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Examining Insensitivity to Probability in Evidence-Based Communication of Relative Risks: The Role of Affect and Communication Format

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Affect can influence judgments of event riskiness and use of risk-related information. Two studies (Ns: 85 and 100) examined the insensitivity-to-probability effect—where people discount probability information when scenarios are affect-rich—applying it to evidence-informed risk communication. We additionally investigated whether this effect is moderated by format, based on predictions from the evaluability and pattern-recognition literatures, suggesting that graphical formats may attenuate insensitivity to probability. Participants completed a prior beliefs questionnaire (Study 1), and risk perception booklet (both studies) that presented identical statistical information about the relative risks associated with two scenarios—one with an affect-rich outcome, the other an affect-poorer outcome. In Study 1, this was presented graphically. In Study 2, information was presented in one of three formats: written, tabular, or graphical. Participants provided their perceptions of the risk for each scenario at a range of risk-levels. The affect-rich scenario was perceived as higher in risk, and, importantly, despite presenting identical relative risk information in both scenarios, was associated with a reduced sensitivity to probability information (both studies). These differences were predicted by participants' prior beliefs concerning the scenario events (Study 1) and were larger for the single-item written format than graphical format (Study 2). The findings illustrate that insensitivity to probability information can occur in evidence-informed risk communications and highlight how communication format can moderate this effect. This interplay between affect and format therefore reflects an important consideration for information designers and researchers.

KEY WORDS: Affect; information format; insensitivity-to-probability effect; risk communication; risk perception; sensitivity to probabilities

1. INTRODUCTION

Two streams of research have investigated how affect influences people's responses to risk information. The first stream is predominantly correlational and exemplified by Slovic and colleagues (e.g., Slovic, 1987, 2000; Fox-Glassman & Weber, 2016) who identified two dimensions of perceived risk: *unknown risk* and *dread risk* (Slovic, 2000). Activities/technologies high on unknown risk are deemed less observable and less well-understood; those scoring high on dread risk are judged to have incontrollable and involuntary risks with the potential for catastrophic consequences. Importantly, this research provides evidence that the affective features of an event or its description can be key drivers of risk perceptions, and identifies a particularly affective dimension: the "dread dimension."

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The second line of research directly manipulates affect and finds that people search for and use probability information less in affect-rich scenarios compared to affect-poor ones. For example, Pachur, Hertwig, and Wolkewitz (2014) found that participants spent time acquiring outcome and probability information equally in an (affect-poor) monetary loss scenario; yet acquired outcome information more frequently than probability information when examining an (affect-rich) medical side-effects scenario. Similarly, Sinaceur, Heath, and Cole (2005) found that while probability information was considered when scientific terms were used (Creutzfeldt-Jakob Disease), when an affect-rich descriptor ("mad-cow disease") was used, people made decisions on their beef consumption based on their emotional reactions. Rottenstreich & Hsee (2001) asked participants how much they would be willing to pay to avoid the hypothetical chance (1% vs. 99%) of either: (1) a "short, painful, but not dangerous electric shock"; or (2) a $20 cash penalty. Willingness-to-pay (WTP) to avoid an affect-poor outcome (cash penalty) increased substantially with the stated outcome probability ($\text{Median}_{\text{WTP}}$ $1 vs. $18); but for the affect-rich outcome (electric shock) was similar irrespective of the probability level ($\text{Median}_{\text{WTP}}$ $7 vs. $10). Such research therefore reports *reduced* sensitivity to probability information when affect is high.

Three important interrelated findings emerge from these lines of research. First, affective reactions play a key role in risk perception. Second, affective features of a risk event or its description, such as vividness, opportunity for control, or potential for clusters of deaths, can influence risk perceptions. Third, people are less sensitive to probabilities when descriptions of decisions evoke high levels of affect. Each of these features has implications for communicating risk, because they relate to how people interpret and respond to those messages.

While different probability formats are used in risk communications, only some have been examined for differential sensitivity to probability information across affect-rich and affect-poor settings. To our knowledge, no one has examined whether there is reduced sensitivity to probability for high-affect events in the *relative risk* format—a gap in the literature that this article addresses. Relative risk specifies how the probability of an adverse outcome increases with exposure to a hazard but without specifying the absolute probability (e.g., "annual risk of death is *X* times higher for those smoking 10 cigarettes per day, compared to non-smokers"). Communication using relative risk can be problematic for comprehension, particularly for rare outcomes (Gigerenzer, 2002; Heard, Rakow, & Spiegelhalter, 2018) and extraneous influences are often particularly important in such instances. It may therefore be the case that insensitivity to probability is more likely when probabilities are expressed using relative risk. Despite the potential for confusion when interpreting relative risks, there are many instances where absolute risks are difficult to compute (e.g., public health communications when the absolute risk varies across individuals). Therefore, sometimes relative risk information is appropriate for evidence-based communication. For example, a recent article by the Centre for Disease Control and Prevention (U.S. Department of Health & Human Services, 2021) reports hospitalizations and death by age for COVID-19—for instance—"compared to 18- to 29-year olds, the rate of death is four times higher in 30- to 39- year olds, and 600 times higher in those who are 85 years and older." We therefore extend understanding of risk communication in two studies, examining whether sensitivity to probability information—*expressed as relative risk*—varies with the degree of affect associated with the communication. Study 1 investigates affect-rich scenarios where people are presented with relative risk information and addresses three questions: (1) How does changing the events described in the scenarios alter perception of risk information? (2) Does an affect-rich scenario promote insensitivity to probability information? (3) Are these effects predicted by people's prior beliefs about the severity and impact of outcomes associated with these risk events. Study 2 further examines those first two questions, and additionally tests whether the degree of (in)sensitivity to probability is moderated by presentation format (e.g., graphical, written). Study 1 is introduced below, while the rationale and predictions for Study 2 are introduced later.[1]

2. STUDY 1

Question 1: How does changing the scenario alter perception of risk information? Research consistently finds that strong feelings and concern are identified for cancer, compared to other health or activity risks, such as automobile accidents (Robinson, Covey, Spencer, & Loomes, 2010; Slovic, 1999;

[1]Ethical approval was granted by the University of Essex (Study 1) and King's College London (Study 2), and informed consent gained from all participants.

