Probability	-0.03***	(0.001)	-0.02***	(0.002)
Directionality (numerical)	0.16*	(0.07)	-0.04	(0.05)
Directionality (negative)	0.68***	(0.07)	0.32***	(0.04)
Variance components (random effect)				
Residual	1.05	(1.02)	1.48	(1.33)
Intercept	1.48	(1.21)	2.35	(1.22)

values and directionality of the verbal probabilities were independent variable, and the estimated probability value of the verbal probability phrases was dependent variable. Additionally, the effects of probability and directionality are treated as both fixed and random effect.

The directionality of the verbal probability phrases was settled as dummy variable of three categories (the numerical, positive, and negative probability phrase) with the positive phrase being the base. Results demonstrated the significant fixed effects of the probability values. Additionally, the effect of both the directionality of the numerical and negative phrase were significant, indicating that the estimated reward values for the numerical probabilities were lower than those for the positive phrases, and those for the negative phrases were higher than the positive phrases (Table 1).

Thus, these results clearly indicate the following three points. First, Study 1 confirmed the risk-reward correlation in the gamble expressed by the verbal probability; as the values of the estimated probability increase, the reward values decrease both in the positive and negative phrases. Second, it also found that the directionality of the verbal probability would differentiate magnitude of the reward value: the reward values for the negative phrases were higher than those for the positive phrases. Third, it also suggests that the verbal probabilities would be considered as implicating the larger rewards than the numerical probability phrases: the estimated reward values for both the positive and negative phrases were higher than those for numerical probabilities.

Study 2

A purpose of Study 2 is twofold. One is to replicate the risk-reward correlation in verbal probability and reward values. Although Study 1 demonstrated the risk-reward correlation in verbal probability phrases, it was limited in variation of the verbal probability phrases. Thus, Study 2 tried to examine the risk-reward correlation in the verbal probability phrases by extending the variation of the verbal probability phrases employed in the experiment.

The other is to examine the effect of directionality more precisely by controlling the linguistic features that can make difference between positive and negative phrases. Although Study 1 compared the positive and negative phrases by employing the verbal probability phrases from the existing studies (Nakamura, 2008; Honda & Yamagishi, 2006), selection of the verbal probability phrases in these studies was performed by non-systematic way. For example, comparison between "certain" and "never" would reflect many different aspects other than the directionality. Although it is impossible to remove all the confounding factors that might concern the investigation of the directionality, it is desirable to examine the difference between the positive and negative probability phrases strictly by excluding the confounding factors as much as possible.

To accomplish the above purposes, Study 2 explored risk-reward correlation in verbal probability phrases by considering the following three linguistic features of the verbal probability phrases stated as follows. First, Study 2 employed antonyms expressions to contrast the positive and negative probability phrases. There are many pairs of linguistic expression that have contractive meanings with regards to magnitude of quantity such as "small" and "large." These pairs of the expressions can be considered as clearly indicating the occurrence or non-occurrence of the event, so Study 2 treated the pairs of the antonym expressions as representing the contrast of the positive and negative directionality.

Second, Study 2 used prefix negation form to construct the positive and negative directionality. Not only the antonym

expressions, but also prefix negation can reverse meanings of primitive word such as “possible” and “impossible.” Study 2 assumed that the prefix negation can reverse the directionality of the verbal probability phrases and selected the pairs of the verbal probability phrases with and without prefix negations.

Third, Study 2 also used the lexical negation (“not”) to construct the positive and negative probability phrases. Adding “not” to the verbal probability phrases clearly reverse the meaning of the verbal probability. Thus, Study 2 also tried to reverse the directionality of the verbal probability phrases by adding “not” to these phrases.

Participants and procedure

One hundred and fifty-one undergraduates participated Study 2 by answering the questionnaire shown in Google form. Study 2 composed the verbal probability phrases as follows. First, it selected 4 pairs of the antonym expressions and 4 pairs of expressions with or without prefix negations. As a result, Then, it composed another 16 verbal expressions by adding “not” to the 8 pairs of the verbal probability phrases. As a result, 32 verbal probability phrases were prepared for Study 2 (Table 2).

Additionally, Study 2 also employed the seven numerical probabilities that were also used in Study 1. Thus, Study 2 used a total of 39 probability phrases.

