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Proceedings of the 38th Annual Cognitive Science Society Meeting, 2016 / Papafragou, A., Grodner, D., Mirman, D., Trueswell, J. (ed./s), pp.544-549

A Tale of Two Disasters: Biases in Risk Communication

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Abstract

Risk communication, where scientists inform policy-makers or the populace of the probability and magnitude of possible disasters, is essential to disaster management – enabling people to make better decisions regarding preventative steps, evacuations, etc. Psychological research, however, has identified multiple biases that can affect people's interpretation of probabilities and thus risk. For example, availability (Tversky & Kahneman, 1973) is known to confound probability estimates while the description-experience gap (D-E Gap) (Hertwig & Erev, 2009) shows low probability events being over-weighted when described and under-weighted when learnt from laboratory tasks. This paper examines how probability descriptions interact with real world experience of events. Responses from 294 participants across 8 conditions showed that people's responses, given the same described probabilities and consequences, were altered by their familiarity with the disaster (bushfire vs earthquake) and its salience to them personally. The implications of this for risk communication are discussed.

Keywords: description-experience gap; risk communication; decision making; availability; bias.

Introduction

People make decisions based on their perception of risks. They also demand that others (e.g., policy makers) propose methods to mitigate risks. Such proposals are often costly to implement and there may be financial or other costs should a risky event occur. It is, therefore, important that risk perception matches reality. Psychological research, however, indicates that people are subject to a range of biases that lead to mis-perception of probabilities leading to inconsistent trade-offs and sub-optimal decisions (see, e.g., Kahneman & Tversky, 1979; Lichtenstein, Fischhoff, & Phillips, 1982; Tversky & Kahneman, 1973, 1974).

The L'Aquila verdict, which saw 6 scientists convicted of manslaughter for failing to adequately communicate earthquake risk prior to the event, shocked the scientific community and prompted urgent re-appraisal of methods used to convey information about low-probability, high-impact events. Prior to the trial, an international commission convened to investigate the earthquake's predictability - and the communication of its risk - recommended that risk assessments be formalised through authoritative operational earthquake forecasting (OEF). It also suggested that social scientists develop methods for communicating risk to the public and decisions makers (Jordan et al., 2011).

Research on seismic aspects of OEF is progressing with new models being developed and tested (see, e.g., Marzocchi, Lombardi, & Casarotti, 2014; Steacy et al., 2014). However, progress on communication remains a major topic of discussion (Jordan et al., 2014).

Biases in Risk Perception

Given the above, it seems valuable to review psychology's findings about how people interpret risk (i.e., the probability of an undesirable outcome). A variety of known effects seem relevant to how a person, faced with information being provided by an expert, might interpret that information and thus react. Some central examples are discussed below.

Prospect Theory and the Description-Experience Gap

Prospect Theory (Kahneman & Tversky, 1979) describes how the majority of people respond when facing risky choices in simple gambles such as: 'Take $100 now' or 'Win $250 if this coin toss comes up heads and nothing otherwise'. In such instances, people are risk averse when dealing with gains and risk seeking for losses. They also act as if low probabilities are higher than they actually are and as if high probabilities are lower.

Many of these observations, however, are shown to reverse in situations where, instead of being told the probabilities, people have to learn them from an environment – the so-called Description-Experience Gap (hereafter, D-E Gap; Hertwig & Erev, 2009).

Risk communication, of course, involves both described probabilities (from the scientists or government) and the probability for risky events that each member of the 'audience' has learnt from their environment.

Availability

Availability (Tversky & Kahneman, 1973) describes the tendency of people to weight the likelihood of events according to how *available* such events are to memory. This makes sense in that, when operating in a natural environment, the number of instances of an event recalled should depend on how many such events have been seen.

It can leads to biased estimates of probability, however, where an event's availability differs from its actual rate of occurrence. For instance, media coverage focusses on 'interesting' – and often rare – events; the result being that people overestimate the likelihood of events (e.g., terrorist attacks) that receive coverage while underestimating probabilities for events that are less often reported upon.

Key aspects of availability are the familiarity and salience of events – that is, how well known they are to the person and how memorable (for a discussion of this, see Sunstein, 2005). For example, most people are aware of (i.e., familiar with) the risks of house fires but these are more salient to someone who has seen such a fire than to people who have simply heard about them. Both familiarity and salience affect the availability of people's memories of particular events and thus their estimates of their probabilities.

