Judgment and Decision Making, Vol. 3, No. 5, June 2008, pp. 411–416

How to make a risk seem riskier: The ratio bias versus construal level theory

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Abstract

Which statement conveys greater risk: "100 people die from cancer every day" or "36,500 people die from cancer every year"? In statistics where both frequencies and temporal information are used to convey risk, two theories predict opposite answers to this question.

Construal level theory predicts that "100 people die from cancer every day" will be judged as more risky, while the ratio bias predicts that the equivalent "36,500 people die from cancer every year" will result in higher risk judgments. An experiment investigated which format produces higher risk ratings, and whether ratings are influenced by increasing the salience of the numerical or temporal part of the statistic. Forty-eight participants were randomly assigned to a numerical, temporal or control salience condition, and rated risk framed as number of deaths per day or per year. The year format was found to result in higher perceived risk, indicating that the ratio bias effect is dominant, but there was no effect of salience.

Keywords: risk perception, ratio bias, construal level theory, health statistics, framing.

1 Introduction

The perception of risk is an important area of research not only for understanding cognitive processes, but also for its practical applications in conveying risk information to the public. In the health domain, perceived risk is generally regarded as the first step in models of health behaviour, and a necessary (but not sufficient) condition for behaviour change (see Weinstein (1993) and Van der Pligt (1996) for reviews). Although other factors have been shown to mediate this relationship (e.g., conscientiousness and gender; Hampson, Andrews, Barckley, Lichtenstein & Lee, 2000), conveying a sense of risk is a major focus of health communication, with the aim of influencing individual judgment and decision making. The present research investigates how risk perception is affected by the framing (cf. Tversky & Kahneman, 1981) of incidence rates, which are often used to convey risk information to the public.

*This research was supported by a Discovery Grant (DP 0558181) from the Australian Research Council awarded to the second author. The authors would like to thank Tim Rakow for extremely helpful and insightful comments on an earlier draft of this manuscript. Correspondence should be addressed to Ben Newell, School of Psychology, University of New South Wales, NSW 2052, Australia. Email: ben.newell@unsw.edu.au

1.1 Temporal construal

Construal Level Theory (CLT) proposes that temporal distance determines how future events are mentally represented (Trope & Liberman, 2003). Near events are represented at a lower level construal, defined as concrete, specific and detailed. Distant events are represented at a higher level construal, which are more abstract, decontexualised and general. For example, moving house next week is likely to be described in terms of concrete, specific actions such as packing boxes, while next year would be described in more abstract, global terms such as a new phase of life.

Chandron and Menon (2004) extended this theory to risk perception, looking at the effects of message cues on judgments of health risk. They framed risks associated with mononucleosis as occurring "every day" or "every year", and found that the day frame increased risk ratings. According to CLT, the risk is represented at the same construal level as the time frame. Since the day frame is perceived as more concrete and proximal than the year frame, the risk seems more immediate and threatening, resulting in higher perceived risk.

1.2 Ratio bias

The ratio bias is the tendency for people to judge a low probability event as more likely when presented as a large-numbered ratio, such as 20/100, than as a smaller-numbered but equivalent ratio, such as 2/10. This effect is attributed to a tendency to focus on the frequency of the numerator instead of the overall proportion (Kirkpatrick & Epstein, 1992).

The ratio bias has been investigated in the health domain by Yamagishi (1997) and Pinto-Prades, Martinez-Perez and Abellán-Perpiñán (2006). Yamagishi (1997) gave participants mortality rates of well-known causes of death, varying both the percentage incidence rate and population frame (deaths per 100 or 10,000 people) within subjects. Results showed that ratings of risk were consistently higher with a frame of 10,000 than a frame of 100, regardless of the actual percentage incidence rate. For example, participants rated cancer as riskier when it was described as killing 1,286 out of 10,000 people than as killing 24.14 out of 100 people. The fact that 12.86% could be considered more risky than 24.14% is a clear demonstration that the ratio bias can strongly influence perception of risk. Similarly, Pinto-Prades et al. (2006) investigated the ratio bias in terms of choices between medical treatments with a given probability of death. They found that the frame determined the point at which participants reached indifference between choices: those given a smaller frame (per 100 people) would choose a particular treatment option up to a 37.1% chance of death, while those given a larger frame (per 1000 people), where the absolute number of deaths was higher, would only accept up to a 17.6% chance of death for the same treatment option.