Table 3. Verbal probability phrases used in Study 2 (Japanese translations in parentheses)

		Positive	Negative
Prefix negation	Affirmation	Possible (可能)	Impossible (不可能)
		Certain (確実である)	Uncertain (不確実)
		Advantageous (有利である)	Disadvantageous (不利である)
		Sure (確か)	Unsure (不確か)
	Negation	Not impossible (不可能ではない)	Not possible (可能ではない)
		Not uncertain (不確実ではない)	Not certain (確実ではない)
		Not disadvantageous (不利ではない)	Not advantageous (有利ではない)
		Not unsure (不確かではない)	Not sure (確かではない)
Antonym	Affirmation	High (高い)	Low (低い)
		Large (大きい)	Small (小さい)
		Favourable (分が良い)	unfavourable (分が悪い)
		Likely (ある)	Never (ない)
	Negation	Not low (低くない)	Not high (高くはない)
		Not small (小さくない)	Not large (大きくはない)
		Not unfavourable (分が悪くない)	Not favourable (分が良いとは言えない)
		Not never (ないとはえいない)	Not likely (あるとはいえない)

Results and discussion

Study 2 also transformed the estimated reward values to logarithmic values (log 10 (x+1)) in the same way as Study 1. To examine whether antonym, lexical or prefix negation affect probability judgment as manipulation check (see Figure 3), Study 2 performed three-way ANOVA in which antonym (positive/ negative) or prefix negation (without prefix/ prefix), lexical negation (without “not” / with “not”) and expressions (4 types) were independent variables, and the estimated probability was dependent variable. Results clearly demonstrate the significant main effects of the antonym or prefix negation and lexical negation, interactions between two factors, and second-order interaction among the three factors (see Table 3). Analyses of simple main effects demonstrate significant difference between antonym expressions prefix negation, and significant effect of lexical negation both for the positive phrases and negative phrases; the positive phrases were estimated higher probabilities than the negative phrases, and the negation decreased the estimated probabilities when it was added to the positive phrases, and when it was added to the negative phrases, vice versa.

Study 2 also performed the same ANOVA to reward judgements, and results demonstrated that significant main effects of the antonym or prefix negation and type of expressions, all the two-way interactions, and the second order interaction (see Table 3). Analyses of simple main effect also demonstrate the same patterns those of probability judgments. These results implicate that the negative phrases were considered as implicating the higher reward values than the positive phrases, and the negation of these phrases increase the reward values when it is added to the positive phrases, and when it is added to the negative phrases, vice versa.

The results of ANOVA consistently demonstrated that the manipulations of the antonyms, prefix negations, and the lexical negations affected both probability and reward judgment as the risk-reward correlation would predict: for the positive phrases, both prefix and lexical negation decreased the estimated probabilities and increased the values of reward judgment, and for the negative phrases, vice versa.

Scatterplot for averages of the estimated values for verbal probabilities and the transformed reward values (Figure 2) demonstrates the inverse relationship between probabilities and reward values both in numerical and verbal probability expressions. In the same as Study 1, all of simple correlations between the average estimated reward values and the numerical probability values, the estimated probability values of the positive phrases, and the negative phrases were statistically significant (-0.94, 0.92, and 0.86; the numerical, positive, and negative phrase, respectively, *p*s<.001). Thus, the risk-reward correlations were found at the group level data in the three types of the probability phrases.

Study 2 also performed the hierarchical linear model in the same way as Study 1, and results of this analysis demonstrated the significant fixed effect of the estimated probability and directionality of the verbal probability phrases on the estimated reward value (Table 1). However, in contrast to Study 1, although the difference between the positive and negative phrases was significant, that between the numerical probability and positive phrase was not significant. These results indicate that whereas the effect of the negative directionality on the reward values was consistent between the two studies, that of the positive directionality was not so. Thus, it can be concluded that Study 2 replicated the results of Study 1 in the following two points: the reward values were correlated to the probability values both in numerical and verbal probability, the negative phrases were estimated as larger rewards than the positive phrases.

Figure 2 Mean estimates of the probability and reward judgements in Study 2
(error bars indicate the 95% confidence intervals).

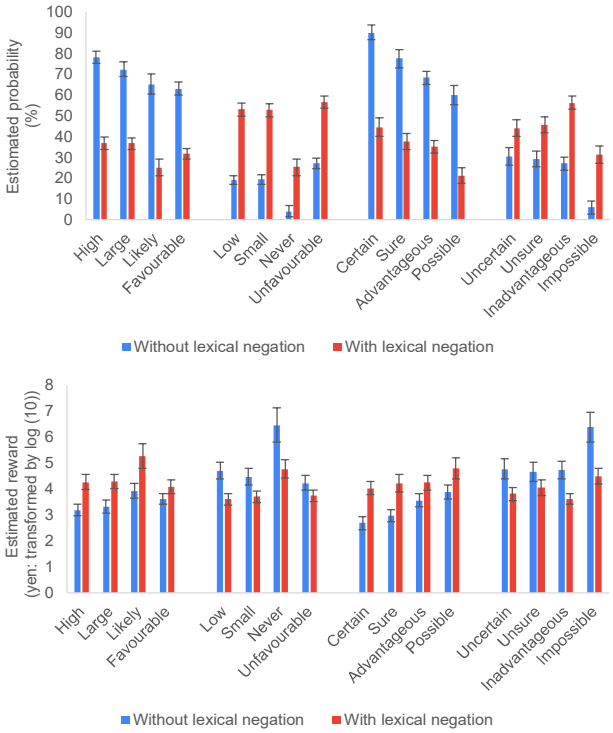
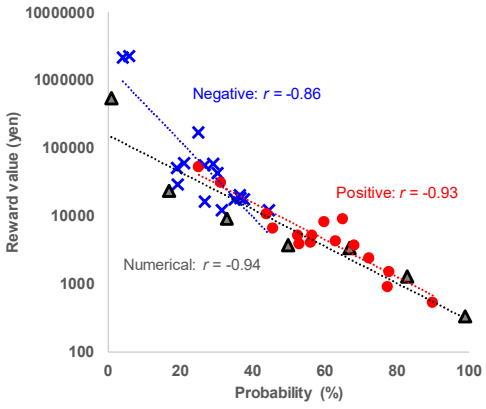