Slovic, Finucane, Peters, & MacGregor, 2004). Clarke and Everest (2006), for example, describe it as the most feared of modern diseases, and through a content analysis of portrayals of cancer in print media, identified that fear/dread, death, and hopelessness are common in the discussion of cancer. It is therefore unsurprising that Slovic and others (Robinson et al., 2010; Slovic, 1999; Slovic et al., 2004) highlight a similar conception of cancer as a "dreaded" affect-laden disease.

Based upon such research, two scenarios were chosen to represent real-life "affect-rich" and "affect-poorer" risk events: lung cancer for the affect-rich scenario and car crash for the (comparatively) affect-poor scenario. A validation study designed to test this difference in affective intensity, adapted Slovic's (1987, 2000) investigations of the dread risk dimension, which is commonly identified as reflecting an affective component in the evaluation of different hazards (Loewenstein, Weber, Hsee, & Welch, 2001). To create a multiitem measure, we identified several characteristics from the dread dimension (potential of catastrophic consequences, voluntariness, potential for fatal consequences, (lack of) controllability, whether risk is easily reducible or not). Supporting our proposed distinction, this study provided evidence that lung cancer was perceived as more dreaded than the car crash risk ($t(120) = 4.02$, $p < 0.001$, $d = 0.52$). Details of this study are in the Supporting Information.

Identical relative-risk graphs were created for each scenario, showing the same "dose-response" function between hazard exposure and adverse outcome. For lung cancer, this presented information about the risks of smoking for two risk groups (Cigarettes smoked: <10 cigarettes, 20+ cigarettes a day) at different risk levels (Number of years smoked: 35 years, 50 years). For car crash risk, the labels were replaced with different types of road (risk groups) and different driving speeds (risk levels).

Because both graphs show identical functions, if people rely solely on this statistical information, risk perceptions at the different risk level and risk line gradients should be similar for both scenarios. If, however, participants have different prior beliefs or thoughts about cancer and car accidents, which influence their perceptions, then a difference should be found between the scenarios. Assuming that people are more fearful and worried about cancer deaths compared to other risks (Robinson et al., 2010), higher perceptions of risk are predicted for cancer than for car crash.

Question 1.2: Does an affect-rich scenario promote insensitivity to probability information? Earlier, we identified Rottenstreich & Hsee (2001) finding that people are less sensitive to probability information for affect-rich scenarios. We therefore predict a smaller effect of risk level on risk perception in the affect-rich cancer scenario than in the car crash scenario.

Question 1.3: Are these effects predicted by people's prior beliefs about the severity and impact of outcomes associated with these risk events? We created a "prior beliefs" measure to examine how individual differences in beliefs about risk events relate to people's interpretations of risk information about those events. Facets of riskiness identified across the risk communication and health utility literature provide the basis for the five questions used in the measure. The dread risk factor (Slovic & Weber, 2002) provided the basis for asking about likelihood of death. Because utility theory and its variants speak to the importance of anticipated outcomes, a severity of the consequence/condition measure was included. Finally, from the health utility literature: one question probing participants' beliefs about quality of life; and two questions based on the pain dimension of the EQ5D (Whitehead & Ali, 2010).

This measure therefore allowed us to assess two subquestions. First, do prior beliefs differ for cancer and car crash (e.g., in line with designating cancer as "affect rich")? Second, do people's general prior beliefs match their subsequent personal risk perceptions in response to specific risk information?

2.1. Methods

2.1.1. Participants

Participants were 85 University of Essex psychology students who participated for course credits.

2.1.2. Stimuli

Participants completed an online prior beliefs questionnaire (run using Qualtrics software) and a risk perception booklet (paper-and-pen task).

Prior Beliefs Questionnaire: Twelve health/activity risks, including the behaviors of interest (lung cancer and car crash) were presented to participants. The remaining risks acted as filler stimuli that obscured which health/activity risks were thel behaviors of interest across the two-part study.[2] All participants were asked the same five questions about each of these 12 risks (presented as two sets of six to simplify evaluation), however participants differed in whether these were asked via rating questions (0–100 scale) or ranking questions (1–6). The five questions for each risk were: (1) assuming the event/health condition has occurred how likely is it to kill them/lead to death; (2) how difficult (on average) would it be for someone to live with the consequences; (3) severity (of the consequence/condition); (4) how likely to have severe pain; and (5) the level of pain one would expect someone to experience (on average).

Risk Perception Booklet: This began with a written explanation of the task (with an example question) and a diagram explaining the term "scale factor of risk" (vertical axis), explaining that a scale factor of 1 (i.e., baseline) means: "No relationship between risk event or activity and the outcome." It also explained that a scale factor greater than 1 means that the risk has increased (using examples for factors of 1.5, 2. 2.5, and 3; e.g., "3.0 = 3 times the risk"). This sought to ensure that participants understood the of main quantity of interest, irrespective of their prior knowledge.