Given this, it seems likely that people's recalled probabilities will differ markedly from the actual probabilities of occurrence for the disasters.

Format Changes

Another effect known to alter interpretation of probabilities is changes to presentation formats. For example, there is evidence that people prefer natural frequencies (e.g., '1 in 100') to percentages (Cosmides & Tooby, 1996; Gigerenzer & Hoffrage, 1995) and even those who dispute this (Sloman et al., 2003) agree that the way probabilities are presented can enhance or impede people's understanding of them.

Relative vs Absolute Change

Finally, it is possible that people are more sensitive to relative than absolute change, leading to the expectation that people's reaction to a disaster risk may (depending on the presentation of the information) be influenced by the degree to which the probability has *changed* as well as by the final probability itself (Stone, Yates, & Parker, 1994).

Aims and Objectives

Given the above, the central aim of this paper is to determine what effects play a role in predicting behaviour when the described probability of a disaster needs to be integrated into a person's pre-existing knowledge – learnt from their experiences with such disasters in the real world.

A key question, then, is whether people's behaviour will be better predicted by Prospect Theory or the D-E Gap? Prospect Theory predicts that low probability events will be overweighted while the D-E Gap predicts the opposite.

Availability, meanwhile, suggests that people's learnt probabilities will be biased by their familiarity with and direct experience of the disaster they are being asked about.

Given this, the aim is to interrogate people's experience with disasters and use this and their responses to illuminate the probabilities they have 'learnt' from the environment.

Method

Participants

Participants were 294 residents of Adelaide (152 female, 133 male and 9 identifying as other) ranging from 13 (see below) to 63 (M = 25.8, SD = 8.7).

Initial recruitment was undertaken via fliers placed around the University of Adelaide, which indicated that only Adelaide residents over 18 could participate. A significant amount of snowball sampling occurred as participants forwarded the survey link to friends and family, however, leading to the inclusion of one respondent who was only 13.

Of the participants, 12 had not completed high school and 46 were high school graduates. The remainder included: 99 who had attended but not yet graduated university; 87 with bachelor degrees; and 50 with higher degrees. Participants received a $20 gift voucher for completing the experiment.

Materials

An online survey was designed, which asked participants: for demographics; to select their response to a hypothetical disaster; and then describe their experience with disasters of that type. The survey questions are expanded on below.

Demographics

Participants provided their age, identified gender, level of education and length of residency in Adelaide.

Disaster Questions

The experiment used a 2x2x2 between-subjects design. (NB: the sample was limited by funding constraints to being slightly underpowered for a 2x2x2 design, it is sufficient for 2x2 interactions.) The scenario described to participants that they had inherited a $400,000 house in the Adelaide Hills and, following this, scientists had revised the probability of a disaster (that would destroy the house) occurring in that area up to 1% per annum for the next 10 year period.

Familiarity. The first condition was familiarity with disaster type. Two disasters were included: earthquakes and bushfires as these reflect different experiences for Adelaide residents. Bushfires, while rare in an absolute sense (i.e., the probability of an individual being affected in any given year is very low) are familiar to Adelaide residents, with major events occurring at a rate of 6-7 per decade, historically (Luke & McArthur, 1978), and multiple, less severe fires occurring every year – with Country Fire Service (CFS) data recording ~12/year in the 2001-2015 period across Greater Adelaide's peri-urban area (CFS, 2015).

Earthquakes, by comparison, are unfamiliar, with only 30 perceptible quakes since records began 132 years ago (i.e., ~0.23 events per year) and none having caused damage since a M5.5 event in 1954. By these data, bushfires are ~50 times as frequent in Adelaide as earthquakes.

Format. The second condition was the format used to express the disaster probability – either a percentage (e.g., 1%) or natural frequency (e.g., 1 in 100). Otherwise, probabilities were identical across conditions with a 1% p.a. chance of the disaster occurring across the next decade.

Magnitude. The final condition was the magnitude change in probability and was either 10 or 100. That is, while the final (annual) probability of the disaster was 1%, this was described as having been increased from either 0.1% or

0.01% - or the natural frequency equivalents.