Table 4. Results of ANOVA in Study 2

Independent variables		Dependent variables: Reward judgment		Probability judgment	
		Antonym	Prefix	Antonym	Prefix
Main effects	Negation	0.29	0.52	30.48***	117.23***
	Pair	57.14***	118.75***	552.68***	331.48***
	Expression	59.89***	52.27***	106.05***	122.16***
Interaction	Negation*pair	107.5***	97,78***	914.73***	602.16***
	Negetion*expression	1.57	20.96***	12.79***	17.79***
	Pair*expression	16.87***	13.51***	71.22***	32.13***
Second-order interaction	Negation*pair*expression	12.13***	6.65***	7.18***	2.35

***: p<.001

Figure 3 Scatterplots for the estimated rewards and probabilities in Study 2



General discussion

This paper aimed to explore whether the risk-reward correlation also would hold in verbal probability phrases. The results of two studies indicated the following two points. First, the results consistently demonstrated the risk-reward correlation in verbal probability: as the estimated values for the certainty implicated by the verbal probability phrases decreased, the estimated reward values increased. The existing studies on the risk-reward correlation mainly employed numerical probability (Hoffart et al, 2019; Pleskac & Hertwig, 2015; Sylark & Prabhu-Naik, 2018) as probabilistic information, and explored the correlation between these probability values and reward magnitudes. However, as is well known, the verbal probability phrases also can convey uncertainty information such as the directionality, so whether the risk-reward correlation also would be found in the verbal probability phrases. This study explored this problem and demonstrated that the risk-reward correlation also holds in verbal probability phrases. As far as the author know, this is a first example that demonstrates the risk-reward correlation between reward value and verbal probability.

Second, the directionality of the verbal probability phrases also affected the risk-reward correlation. This finding is interesting because it appears to contradict the implications from the existing studies that have demonstrated difference between the positive and negative probability phrases (e. g., Teigen & Brun, 2003; Honda & Yamagishi, 2006). These studies have demonstrated that outcomes expressed by the positive probability phrases are preferred to those expressed by the negative phrases, even when the implicated probability values are same. Thus, these studies might suggest that magnitudes of the rewards associated to the negative probability phrases would be lower than that for the positive probability phrases. In contrast to this suggestion from the existing studies, this study demonstrates that the negative probability phrases were associated to the larger rewards than the positive probability phrases. To reconcile a discrepancy between the present results and the findings in the existing studies, it is necessary to make some theoretical considerations with regards to what information in the negative and positive phrases are really contained.

The present study suggests that there remain much room to be explored with regards to information conveyed by the verbal probability phrases other than the implicated magnitude of uncertainty. This suggestion itself appears to be natural considering how the concept of probability has been constructed. Historically, the verbal probability is older than the numerical probability. As is well known, an etymology of “probability” is Latin “probabilitas,” which can also mean " probity ", a measure of the authority of a witness in a legal case in Europe, and often correlated with the witness's nobility (e. g., Hacking, 2006). Notion of probability had been expressed by ambiguous verbal expressions that contain various nuance or implication other than the degree of uncertainty, and throughout mathematical and philosophical argument for a long time, probability become numerical

expression without any contextual information other than the degree of uncertainty. Thus, exploration of the meaning of the verbal probabilities rather than the numerical probability might uncover how people communicate information about uncertainty in everyday life. Specifically, the most influential explanation on the risk-reward correlation is the ecological rationality approach (Hoffart et al., 2019; Leuker et al, 2019a, b; Pleskac & Hertwig, 2014; Pleskac et al, 2021) that assumes the risk-reward correlation reflects the statistical structure of gambling environments. If so, what aspect of statistical structure is reflected by the use and the directionality of the verbal probability phrases? Answering these questions would be fruitful to uncover the meaning of uncertainty information in human life.

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