LETTERS
PUBLISHED ONLINE: 5 OCTOBER 2015 | DOI: 10.1038/NCLIMATE2822
nature climate change

Rare disaster information can increase risk-taking

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The recent increase in the frequency and impact of natural disasters[1] highlights the need to provide the public with accurate information concerning disaster prevalence. Most approaches to this problem assume that providing summaries of the nature and scale of disasters will lead people to reduce their exposure to risk[2]. Here we present experimental evidence that such *ex post* 'news reports' of disaster occurrences can increase the tolerance for risk-taking (which implies that rare events are underweighted[3]). This result is robust across several hundred rounds of choices in a simulated microworld, persists even when the long-run expected value of risky choices is substantially lower than safe choices, and is contingent on providing risk information about disasters that have been (personally) experienced and those that have been avoided ('forgone' outcomes). The results suggest that augmenting personal experience with information summaries of the number of adverse events (for example, storms, floods) in different regions may, paradoxically, increase the appeal of a disaster-prone region. This finding implies a need to communicate long-term trends in severe climatic events, thereby reinforcing the accumulation of events, and the increase in their associated risks, across time[4].

For the past 20 years Munich Re have surveyed the previous year's natural catastrophes. Their most recent report[1] states: 'It is not just that the number of natural catastrophes studied over the decades has increased … as a result of climate change, but that the impact of these events (as anticipated) has also become much greater and more costly'. Thus, although climate change is gradual, its impact on communities is not only incremental and chronic but can also be sudden and acute because climate change alters the prevalence and severity of discrete climate-related negative events (for example, storms, floods, crop failures)[5]. This fact underscores the importance of understanding how people react to information about the risk of natural catastrophes.

A common response to this communication problem is to assume that more information is better, and that providing descriptive summaries of risk levels will lead people to reduce their exposure to relevant risks. This approach is taken in many fields; examples include information about vehicle accidents in a given area[6–8], the risk of forest fire[9], flood risks[10], and terrorist attacks (for example, the US Traveler Enrollment Program).

Although evaluations of the response to these systems are scarce[8,9], the hoped-for positive effect of summarized information does not always materialize. Several studies suggest that publicly available information summaries concerning catastrophic events sometimes have the paradoxical effect of decreasing overall risk estimates[11–13]. For example, in a study of residents living in an area close to, but unaffected by the 2011 Tohoku tsunami[13], participants were presented with scenarios involving waves of varying heights and asked whether each requires an evacuation. Comparing responses made before and after the tsunami, these unaffected residents' estimates of wave heights warranting an evacuation were higher after the disaster. This suggests an increased tolerance for risk following the provision of information about a disaster that one avoided.

In two experiments, we investigated the (causal) effect of providing *ex post* information about each individual rare negative event that occurred in a simulated microworld (Fig. 1). Our participants made a choice about where to 'live' for each one of 400 rounds. The 'microworld' contained three regions, each having a village with multiple dwellings: participants could earn points for choosing to live in a particular dwelling in one of the villages; but lost many points when a catastrophe hit their dwelling. Points won represent an experimental analogue of the 'utility' garnered from a profitable and peaceful life in one's chosen 'home', whereas points lost represent the 'disutility' of a life impacted by a major disaster. Throughout the experiment, all participants were given an accurate description of the *ex ante* risks of catastrophe in each region (Fig. 1). However by varying the type of *ex post* round-by-round feedback about when and where catastrophes occurred (described below), we examined how the reporting of negative events affected participants' choice between regions that carried different levels of risk (Table 1).

One region of the microworld was safe: catastrophes never occurred, but the available points on each round were modest. A second region offered more points if no disaster occurred but rare catastrophes occurred (10 in 100 rounds) which affected 9% of dwellings in the region (incurring a loss of points). A third region had very rare catastrophes (1 in 100 rounds) that were of higher impact (affecting 90% of dwellings in the region), although offering the same benefits and overall risks as the second region (that is, an individual home owner faced the same probability of disasters in both regions; Table 1).

In the Own House condition, participants learnt of a catastrophe only when their current dwelling was damaged. In the Local Village condition participants learnt when a catastrophe hit 'their' village, and saw how many dwellings were damaged in that village. In the All Villages condition, participants learnt when a catastrophe hit any village, and saw how many dwellings were damaged there. These three feedback conditions were designed to mimic the different amounts of information that people might have access to: if they relied solely on their personal experience (Own House), if (additionally) they could access local information sources (Local Village), or they could also source information from afar via the media or authorities (All Villages).