Each subsequent page of the booklet consisted of a graph, plus three risk-related questions. Eight such pages were created for Study 1, interleaved with an additional eight pages to act as fillers. Whether lung cancer (affect-rich) or car crash (affect-poor) stimuli set were present first was alternated between participants. Within each event set (lung cancer, car crash), the order of the stimuli was randomized for each participant.

For the graphs presented, the data points were identical across all eight pages, however, four were described as smoking-related lung cancer risk (with variables: number of cigarettes and years smoked) and four were labeled as speed-related car crash risk (with variables: km/h and type of road). These differences in labeling were in the graph title, the X-axis and the two groups presented on the graph and defined in its legend (see Fig. 1 and Supporting Information).

[2]A second investigation having a similar format was run concurrently within the same testing sessions, where eye, nerve, and kidney disease were the main risk events of interest. An integrated testing session was used because it allowed experimental stimuli from the other experiment to act as filler items. This other experiment falls outside the scope of this article and is not reported.

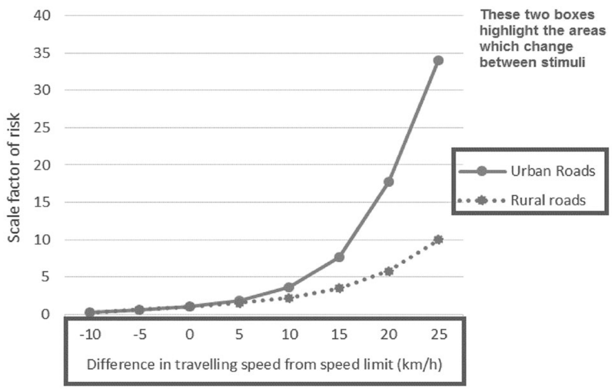


Fig 1. Data presented for the Study 1 risk scenarios (Annotated to reflect areas of change).

A visual analogue scale (16.0 cm long), labeled at each end, was used as the response method for each question, to reduce the opportunity for numerical anchoring (Jacowitz & Kahneman, 1995). The questions were: (1) How risky is it… (*No risk at all* vs. *Maximal risk possible);* (2) How important is it to keep one's level of risk below… (*Not important* vs. *Extremely important)*; and (3) How safe is it…to have a certain level of risk (*Not very safe* vs. *Extremely safe)*.

The specific risk scenario, risk level and risk line gradient named in the question changed for each booklet page. Table I shows the design of the eight risk pages.

2.1.3. *Procedure*

Participants completed the prior beliefs questionnaire online, and the risk perception booklet in person. These sessions were separated by a minimum delay of 8 hours. However, most participants had longer delays (typically 1–14 days).

2.1.4. *Design*

The experiment employed a $2 \times 2 \times 2$ within-subjects design. The factors were risk level (low vs. high), risk type (speed-related crash risk vs. smoking-related cancer risk), and risk line gradient (shallow vs. steep). This design, with our sample size ($N = 85$), afforded more than 80% power to detect a small-to-medium main effect of $d = 0.35$ using a two-tailed test with α set at .05.

The dependent variable was derived by averaging the three ratings (risk, importance, safety). Safety ratings were reverse coded (to make the direction

Table I. A Description of the Eight Risk Scenario Pages Presented in Study 1

Lung Cancer		Car Crash	
Low RL/ Low RG35yrs/<10Cigarettes	**Low RL/High RG**35yrs/20+ Cigarettes	**Low RL/ Low RG**5km/h /Rural	**Low RL/High RG**5km/h /Urban
High RL/Low RG50yrs/<10Cigarettes	**High RL /High RG)**50yrs/20+Cigarettes	**High RL/Low RG**20km/h / Rural	**High RL /High RG)**20km/h / Urban

RL = Risk Level; RG = Risk Gradient

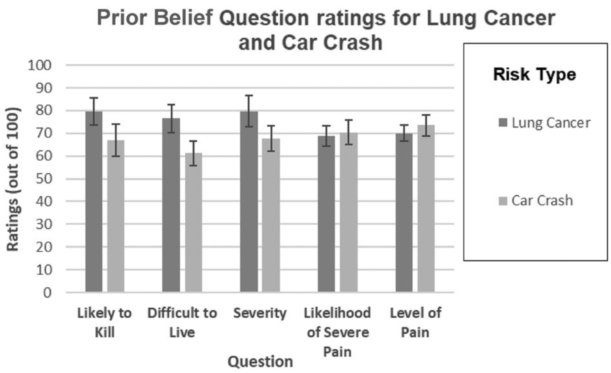


Fig 2. Mean ratings for the five prior belief questions for lung cancer and car crash. (Error bars represent 95% confidence intervals).

of evaluation consistent with the other ratings). All Cronbach's alphas for these measures were good-excellent (α-range = 0.70–0.86).

2.2. Results and Discussion

2.2.1. Prior Beliefs about Risk Events

The prior beliefs questionnaire was analyzed to understand what participants thought about the events/disease states under investigation; and, subsequently, to determine whether prior beliefs predict responses to the graphs. Both rating and ranking data produced similar patterns of results, therefore only the rating data is presented here. Analysis of the ranking data is in the Supporting Information.