Options. In all cases, participants selected from the same set of four responses. These were: 1) Do nothing; 2) Spend $10,000 on preparing the house to better cope with the named disaster and reduce the probability of it being destroyed by half; 3) Spend $20,000 on preparing the house to better cope with the named disaster and reduce the probability of it being destroyed by three-quarters; and 4) Sell the house at a $40,000 loss.

These options thus reflect increasingly extreme *immediate* responses to the revised disaster probabilities and, in that sense, are ordinal. They also, however, form (approximate) pairs in expected value terms, with the EV of options 1 and 4 both being approximately -$40,000 when considered across the 10 year period of increased risk – while options 2 and 3 are both valued at approximately -$30,000. (These approximate values were used as it seemed unlikely that participants would use probability theory to calculate the precise values; i.e., that a 1% p.a. risk equates to a 9.56% chance of disaster across the decade). Given this, the choice data is more appropriately regarded as nominal.

Experience Questions.

In addition to the demographic and main experimental questions, five questions captured participants' real world experience with the disasters they were asked about. The first two of these asked: how many such events the participant recalled having occurred in Adelaide; and how many of those recalled events caused significant damage.

Three questions asked about the disaster's salience to the participant. Specifically, whether: 1) the participant; 2) their friends/family; or 3) people in their local area, had suffered injury or property loss from such a disaster.

Procedure

Participants accessed the survey in their own time using the URL and an identifier code on tear-off tabs at the bottom of the fliers. After an initial page describing the basics of the experiment, participants were sorted into groups according to which of the 8 identifier codes they entered (corresponding to the possible condition combinations).

They were then shown the disaster question for that condition and asked to select their response. After this they were asked the five follow-up questions and four demographic questions. Finally, they were asked to enter their email address (to arrange gift voucher pick-up). Most participants completed the task in less than 10 minutes.

Results

Initial analyses indicated that the *magnitude* manipulation was having no effect (main or interaction), therefore results are discussed without further mention of this. Table1 shows the percentage of participants selecting each of the four options – overall and, separately, divided by the *familiarity* and *format* conditions.

Looking at Table 1, one sees three instances where the odds of a participant selecting a particular option seems to be affected by the manipulations with people about twice as likely to select to "Do nothing" rather than something in the low familiarity (Quake) and percentage formats conditions, Odds Ratio = 2.45 and 2.25, respectively. Participants in the frequency format conditions were, similarly, twice as likely to choose to sell the house as not, Odds Ratio= 1.98.

Table 1. Percentages of participants selecting each option overall and by condition.

		Do nothing	$10K prep	$20K prep	Sell house	Total
Overall		20.1	42.2	20.1	17.7	100
Familiarity	Quake	13.6	18.7	9.5	8.8	50.7
	Fire	6.5	23.5	10.5	8.8	49.3
Format	Perc.	13.3	21.8	8.8	6.5	50.3
	Freq.	6.8	20.4	11.2	11.2	49.7

To assist in seeing interaction effects, Figure 1 shows the proportion of participants selecting each of the options, divided simultaneously by both familiarity and format.

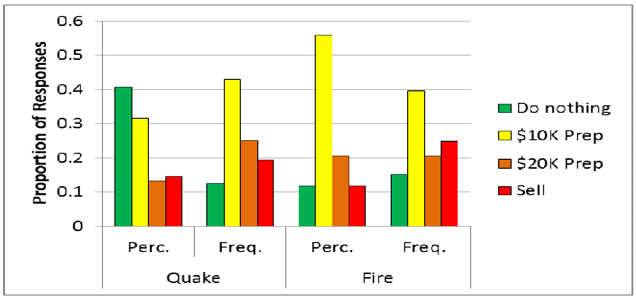

Figure 1: Participant responses by familiarity and format.

As was seen in Table 1, both manipulations affect responses and Figure 1 suggests an interaction effect – with participants seeing the earthquake version of the task with percentage probabilities far more likely (41%) to do nothing than any other group (~13% across the three other groups).

A 2x4 Chi-square test confirmed that familiarity was significantly associate with participant choice, $\chi^2 = 9.2$, $p =$ .036. Analysis of residuals indicated the familiarity effect was driven by more participants selecting option 1 (do nothing) in the unfamiliar (Earthquake) condition relative to the familiar (Bushfire) condition.