There were two environments (each encountered for 200 rounds): a balanced or 'moderate' environment where all three villages offered the same expected value (that is, average number of points), and a 'severe' environment in which the two risky regions had 25% lower expected value than the safe region

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Figure 1 | Screenshot of the GeoRisk Microworld used in the experiments. On each round, participants could choose to reside in one of three regions (villages). Descriptive summaries about pay-offs and risks were provided (top right panel). In the Own House condition, only damage to the current dwelling was presented (denoted by a colour-filled square and a loss of points). In the Local Village condition, damage to all houses in the village where the participant currently resided was summarized (this is shown in the screenshot—the pink area endured a catastrophe affecting 10% of dwellings). In the All Villages condition, affected houses in all villages were displayed.

Table 1 | Description of the environments used in the experiments.

	Moderate environment			Severe environment		
	Safe	**Risky 1**	**Risky 2**	**Safe**	**Risky 1**	**Risky 2**
Mean positive payout	+10	+15	+15	+10	+15	+15
Mean negative payout (if negative event occurs)	N/A	−541	−541	N/A	−819	−819
Pr (disaster)	0	0.01	0.10	0	0.01	0.10
Pr (negative event|disaster)	N/A	0.90	0.09	N/A	0.90	0.09
Therefore Pr (negative event)	0	0.009	0.009	0	0.009	0.009
Expected value (per round)	10	9.996	9.996	10	7.494	7.494

In Experiment 1 the moderate environment preceded the severe environment, and in Experiment 2 this order was reversed. Mean positive payout is the average amount participants win per round if no negative event affects their dwelling. Mean negative payout is the average amount participants lose if a negative event affects their dwelling. The variability around each mean was drawn from a uniform distribution of integers, U[−3,+3]. The probability of disaster refers to the probability that a disaster will affect a region; the probability of a negative event given that a disaster hits refers to the extent of damage in the region. The information in bold was available to participants; risks were presented as relative frequencies (for example, 1 in 100 rather than 0.01; see Fig. 1). N/A, not applicable.

(Table 1). We conducted two experiments: in the first, the moderate environment preceded the severe environment; and in the second, this order was reversed—all other aspects (save the participant pool—see Methods) were identical. Here we focus on the data collapsed across both orders because they illustrate succinctly the key finding: providing more information about recent disasters may, paradoxically, increase risk-taking.

Figure 2 shows the average proportion of risky choices in the moderate and severe environments (averaged across rounds and environment order) for each feedback condition. Risky choices refer to choices to 'live' in one of the two risky villages ('Risky1' and 'Risky2' combined—see Table 1). The clear result is that this preference for risk is highest when participants received round-by-round feedback about the occurrence of negative events in all villages—that is, both experienced and avoided disasters. Moreover, this preference persisted in the severe environment when the expected (that is, long-run) points' earnings were 25% lower in the risky villages compared to the safe one.

A mixed-model ANOVA, with environment order and feedback type as between-subjects factors, and environment type and round block as within-subjects factors (each block having 50 choices), revealed a main effect of feedback type, $F(2,174) = 3.96$, $p = 0.021$; partial $\eta^2 = 0.044$. Follow-up tests confirmed a higher proportion of risky choices in All Villages ($M = 0.55$; s.e.m. = 0.033) compared to either Own House ($M = 0.43$; s.e.m. = 0.038) ($p = 0.034$) or Local Village ($M = 0.40$; s.e.m. = 0.041) ($p = 0.009$). This effect of

NATURE CLIMATE CHANGE DOI: 10.1038/NCLIMATE2822

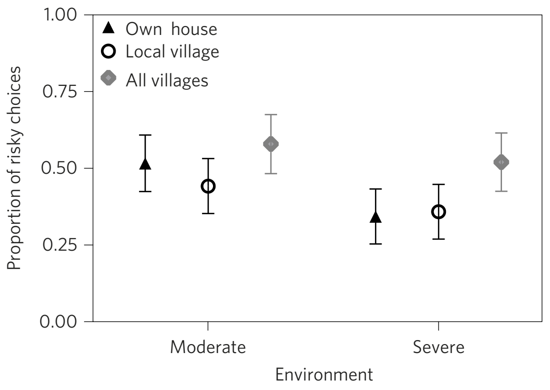

Figure 2 | The mean proportion of risky choices (selection of a house in one of the two risky areas) in the moderate and severe environments. The conditions refer to situations in which participants received feedback about the occurrence of a catastrophe only for their Own House, for their Local Village or for All Villages. Data from the two experiments are combined and averaged across rounds. Error bars are 95% confidence intervals for the mean.