As Fig. 2 highlights, ratings for cancer were higher than those for car crash ($F(1,41) = 10.45$, $p = 0.002$, $\eta^2 = 0.203$, medium-large effect).[3] Such differences are larger for the likely-to-kill, difficult-to-live, and severity questions compared to either pain-related question. This pattern is reflected in a significant interaction between risk type and question ($F(4,164) = 13.53$, $p < 0.001$, $\eta^2 = 0.248$, large effect) and confirmed in paired *t*-tests where higher ratings for lung cancer compared to the car crash are found for the likely-to-kill, difficult-to-live, and severity questions (all $t(41) > 4.02$, $p < 0.001$, $d > 0.62$, large effects) but not for likelihood-of-severe-pain or level-of-pain questions (both $t(41) < 1.15$, $p > 0.255$, d-range: 0.07–0.18).

[3]No significant main effect of question was found ($F(4,164) = 2.22$, $p = 0.069$, $\eta^2 = 0.051$, small-to-medium effect)

2.2.2. Risk Perceptions

A 2 (risk type) × 2 (risk level) × 2 (risk line gradient) factorial ANOVA was conducted with the combined mean risk perception score as the dependent variable. This analysis investigates whether the risk type (cancer vs. car crash) influences how participants respond to the probability (relative risk) information and allows investigation of insensitivity-to-probability for affect-rich risk events. As the focus is on the relationship between risk type and risk level, unless a three-way interaction reveals that risk line gradient influences this relationship, risk line gradient (e.g., whether the line is shallow or steep) will not be further analyzed in relation to risk type. However, because the interaction between risk level and risk line gradient permits checking whether participants understand the graphical displays, this interaction, if significant, will be analyzed.

The ANOVA revealed significant main effects of risk level, risk type and risk line gradient (all $F > 47.96$, $p < 0.001$, $\eta^2 > .378$, large effects). As Fig. 3 shows, perceptions of risk increased with risk level and line gradient and were higher for smoking-related lung cancer than the speed-related car crash scenario. The difference between the low- and high-risk levels appears less pronounced for the smoking-related lung cancer stimuli. This interaction was significant ($F(1,79) = 31.37$, $p < 0.001$, $\eta^2 = 0.284$, large effect) as was the interaction between risk level and risk line gradient ($F(1,79) = 34.52$, $p < 0.001$,

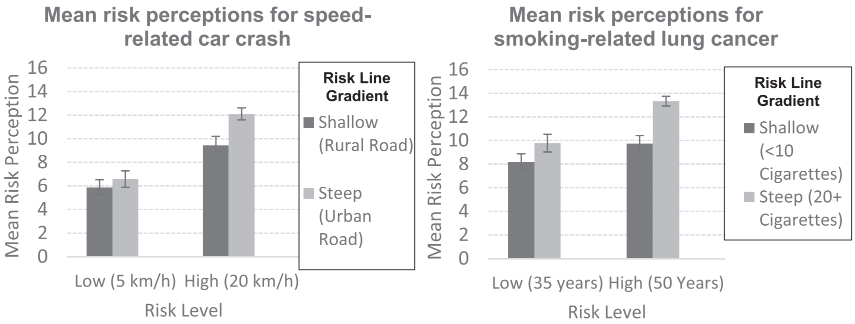


Fig 3. Mean risk perceptions for the two scenarios for each risk level at each risk gradient (Error bars represent 95% confidence intervals).

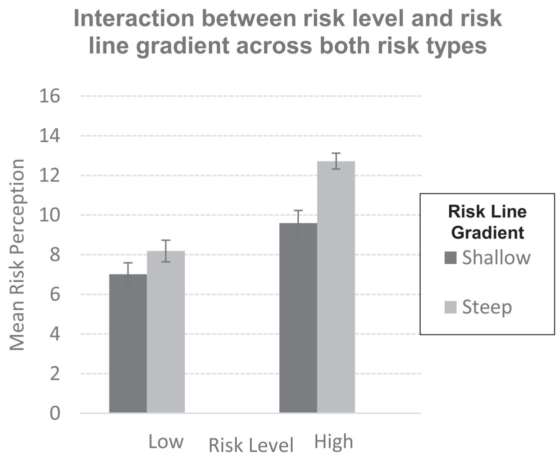


Fig 4. Risk Level × Risk Line Gradient Interaction (Error bars represent 95% confidence intervals).

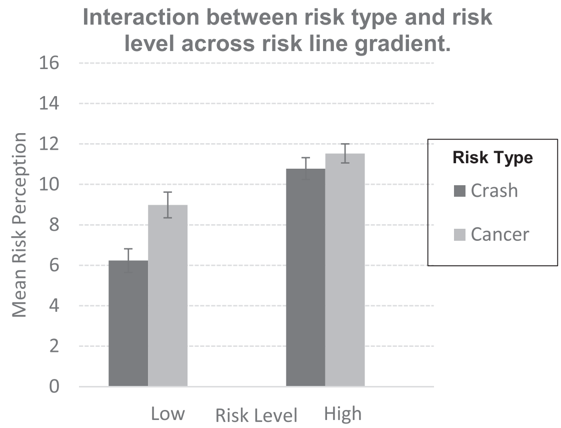


Fig 5. Risk Type × Risk Level Interaction (Error bars represent 95% confidence intervals).

$\eta^2 = 0.304$, large effect).[4] No three-way interaction was identified ($F(1,79) = 0.02$, $p = 0.902$, $\eta^2 < 0.001$).

Follow-up analyses of each significant two-way interaction continue below.

2.2.2.1. Risk Level X Risk-Line Gradient: Checking Graph Understanding. Risk level and risk line gradient represent the two variables shown on the stimulus graph. If people accurately read off information from this graph, then plotting participants' risk perceptions for the four data points (Fig. 4) should look similar to the graph (Fig. 1).