The effect of format was also significant, with people presented probabilities in natural frequency format tending towards more active responses. Specifically, the format change equated to a 'upward' shift of half a category on average. Again, a 2x4 Chi-square test indicated that format was significantly associated with participant choice, $\chi^2 =$ 10.8, $p =$.012. The residuals of this test told a similar story, with differences in the proportion of people choosing to do nothing in the percentage format being significantly higher than in the natural frequency format – although here there was also a significant difference for option 4 (sell house), selected by more people in the frequency format. That is, the frequency format discouraged doing nothing and encouraged the most extreme response (sell house).

Table 2. Log-linear analysis of 4x2x2 contingency table.

	Interactions	G^2	df	p
1	Choice*Format*Familiarity	38.6	10	<.001
2	Choice*Format	12.6	3	.006
3	Choice*Familiarity	12.0	3	.007
4	Format*Familiarity	.06	1	.807
5	Choice*Format (No Familiarity)	26.5	6	<.001
6	Choice*Familiarity (No Format)	25.9	6	<.001
7	Format* Familiarity (No Choice)	13.9	4	.008

Note: rows 2-4 and 5-7 differ according to whether G^2 is calculated after collapsing across the 3rd condition or after removing its effect. Note 2: $G^2 \approx \chi^2$.

To assess the interaction effect, a 4x2x2 (choice x familiarity x format) log-linear analysis was conducted. Looking at its results in Table 2, one sees that most associations are significant – excepting between Format and Familiarity (row 4, which reflects the near-equal numbers in the conditions). Rows 2 and 3 correspond to the above 2x4 tests and provide similar results. The key point from the table, however, is the highly significant 3-way interaction (row 1) – that is, format and familiarity interact with choice both individually and when considered together.

Availability of Experience

Recalled Events.

Peoples' recollection of disasters was tested simply by asking them to indicate how may such events they recalled from their residency in Adelaide and how many resulted in "widespread" damage. As no participants had resided in Adelaide long enough to recall the 1955 earthquake, no participants should have recalled earthquakes causing damage, making this comparison with the bushfire group redundant. Given this, Figures 2 and 3 show only the total number of disasters recalled plotted against the predicted numbers based on participant's length of residency in Adelaide and the observed base rates of occurrence.

Looking at Figures 2 and 3, one can see marked differences in the numbers of events recalled, with 7 being the highest value provided by a participant for number of earthquakes recalled whereas, in the bushfire condition, several values were close to 100 and the highest was 1000 (requiring the log scale seen in Figure 2).

A similarity between the two figures, however, is seen in the consistent *under*-recollection of disasters. That is, people recalled fewer bushfires and earthquakes than the base rates suggest they have experienced – and this effect was far stronger in the bushfire condition where the typical number recalled was less than 10 but the prediction was more than 200. Calculation of the proportion of recalled over experienced events across the two conditions shows a clear difference, with average proportion recalled being 0.54 (median = 0.22) for earthquakes and 0.05 (median = 0.02) for bushfires. That is, the lower probability events (earthquakes), while recalled less often than the base rate predicts, are disproportionately better remembered than the more common bushfires – by a factor of 10.

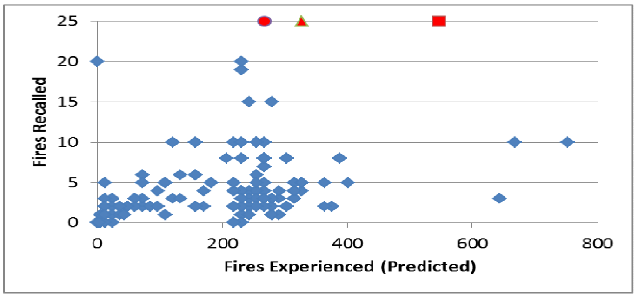

Figure 2: Scatterplot of predicted (residency x base rate) vs actual recalled number of bushfires. Red datapoints are outliers with (from left) 50, 80 and 1000 recalled fires.