1.3 Concrete versus abstract processing

What ties the temporal construal and ratio biases together is the difference between concrete and abstract information processing. The more concrete the information is, the easier it is to imagine and associate with affect (Newell, Mitchell, & Hayes, in press; Slovic, Monahan & MacGregor, 2000), resulting in higher perceived risk. In temporal information, using a closer temporal frame such as "every day" increases the concreteness and proximity of the threat, and therefore increases perceived risk (Chandron & Menon, 2004). In numerical information, frequencies are more concrete than probabilities or percentages (e.g., Gigerenzer & Hoffrage, 1995; Slovic et al., 2000). For example, Newell et al. (in press) found that frequency information led to higher ratings of the imaginability of rare events, such as suffering the side effects of a vaccine, than did probability information. In addition, small numbers are perceived as being more concrete than large numbers (Denes-Raj & Epstein, 1994), leading to a bias towards the numerator of a numerical ratio.

In statistics where both frequencies and temporal information are used to convey risk, these two biases towards concrete information will be in opposition to each other. Construal level theory predicts that "100 people die from cancer every day" will be perceived as more risky due to the use of closer temporal proximity. In contrast, the ratio bias effect predicts that "36,500 people die from cancer every year" will result in higher risk ratings, because risk will be inferred from the absolute number of deaths without sufficient regard for the temporal frame (day or year). The aim of the experiment was to investigate whether one of these effects is more dominant in health statistics, when the biases are in opposition.

2 Method

2.1 Participants

Forty-eight undergraduate students (35 female and 13 male) from the University of New South Wales participated for course credit, with an average age of 19.27 years (SD = 2.43).

2.2 Design

The experiment was set up as a 3 x (2 x 11) factorial design. The salience factor (emphasising the numerical or temporal information, versus a control condition) was between subjects, with 16 participants randomly assigned to each group. The format factor (every day versus every year) and cause of death (11 causes) were repeated within subjects, with the two formats completed one week apart. That is, each participant filled in a first questionnaire with one format (e.g., year) and then returned one week later (range: 6–9 days) to fill in a second questionnaire with the other format (e.g., day). The order of day and year formats was counterbalanced. A similar repeated measures design was used effectively in Yamagishi's (1997) study, and ensures that individual interpretations of "risk" and response tendencies are taken into account.

2.3 Materials

Following the method of Yamagishi (1997), eleven major causes of death were used: heart failure, stroke, pneumonia, AIDS, motor vehicle accidents, cancer, homicide, respiratory diseases, renal failure, heart disease, and diabetes. Mortality rates were based on the government report *Causes of Death, Australia 2003* (Australian Bureau of Statistics, 2004). The mortality rates were approximately equivalent for day and year formats, but were adjusted slightly to give numbers to the nearest 100 in some cases (this was not systematic, i.e., some rounded down and some rounded up). For example, the diabetes statistics used were 8 per day and 2,900 per year, even though

Table 1: Example of salience conditions (cancer deaths per day)

Condition	Format
Control	In Australia 100 people die every day from cancer
Numerical	**100 people** in Australia die every day from cancer
Temporal	**Every day** in Australia 100 people die from cancer

2,920 is the exact equivalent (i.e., 8 x 365). This approach was taken because the generic term "every year" was used, and the exact number of deaths from a particular cause varies each year.

The information about each cause of death was given in a single sentence followed by a rating scale, with all eleven causes on the same page. The order was arranged so that causes with similar incidence rates were not consecutive. To produce the numerical or temporal salience, the relevant information was placed at the beginning of the sentence in bold underlined font (as shown in Table 1). The effect of the font was enhanced by repetition for the eleven causes of death.

This is similar to the method of Chandron and Menon (2004), who also used repetition of "every day" or "every year" at the beginning of sentences. Perceived risk was measured by a 26 point Likert scale, anchored at 0 "no risk at all" and 25 "highest possible risk". This maintains consistency with the Yamigishi (1997) study, and since it is a less familiar scale it may have decreased the possibility of participants remembering their previous responses when completing the second questionnaire (i.e., when they returned one week later). Participants were asked to rate the risk for the average Australian rather than themselves, in order to reduce the influence of personal experience and increase reliance on the statistics.

3 Results

The year format resulted in higher mean risk ratings than the day format, averaged across salience conditions and the eleven causes of death. Table 2 shows the mean risk ratings for each cause, all of which had higher risk ratings for the year format.