As Fig. 4 illustrates and simple main effects analysis confirmed, participants respond to the increase in risk between the low and the high risk levels, which is larger for the steeper ($F(1,79) = 234.47$, $p < 0.001$, $\eta^2 = 0.748$, large effect) than the shallower line ($F(1,79) = 121.30$, $p < 0.001$, $\eta^2 = 0.606$, large effect). Interestingly, the analysis of the effect of risk line gradient was significant at both the low ($F(1,79) = 21.145$, $p < 0.001$, $\eta^2 = 0.211$, large effect) and high ($F(1,79) = 122.38$ $p < 0.001$, $\eta^2 = 0.608$) risk level. Although the difference would be predicted for the high-risk level, risk perceptions at the lower level should be almost identical for the shallow and steep lines, because those lines are close together at the lower risk level.

2.2.2.2. Risk Type × Risk Level: Evidence for Insensitivity to Probabilities for An Affect-Rich Scenario. The significant interaction between risk type and risk level indicates that, despite presenting identical relative risk information, participants incorporate this into their risk perceptions in different ways for the two risk types (Fig. 5).

Simple main effects analysis revealed significant effects of risk type at both risk levels: low ($F(1,79) = 57.23$, $p < 0.001$, $\eta^2 = 0.420$, large effect) and high ($F(1,79) = 9.62$, $p = 0.003$, $\eta^2 = 0.109$, moderate–large effect). There were also significant effects of

[4] A significant interaction between risk line gradient and risk type was found. As described, since no three-way interaction between the variables was identified, no further analysis was conducted.

Table II. Analysis of the Fit Between Rank Order for the Prior Belief Questions and Risk Perceptions for the Lung Cancer Versus Car Crash Comparison

Question	T_b	p
Likely to Kill	0.177	<0.001
Difficult to Live	0.249	<0.001
Severity	0.189	<0.001
Severe Pain	0.090	0.007
Pain Level	0.045	0.109

risk level at both levels of risk type: speed-related crash risk ($F(1,79) = 209.90$, $p < 0.001$, $\eta^2 = 0.727$, large effect) and smoking-related lung cancer risk ($F(1,79) = 125.89$, $p < 0.001$, $\eta^2 = 0.614$, large effect). Thus, while participants still perceive a difference between the low and high risk levels (i.e., do not show complete neglect of probability information), the effect of risk level is smaller for the cancer stimuli, than the crash risk stimuli. Thus, participants show less sensitivity to probability information for the (affect rich) cancer scenario compared to the car-crash scenario.

2.2.2.3. Do Prior Beliefs and Risk Perceptions Match?. The match between the risk perception and prior beliefs measures was calculated, separately for each participant. A code of +1 was recorded if prior beliefs and risk perceptions matched (e.g., lung cancer rated high on both measures), and −1 if these were mismatched. The mean of these codes provides an estimate of the Kendall's tau correlation coefficient (T_b; Siegel & Castellan, 1988). A full description of this analysis is in Supporting Information. As shown in Table II, significant positive correlations (of small-moderate size) between the prior belief questions and risk perceptions were found for all but the pain level question. If one's cancer (crash) ratings are higher, one also tends to rate cancer (crash) higher on the risk perception measure.

2.3. Summary

Supporting the distinction between the cancer and car crash scenarios and consistent with the direction of differences in risk perceptions, a higher fear of death and lower perceptions of quality of life for the cancer risk were identified (Research Question 1.3). Cancer was perceived as riskier than the car crash scenario (Research Question 1.1) and evidence of reduced sensitivity to probability information (relative risk) was found in the affect-rich cancer scenario (Research Question 1.2).

3. STUDY 2

In Study 1, participants' perceptions altered in the appropriate direction as relative risks varied. Thus, we see evidence of *lower* sensitivity to probability information in an affect-rich scenario, though not to the same degree that others report (e.g., Rottenstreich & Hsee, 2001). One reason for this may lie in our presentation format for the statistical information. While Study 1 used a graphical display, previous examinations of insensitivity to probabilities (e.g., Pachur et al., 2014; Rottenstreich & Hsee, 2001) focus on written information, particularly single-item probability formats. We hypothesize that graphical displays may be associated with a weaker pattern (i.e., reduced sensitivity but not full insensitivity). Indeed, there is good evidence from the pattern-recognition and evaluability literatures to suggest that format and affect might be related, and to support a "benefit" (in reducing insensitivity) to presenting information in a graphical format.

First, Lipkus & Hollands (1999) report that visual displays help reveal *data patterns* (e.g., trends) and serve to make the information more concrete. In our investigation, pattern spotting involves both the simple pattern (as number of years smoked increases, relative risk increases) and the complex interaction (increase in relative risk level is steeper for the line showing the higher amount of exposure—that is, 20+ cigarettes rather than <10 cigarettes) The graphical format therefore allows people to more easily gather and process "gist" information on the general patterns of differences across the different risk levels and risk lines, making evaluation easier. Supporting this interpretation, Petrova, Traczyk, & Garcia-Retamero (2018) suggest that visual-aid manipulations can help decisionmakers to extract gist information and increase sensitivity to probabilities.