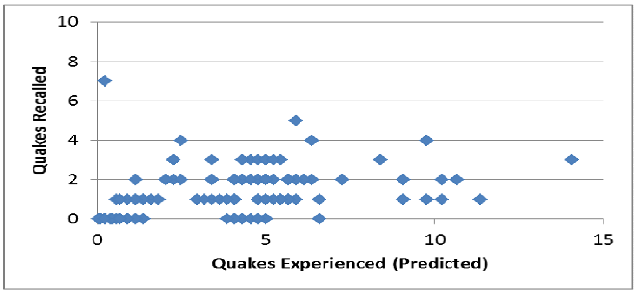

Figure 3: Scatterplot of predicted (residency x base rate) vs actual recalled number of earthquakes.

Interestingly, the number of recalled events seems largely unrelated to the participants' choices by in the experimental task – as shown in the mean rank data in Table 3.

Table 3. Mean rank of proportion of events recalled.

Choice	Earthquake	Bushfire
Do nothing	123.6	176.1
$10K preparations	113.1	170.4
$20K preaprations	134.6	169.5
Sell House (-$40K)	125.6	170.9

Analysis of differences between the groups in Table 2 was undertaken via a 2x4 (familiarity x choice) ANOVA, run - due to the skewed data - on the ranked proportion of events recalled (as per Conover & Iman, 1981). This confirmed the difference in proportion of events recalled between the earthquake and bushfire familiarity groups, $F(1, 283) = 21.3$, $p << .001$ but indicated no significant difference between the proportion of events recalled by participants making different choices, $F(3, 283) = 0.27$, $p = .848$, and no interaction effect between choice and disaster type.

Salience.

The salience, to an individual, of the disaster type they were asked about was scored on a 0-3 scale according to how many of the three, salience questions they answered 'yes'.

The data for bushfires and earthquakes are shown in Figures 4 and 5, respectively. Comparing these figures, one sees, firstly, that salience differs markedly between the bushfire and earthquake groups – as expected, given our sample. Most (59%) of the bushfire group had non-zero salience, compared to only 14% of the earthquake group.

Looking at the Figures together, though, one can see hints of the same pattern of results – increased salience seems to push people away from the two (financially) worse options (doing nothing or selling the house) and towards paying for preparations to reduce the risk to their house.

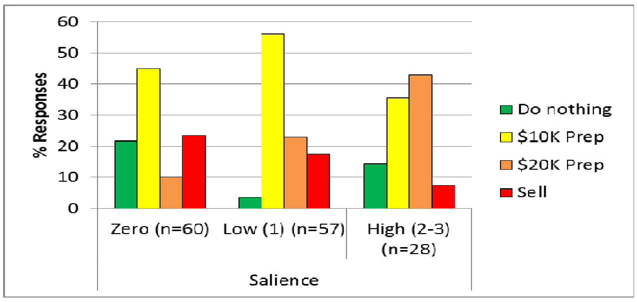

Figure 4: Participant responses by salience (bushfire).

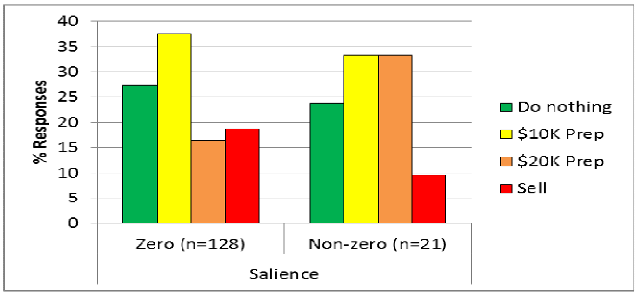

Figure 5: Participant responses by salience (earthquake).

Given only two people scored 3 on salience in either disaster condition, scores of 2 and 3 were grouped as 'high' salience for a 3x4 (salience x choice) chi-square test examining data from both disaster types simultaneously. This showed a significant association between salience and participants' choices, $\chi^2(6) = 22.1$, $p = .002$. Examination of residuals indicated this result was driven by an increased tendency for people with salience zero to elect to 'do nothing' and a decreased tendency for them to select '$20K preparations', whereas people with salience 1 disproportionately selected '$10K preparations' and those with higher salience '$20K preparations'.

Running the same analysis on just the bushfire data produced near-identical results but a 2x4 (salience x choice) chi-square test conducted on the earthquake data alone failed to reach significance – despite the similarity in patterns noted above, $\chi^2(3) = 3.8$, $p = .300$ – indicating that the overall effect is primarily driven by the bushfire data.