A 3 x (2 x 11) repeated measures ANOVA was conducted, with factors of salience (control, numerical, temporal), format (day, year) and cause of death (11 causes). A significant main effect of format was found, such that the year format resulted in higher risk ratings than the day format ($F(1,45) = 6.17, p = 0.017$). As expected when using different incidence rates, there was also a significant main effect of cause ($F(1,10) = 36.00$; $p = 0.000$), indicating that the overall risk ratings varied amongst the different causes of death. The rank order of risk ratings amongst the 11 causes generally followed the rank order of incidence rates, with the exception of motor vehicle accidents and heart failure, which are ranked as relatively more risky than their incidence rates suggest. The reason for this is not immediately obvious, but it could be related to lower ratings for diabetes, pneumonia and respiratory diseases, which may be perceived as less obvious causes of death. There was no significant main effect of salience, and there were no significant interactions.[1] There was no significant main effect of order (day versus year format first), nor did this factor interact with any other factors.

Table 2: Incidence rates and mean risk ratings for day and year formats, averaged across salience conditions. Scale anchored at 0 = "no risk at all" and 25 = "highest possible risk."

	Number of deaths		Mean risk rating	
Cause of death	Day	Year	Day	Year
Cancer	100	36,500	18.90	19.42
Heart disease	70	25,500	17.90	18.71
Stroke	30	11,000	16.25	16.54
Respiratory diseases	16	5,800	13.40	14.19
Pneumonia	10	3,600	12.19	12.63
Diabetes	8	2,900	11.40	13.27
Heart failure	7	2,500	14.38	15.60
Motor vehicle accidents	6	2,200	13.13	16.38
Renal failure	5	1,800	9.54	10.50
Homicide	3	1,100	9.06	10.98
AIDS	1	350	9.42	11.63
MEAN			13.23	14.53
(SD)			(4.31)	(3.48)

On an individual level, almost two-thirds of the participants (30 out of 48) gave higher average year ratings than day ratings, with a mean difference of 3.57 (SD = 2.34) on the 26 point risk rating scale. The minority of participants (18 out of 48) who gave higher average day ratings than year ratings had a smaller mean difference of 2.49 (SD = 1.70). The higher ratings were not related to the order in

[1] Although the difference between day and year ratings appears to be more pronounced amongst the causes with lower incidence rates, there is no significant interaction between cause of death and day versus year format.

which participants completed the two formats, suggesting that there are effects in both directions amongst the individual participants. This can be illustrated using a *P-P* plot, based on individual paired *t*-tests of day versus year ratings (11 causes x 2 formats). By definition of the *p*-value, if H_0 is true, then the set of 48 individual *p*-values will be uniformly distributed from 0 to 1, with equal numbers and distribution in each direction. The cumulative probability for each observed *p*-value was calculated such that higher day ratings were equal to *p*/2 (i.e., small *p*-values approach 0) and higher year ratings were equal to 1-(*p*/2) (i.e., small *p*-values approach 1). Figure 1 shows the expected cumulative probabilities against the observed cumulative probabilities for H_0. The graph clearly shows that the distribution of observed *p*-value probabilities deviates from the expected uniform distribution line, such that both directions have more participants at the extreme ends (i.e., small *p*-values) than would be expected by chance (particularly in the year higher than day direction, approaching 1 on the expected cumulative probability axis), and that overall there are more participants in the year higher than day direction (those above 0.5 on the expected cumulative probability axis).

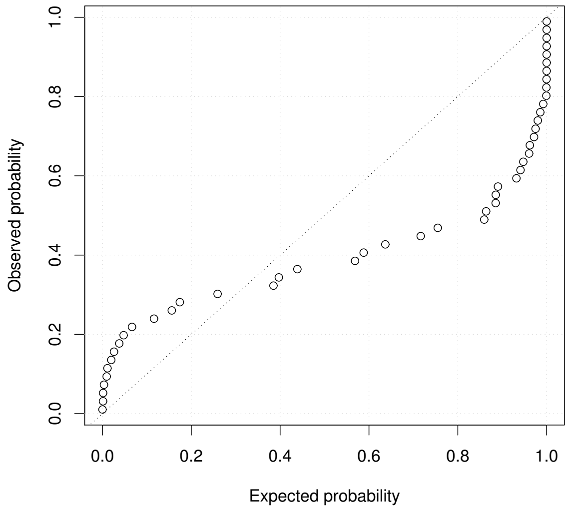

Figure 1: *P-P* plot of the observed cumulative probability of individual p-values against the expected cumulative probability. Under the null hypothesis that risk ratings are equal in the day and year formats, a uniform distribution along the identity line is expected. Points above 0.5 on the expected cumulative probability axis indicate year higher than day, with the smallest p-values approaching 1. Points below 0.5 on the expected cumulative probability axis indicate day higher than year, with the smallest p-values approaching 0.