Second, findings on evaluability suggest that attributes which are more difficult to evaluate—either inherently or due to the way they are presented—may have limited impact on decisions (Hsee & Zhang, 2010). Importantly, one of these presentational effects relates to how much information is presented simultaneously (Hsee, 1996; Gyrd-Hansen et al., 2011). This work implies that some attributes of an option are easier to evaluate when two options having different values for that attribute are presented together (joint evaluation) rather than separately (single) evaluation. This is reflected in differing evaluations of options (e.g., willingness-to-pay) in those two modes of evaluation (joint vs. single; Hsee, Loewenstein, Blount, & Bazerman, 1999). We can see parallels between joint presentations in our graphical displays, and separate presentations in typical written displays.

To investigate the interaction between format and affect, Study 2 reexamines sensitivity to probability (relative risk) information, using the same type of stimuli as Study 1 to compare affect-rich against affect-poor scenarios; but also randomizes participants to receive this information in a graphical, tabular, or single-item written format. In the single-item format, only one piece of information with one probability level is presented at a time. Study 2 therefore investigates whether the effects of risk type (affect-rich vs. affect-poor) is magnified in the single-item written format because contrasts with other possibilities are not explicit (i.e., those patterns/joint evaluations of information are not immediately obvious) and consequently rely on other sources of information such as affect.

We included the tabular format because there are two factors which could explain why graphical displays should improve the processing of pattern information. First, graphical displays allow for a visual representation of the data rather than relying solely on interpretation of the written word. Second, they allow simultaneous presentation of multiple pieces of information, potentially making it easier to compare risk at different levels of exposure. Examining three formats allows us to consider the contribution of these aspects to risk perception.

Two predictions are made on the role of format as follows:

[Prediction 2.1: Format and Pattern Recognition]: As in Study 1, using probability information appropriately would be reflected in an interaction between risk level and risk line gradient. Following the argument of Lipkus and Hollands (1999) it is predicted that an interaction between risk level and risk line gradient will (again) be found for the graphical display. Such an interaction may either be absent or weakened in the single-item format. For the tabular display, two conditional predictions are made. If visual depiction is key to the benefit of the graphical display, then the tabular format should mirror the results expected for the single-item written format. If, instead, simultaneous presentation is important, the two-way interaction should be found, thus mirroring the graphical format.

[Prediction 2.2: Format and Insensitivity-to-Probability]: Graphical displays are hypothesized to help people identify patterns in data (Prediction 2.1) that can then inform their decisions. We therefore predicted lower sensitivity to probabilities (relative risk) in the single-item format compared to the graphical format. For the tabular display, again, two conditional predictions are made. If visual depiction is the key benefit of graphical displays, the tabular format should yield results similar to those expected for the single-item format (i.e., lower sensitivity to probabilities). If, instead, simultaneous presentation is important, the degree of sensitivity to probability should match the graphical format.

3.1. Methods

3.1.1. Participants

Participants were 100 King's College London students and staff, who participated either in partial fulfilment of a course requirement (first-year psychology students) or for payment. Paid participants could be staff or students from any department/section of the university. Sixty-two participants reported English as their first language, 22 rated their English language ability as very good, 15 as good, and 1 as not good.

3.1.2. Stimuli

The risk perception task was near-identical to Study 1, presenting the same experimental scenarios (again interleaved with other scenarios[5]) and using the same type of randomization procedure. Two changes were made to this task. First, to minimize nonaffectual differences between the scenarios, the X-axis was adapted so that, while the labels changed, the X-axis scale points were identical in both scenarios. Table III presents the combinations for the eight risk perception pages. Second, while some participants received information in a graphical display, some participants received the same information in either a tabular or single-item written display. Fig. 6 displays the risk information for one page of the task.

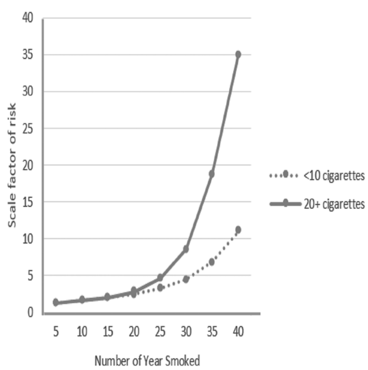
[5]The data for these other scenarios are not reported here; see the Supporting Information for details.

Table III. A Description of the Eight Risk Scenario Pages Presented in Study 2

Lung Cancer		Car Crash	
Low RL/ Low RG20yrs/<10Cigarettes	**Low RL/High RG**20yrs/20+ Cigarettes	**Low RL/ Low RG**20km/h/Rural	**Low RL/High RG**20km/h/Urban
High RL/Low RG35yrs/<10Cigarettes	**High RL /High RG**35yrs/20+Cigarettes	**High RL/Low RG**35km/h/Rural	**High RL/High RG**35km/h/Urban

RL = Risk Level; RG = Risk Gradient

(a) **GRAPH**



(b) **TABLE**

Number Of Years Smoked	Scale Factor of Risk: <10 Cigarettes A DAY	Scale Factor of Risk: 20+ Cigarettes A DAY
5	1.2	1.2
10	1.6	1.6
15	2	2
20	2.5	2.8
25	3.2	4.6
30	4.5	8.6
35	6.8	18.7
40	11	35

(c) **SINGLE ITEM WRITTEN**

"The scale factor of risk of lung cancer for someone who **smokes <10 cigarettes a day** for **35 years** (compared to someone who has never smoked) is **6.8"**

Fig 6. Examples of the three formats (graphical, tabular and single-item written) for the risk of lung cancer for someone smoking <10 cigarettes a day for 35 years.

Participants in the graphical presentation condition were presented with a graph of the risk information (Fig. 6). The *X*-axis of the graph (e.g., number of years smoked), graph legend (e.g., <10 cigarettes a day, and 20+ cigarettes a day) and graph title were changed to match the scenario presented.