feedback type remained, and was numerically larger (Fig. 2), when considering only the severe environment: $F(2,174)=5.26, p=0.006$; partial $\eta^2=0.057$; with follow-up tests again revealing more risk-taking in All Villages than in Local Village ($p=0.008$) or Own House ($p=0.004$). For additional analyses, see Supplementary Fig. 5.

Examination of round-by-round choices (see Supplementary Figs 1–4) suggests that participants in the All Villages condition were affected by the low frequency of *ex post* feedback summaries indicating a disaster had occurred compared to the high frequency of those showing no disasters. Across individuals, lower observed frequencies of summaries entailing a disaster were associated with making riskier choices (this was only found in the Risky1 region, where there was sufficient variance in the frequency of events). Furthermore, although summary information about a disaster in a given round resulted in an initial avoidance response, risk tolerance returned to similar levels within three to four rounds. This rebound effect was driven in part by participants who had viewed a disaster from the safe region then moving into the risky region where the disaster had recently occurred (see Supplementary Figs 2 and 3).

Recent psychological research has tended to focus on how people's beliefs about climate change alter in the face of different types of information[14,15], or personal experience of climate-related events[16–18]. Our investigation complements and extends that research to examine how people can be expected to act in response to a particular kind of climate-change-related information: the (inevitable) rise in disaster prevalence[1,5]. We find that forgone feedback about other regions (conveyed via descriptive summaries depicting the distribution of a catastrophe's impact) increased participants' appetite for risk.

We propose that this occurs because round-by-round feedback providing full information about all regions reinforces the fact that "most of the time, nothing 'bad' happens in the risky areas". This is particularly relevant for information on occurrences outside one's current location. The ensuing comparison between locations can encourage some individuals to become (relatively) satisfied with accepting risk, or dissatisfied with playing 'safe' (depending upon their current location). Naturally, this interpretation corresponds to our particular experimental task in which *ex ante* risks were fully specified and moving costs were low (see Methods). Although this environment might not generalize to all real-world settings (*ex ante* risks are not always known, for example), the results nonetheless illuminate what might cause the counterintuitive effect of information summaries found in some field studies[11–13].

These results dovetail with related findings in the decisions-from-experience literature[3,19,20]. This research shows that, in contrast to situations in which people have only descriptive risk information[21], people making experience-based decisions choose as if they give less weight to rare events than their objective likelihood of occurrence would warrant; a tendency which is exacerbated when forgone feedback from all choice options is available[20,22,23]. People also appear to rely more on experience when both described and experienced information are available[24].

Such findings have been invoked to explain why climate change does not 'scare' people (yet)[4,25]: direct experience of climate-change-related (or attributed) disasters remain relatively rare and thus insufficient to motivate the unaffected majority, whereas incremental and chronic effects of climate change are often difficult to disentangle from daily experiences of weather fluctuations[26]. Recent studies, however, suggest that direct experience of disasters attributed to climate change can influence risk perception and intended behaviour[18]. Our results suggest that over time the influence of such disasters and the *ex post* summaries of risks that accompany them could be undermined by a combination of personal, local and vicarious experience that reinforces an increased tolerance of risk.

One limitation of our investigation is that we did not explore a wide range of pay-off distributions: our 'risky' regions were always superior to the 'safe' region if no disaster occurred (see Table 1). However, we feel this is consistent with a critical challenge in risk communication in the face of climate change: how to reduce the tolerance for (catastrophic) risk in regions which offer high utility most of the time. This challenge is relevant, for instance, to a person deriving high utility from daily access to the ocean but who runs the (rare) risk of inundation from an abnormally high tide; or a farmer who chooses to reap the benefits of working the fertile soil of a flood plain.