4 Discussion

The present research set out to investigate how different statistical formats influence risk perception. The aim was to find out which of two opposing effects — ratio bias or temporal construal — is more influential in judgments of risk, and whether this can be affected by a salience manipulation. The key finding was that when the ratio bias and the temporal construal effect are in opposition, the ratio bias appears to dominate. Across all eleven causes of death, risk ratings were higher when a "year" format (which had a large frequency based on a longer time period) was used than when a "day" format (which had a small frequency based on a shorter time period) was used. This was despite the fact that the incidence rates in the two formats were equivalent. Increasing the salience of numerical or temporal information through font and order within each statistic had no effect on the relative influence of the ratio bias and temporal construal.

The present experiment replicates and extends the findings of Yamagishi (1997) by demonstrating that a temporal frame (e.g., day or year) is neglected in a similar way to a numerical frame (e.g., per 100 or 10,000) when rating the risk of causes of death. However, our failure to find an overall effect of temporal construal is inconsistent with the findings of Chandron and Menon (2004). The different pattern of results may be due to the way in which temporal construal is manipulated. In their study, Chandron and Menon presented participants with risk descriptions of the form "Every year *a significant number of people* die from. . . "; this contrasts with the numerical information we provided (e.g., "Every year *100 people* die from . . . "). It is possible that the effect of temporal construal demonstrated by Chandron and Menon (2004) was due to the ambiguous nature of the phrase "a significant number of people." In their discussion the authors acknowledge this possibility, suggesting that the temporal information may have been used as an indication of what "a significant number" meant. The numerical figures included in the present study overshadowed the effect of temporal construal for the majority of participants.

Although the term "ratio bias" usually refers to a numerical ratio, the effect found in the present experiment can be explained in the same way, using the heuristic of anchoring and adjustment (Tversky & Kahnemann, 1974).[2] According to this account, the number of deaths is used as a cue to ratings of risk, with insufficient adjustment for the frame (day or year). In this case, the statistic was framed in a temporal form, but the same principle

[2] See Denes-Raj and Epstein (1994) for an alternative explanation of the ratio bias, based on cognitive-experiential self theory: CEST.

can be applied to any statistic where a frequency is given in context — successful operations per hospital, faulty goods per order, robberies per suburb, etc. Any frame may be neglected in a similar way to the more typical numerical denominator, leading to greater perceived risk whenever a larger frame (and therefore higher frequency) is used.

The finding that the ratio bias persists even when placed in opposition to the effect of temporal frame adds to existing evidence of its strong influence on judgment and decision making. The ratio bias has been shown to cause non-optimal decisions in both forced choice tasks (Denes-Raj & Epstein, 1994) and more realistic scenarios, such as choosing which job to apply for (Alonso & Fernandez-Berrocal, 2003). Monetary incentives to make better choices may reduce the number of non-optimal choices within subjects, but even this does not prevent the effect of the ratio bias (Dale, Rudski, Schwarz & Smith, 2007).

From the individual results, the finding that some participants show the opposite effect (i.e., risk ratings higher in the day format) could be related to individual differences in numeracy (Reyna & Brainerd, 2008). When a mixed numerical/temporal ratio is provided, the less numerate participants may focus more on the non-numerical information (day or year) as a cue to risk ratings, leading to a bias towards the closer temporal proximity of the day format. Again, this could be attributed to anchoring and adjustment (Tversky & Kahnemann, 1974), where there is a focus on one part of the statistic with insufficient adjustment for the accompanying information.

The ratio bias has practical implications for risk communication. A simple incidence rate may be the first awareness some people have of a particular risk, so increasing risk perception by using the most effective format could be the difference needed for them to take further action. Although a sense of risk may not itself be sufficient to modify behaviour, it is considered in most health models to be a necessary precondition (Weinstein, 1993; Van der Pligt, 1996), so anything that increases perceived risk, such as using a larger frame to describe incidence rates, will also increase the chance of reaching positive behavioural outcomes. Although this perspective assumes that increasing risk perception is desirable, it should be acknowledged that such an effect may not always be accurate or beneficial (such as overweighting the risk of side effects from a vaccine, when avoiding the vaccine is actually more risky). In addition, using mixed statistics where the frequency and its frame are in different forms (such as numerical/temporal) may lead to reduced accuracy in risk perception as a result of individual biases towards one form over the other.

Further research on the use of different statistical formats, including non-numerical frames, would enable a better understanding of its effect on risk perception.

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