In the tabular condition, each data point used to plot the graph was transferred into one cell of the table (Fig. 6). Again, the table title, variable names, and variable levels were changed to match the scenario being presented. This meant that for both the graphical and tabular format information, other data points on the different lines were presented to create the graph (and equally detailed table). Note that, while multiple data points were represented in each stimulus (table or graph) of the tabular and graphical conditions, participants were only ever asked about one data point on a given presentation of a stimulus.

In the single-item written condition (Fig. 6), each page presented a sentence which gave just one piece of information (i.e., one data point from the table/graph). All other information in bold, plus the name of the disease or event risk presented (lung cancer or car crash) was also changed to match those presented in the risk question.

3.1.3. Procedure

After random assignment to either the graphical, tabular, or single-item written format, participants completed the risk perception task. Finally, participants were asked if English was their first language and, if not, how well they could speak English (a standard UK Census question, Office for National Statistics, 2011) with answers on a four-point scale, from "not at all"(1) to "very well"(4).

3.1.4. Design

Each task booklet followed a 2 × 2 × 2 within-subjects design. The three within-subjects factors were: risk type (car crash vs. lung cancer), risk level (low vs. high), and risk line gradient (shallow vs. steep). The fourth factor, format (graphical vs. tabular vs. single-item written) was manipulated between-subjects. The study therefore had a 3 × 2 × 2 × 2 mixed-design study. This design, with our sample size ($N = 100$), afforded more than 90% power to detect a small-to-medium main effect of $d = 0.35$ using a two-tailed test of a within-subjects factor with $\alpha = 0.05$. Inevitably, the power to detect a pairwise difference between formats (between-subjects, two-tailed) was more modest, with 50% power to detect a medium-sized effect of $d = 0.50$ with $\alpha = 0.05$

As for Study 1, the dependent variable was the mean risk perception score, derived from the three risk ratings: risk, importance and safety (reverse coded). Reliability analysis revealed good-to-excellent Cronbach's alpha (α-range = 0.71–0.93).

3.2. Results and Discussion

3.2.1. Data Treatment

Where a participant failed to answer all three questions, no combined risk perception score was calculated for that response. For 5 participants, at least one combined score was missing.

3.2.2. Analysis Introduction

A 3 (format) × 2 (risk type) × 2 (risk level) × 2 (risk line gradient) mixed factorial ANOVA was conducted with the combined mean risk perception score as the dependent variable. Although many analyses could be conducted, with two specific predictions, discussion will focus only on the relevant analyses which inform these predictions. For Prediction 2.1 and 2.2, these focus on how an interaction between two variables (risk level and risk line gradient for Prediction 2.1; or risk level and risk type for Prediction 2.2) is affected by format. Therefore, presentation and analysis of these two interaction patterns will be conducted, split by format—even if the three-way interaction is not significant.

3.2.3. Examining Prediction 2.1: Does Format Affect Pattern-Recognition?

This question was analyzed by examining the interaction between risk level and risk line gradient for information presented in the different formats (Fig. 7). Analysis revealed a significant interaction between risk level and risk line gradient, $F(1,91) = 21.79$, $p < 0.001$, $\eta^2 = 0.193$. This is illustrated by two features: (1) high risk perceptions for the higher amount level reflect that relative risk increases as the risk level increases; (2) a steeper increase in risk perceptions for the steep line than the shallow line reflects that these differences in relative risk are larger for the steeper than shallower line). However, how well these patterns were identified is qualified by presentation format (three way-interaction; $F(2,91) = 3.11$, $p = .049$, $\eta^2 = 0.064$, moderate effect).

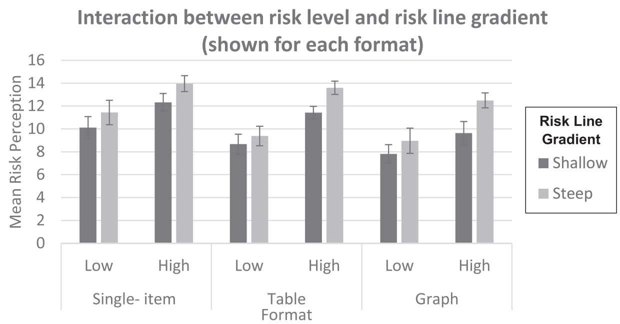


Fig 7. Interaction between risk level and risk line gradient on risk perceptions in the three formats. (Error bars represent 95% confidence intervals).

For the graphical format, these two features of the data are reflected in participants' risk perceptions where, as predicted, a significant interaction between risk level and risk line gradient was found, $F(1,32) = 10.32$, $p = 0.003$, $\eta^2 = 0.244$ (large effect).

For the single-item written format, we see a different pattern. Risk perceptions increase with risk level; however, there is little evidence that the gradient is steeper for the steep risk line gradient line. Indeed, there was no significant interaction between risk level and risk line gradient in this format, $F(1,31) = 0.59$, $p = 0.447$, $\eta^2 = 0.019$, and a smaller effect than the other formats.

The pattern of results for the tabular format was similar to the graphical format; for the interaction between risk level and risk line gradient, a large and significant effect was found, $F(1,28) = 23.73$, $p < 0.001$, $\eta^2 = 0.459$. This pattern suggests that having all the information presented simultaneously is enough to help participants spot patterns embedded in the data, and that a graphical display is not necessary for this.