Our interpretation of the current findings suggests that to reduce tolerance for climate-related risks, descriptive risk summaries should focus on long time intervals. The longer the time interval the more likely it is to include (multiple) disasters, thereby switching the emphasis from the non-occurrence to the occurrence of events[26]. Summaries should also emphasize the increasing prevalence (trend) of disasters (for example, 3 disasters in 1800–1849; 6 in 1850–1899; 10 in 1900–1949, and so on.), which could be graphically presented and simulated to highlight the increasing chance of future disasters[27] Communication strategies of this kind would move away from the '1 in 50- or 100-year storm' rhetoric often seen in the media and provide a specific time period (or reference class[28,29]) for given events as well placing current, immediate, risks within the context of peoples' own and vicarious experience over time.

Received 22 May 2015; accepted 7 September 2015; published online 5 October 2015

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Acknowledgements

This study was supported by the Leverhulme Trust (RPG-384), by the I-CORE programme of the Planning and Budgeting Committee and the Israel Science Foundation (Center No. 41), and by the Australian Research Council (LP120100224). B.R.N. received salary support from an Australian Research Council Future Fellowship (FT110100151) and acknowledges support of the ARC Centre of Excellence for Climate System Science (CE110001028). We thank A. Kary and R. Parikh for assistance with data collection and T. Lejarraga for insightful comments on an earlier draft.

Author contributions

B.R.N., T.R. and E.Y. devised and designed the experiments. M.S. developed the computer program and implemented the designs. B.R.N. and T.R. oversaw the running of the experiments. B.R.N., T.R. and E.Y. conducted the data analyses and wrote the paper.

Additional information

Supplementary information is available in the online version of the paper. Reprints and permissions information is available online at www.nature.com/reprints. Correspondence and requests for materials should be addressed to B.R.N.

Competing financial interests

The authors declare no competing financial interests.

Methods

Participants in Experiment 1 were drawn from the University of Essex (UK) participant pool ($N = 90$, 56 female, mean age = 24.8; s.d. = 5.98) and those in Experiment 2 from the University of New South Wales (Australia) participant pool ($N = 90$, 64 female, mean age = 19.4; s.d. = 2.63). Both samples comprised predominately university students. In the absence of a direct prediction about effect size, we based our sample size ($n = 30$ per between-subjects condition) on our previous work using similar experimental paradigms[20]. In each experiment, participants were assigned randomly to one of the three between-subjects conditions: feedback received about Own House, Local Village, or All Villages. At the start of the experiments participants read summary instructions that described the basic set-up of the task. Following this, a screen similar to Fig. 1 was shown and participants were free to choose which of three regions (and which house within a region) to 'live in' for the current round. Each region included 100 houses. The allocation of colours to regions, and the position of the risky and safe regions on the screen (for example, by the coast, on the mountain), was randomized for each new participant. Once the choice was made, one round of the simulation was run according to the specified probabilities of disaster, and the participant received feedback (as specified by their assigned condition) about the occurrence, or non-occurrence, of a catastrophic event (in this case an earthquake). Participants were then told how many points they had earned on that round, and how many points they had lost (if a disaster had occurred)—both values were displayed on screen. Participants were then asked to choose a dwelling for the next round. There was no restriction on movement to regions or houses within those regions, but a 'moving cost' was implemented which was proportional to the distance from the current location. This moving cost was relatively low, being less than the amount the participant could expect to gain each round if no catastrophe occurred, and was subtracted from any earnings on each round. Participants were able to see the moving cost associated with each dwelling before committing to a move. The experiments then proceeded in this manner until trial 201, on which an on-screen dialog box announced that the pay-offs associated with two of the regions had now changed. In Experiment 1 the change was from moderate (in which disasters incurred a loss of 541 points) to severe (a loss of 819 points; see Table 1) and in Experiment 2 the change was from severe to moderate. The remaining 200 trials were then completed and at the end of the experiment participants were paid according to the number of points they had accumulated at a rate of 1,000 points = 1GBP in Experiment 1 and 1,000 points = 1.10AUD in Experiment 2. (An analysis of the points earned in each condition is presented in the Supplementary Information—see Supplementary Table 2). All participants were debriefed concerning the aims of the experiment. The procedures in both experiments were reviewed and passed by relevant ethics panels in the two institutions. A manual describing how to operate and implement the GeoRisk Microworld software used in the experiments is available at http://tx.technion.ac.il/~yeldad/GM.