Discussion

These results provide a number of insights into difficulties facing people interested in the communication of disaster risk. Practical points relating to risk communication are discussed in the two following sections, prior to a discussion of theoretical implications in terms of Prospect Theory and the Description-Experience Gap.

Familiarity and Format

Two of our three manipulations showed clear effects: familiarity with disaster type; and the probability presentation format. The first is perhaps unsurprising, as one might expect that familiarity with a disaster might affect how one responds to it - and knowing how one *should* respond is likely to reduce the tendency (seen in our data) of people to do nothing when faced with an unfamiliar disaster.

The second observation, that people respond more strongly when shown probabilities in a natural frequency format than percentages seems more surprising but accords with Gigerenzer and Hoffrage's (1995) suggestion that people better understand this format. That is, it suggests that percentages may be an added level of abstraction that detracts from the immediacy of the risk communication.

Availability: Recalled Disasters and Salience

Interestingly, despite the clear effect of the disaster *familiarity* condition, the number/proportion of disasters recalled by participants had no bearing on their responses. That is, people who remembered more or fewer disasters relative to the ground truth did not differ from one another in terms of their responses to our questions. The clearest trend from this data was that, for both types of disaster, people tended to recall fewer than the base rate of occurrence suggested they had experienced.

By contrast with recollection, salience clearly affected responses with people having had more direct experience of disasters inclined to take stronger precautions but also to avoid overreaction, as selling the house in our example would be classified (in expected value terms, at least). The implications of this for risk communication are awkward in that it suggests that messages need to be tailored according to whether a person has had *salient* experience of a disaster – as those without such may overreact or fail to act when presented with the same information to which a more experienced person will react appropriately.

Theoretical Implications

The recalled experience and salience data have implications for how best to approach risk communication. That people tended to underestimate the occurrence of disasters fits with the Description-Experience Gap understanding of learnt, low probabilities – tending to be lower than the true probability – rather than the Prospect Theory assumption that low probability events will be overweighted.

However, the fact that the less common of the two disasters (earthquakes in the Adelaide context) shows *higher* rates of recall suggests that earthquakes are rare enough to be more memorable than bushfires – making them more available and thus causing their occurrence to be underestimated *less* than the more common bushfires.

This has implications for situations where smaller scale disasters occur relatively frequently – specifically, that people will tend to markedly underestimate the rate of occurrence of these, possible as a result of memory limitations – in both encoding numbers of similar, unremarkable events and then in retrieval when asked to recall a number of such events.

Future Research

The results suggest a number of directions. First is an attempt to more rigorously examine experience – that is, the roles of familiarity, recalled events and salience. How these relate to one another may shed further light on when and how to communicate risk. A first step would be to examine the different salience questions separately as it seems unlikely that these will be equally predictive (e.g., personal loss may have more impact than losses in the local region).

A second step would be to conduct the reverse of the familiarity condition used herein – that is, test a sample in a location where earthquakes are more common and bushfires rarer to ensure that it is the manipulation and not differing characteristics of these disasters driving the results.

Finally, future work should pay closer attention to the question of what is the *right* thing to do? Despite a brief discussion of expected value, the decision here was complex enough that no cut-and-dried correct answer existed. Given the goal of improved risk communication, it is important, however, to know if people are reacting appropriately – which requires a correct answer for comparison.

Conclusions

A person's familiarity with a disaster - and its salience to them - impacts how they interpret and respond to events with the same risks. The unfamiliar earthquake risk in our experiment disproportionately produced inaction, while low salience did the same or pushed people to overreact. People with personal experience of disasters, by comparison, tended to prepare and try to mitigate their effects.

Also of interest was the observation that presenting probabilities as natural frequencies resulted in people taking more active steps to mitigate or avoid the disaster.

Finally, our results offer insights into how people learn the probabilities of disasters from the real world, the biases that tend to affect these and how these interact with biases known to affect described probabilities.

Acknowledgments

This research was funded by a University of Adelaide interdisciplinary research fund (IRF) grant. MBW and SBH acknowledge support from the CIBP group's industry sponsors: B.G. Group, ExxonMobil, Santos and Woodside. DJN was supported by the ARC Future Fellowship scheme.

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