3.2.4. Examining Prediction 2.2: Does Sensitivity to Probability Vary with Format?

Sensitivity to relative risk (probability) information can be examined by considering the interaction

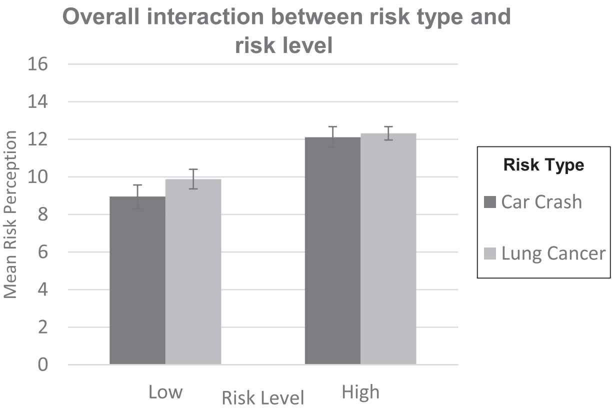


Fig 8. Analysis of the interaction between risk type and risk level (data collapsed across risk line gradient) (Error bars represents 95% confidence interval).

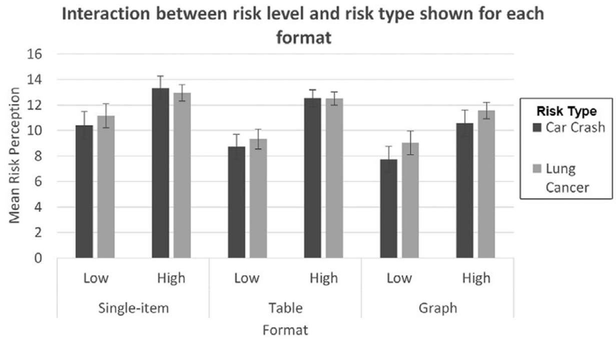


Fig 9. Interaction between risk level and risk type on risk perceptions in the three formats. (Error bars represent 95% confidence intervals).

between risk type and risk level. This is because, if participants are less sensitive to probability for affect-rich scenarios one would expect to see a shallower increase in risk perceptions for the cancer compared to the car crash scenario.

Considering the effect collapsed across all formats (Fig. 8), there appears to be reduced sensitivity to the risk level in the lung cancer scenario. Thus, the increase in risk perceptions as risk level increases is greater for car crash than for lung cancer. This interpretation is supported by a significant interaction between risk type and risk level ($F(1, 91) = 7.72$, $p = 0.007$, $\eta^2 = 0.078$, moderate effect). Analysis of the simple main effects, however, finds similarly-sized standardized effects of risk level for the cancer ($t(95) = 11.43$, $p < 0.001$, $d = 1.16$, large effect) and crash scenario ($t(96) = 11.12$, $p < 0.001$, $d = 1.13$, large effect). However, a larger effect of risk type is found at the lower risk level ($t(86) = 3.92$, $p < 0.001$, $d = 0.39$, small-medium effect), where risk perceptions are significantly higher for the cancer scenario, while this is not found at the higher risk level ($t(94) = 0.79$, $p = 0.434$, $d = 0.08$, very small effect).

Even though the three-way interaction did not reach significance ($F(2{,}91) = 0.93$, $p = 0.400$, $\eta^2 = 0.020$, small effect), planned comparisons were used to investigate this interaction for each format separately because of its importance in assessing the effect of format on the insensitivity effect. Fig. 9 illustrates the interaction for each format.

Looking at the formats individually, there is evidence of the predicted pattern, though the differences between formats are small. The insensitivity-to-risk level effect is strongest in the single-item written format, with evidence of the trademark crossover interaction effect which Rottenstreich and Hsee (2001) found, and weakest in the graphical format. Analysis of this interaction between risk type and risk level in each of these formats supports this description of the degree of (in)sensitivity, with a significant interaction for the written format ($F(1{,}31) = 6.63$, $p = 0.015$, $\eta^2 = 0.176$, large effect), a medium-sized effect that misses significance for the table format ($F(1{,}28) = 2.95$, $p = 0.097$, $\eta^2 = 0.095$) and a small effect and nonsignificant interaction found in the graphical format ($F(1{,}32) = 0.47$, $p = 0.499$, $\eta^2 = 0.014$).

3.3. Study 2: Summary

Replicating Study 1's findings, Study 2 found: (1) perceptions of risk are higher for lung cancer than car crash risk; and (2) lower sensitivity to relative risk information in the cancer compared to car crash scenario. Additionally, format influenced risk perception. First, risk perceptions mapped more closely onto the probability information for the graphical and tabular formats; whereas, subtle differences in probability information (varying as a function of two features) were not clearly reflected in the risk perception ratings for the single-item condition. Second, the standard insensitivity-to-probability effect (with less impact of probability information for affect-rich scenarios) was seen in the single-item condition but was not significant in separate analyses of the other two conditions. However, some caution is called for in the interpretation of these differences between conditions because we did not observe the significant three-way interaction from which we would infer clear differences between the two-way interactions.

This may reflect a limitation arising from our sample size which, while providing excellent power to detect main effects and two-way interactions within-subjects, has much less power to detect three-way interactions involving a between-subjects factor with three levels.

4. GENERAL DISCUSSION

Research has shown that affective responses can influence perceived riskiness and that manipulating affect influences people's use of probability information. Extending this research, Studies 1 and 2 investigated how scenario type (affect rich vs. affect poor) affects risk perceptions when probability information is presented in a relative risk format. We examined how prior beliefs relate to risk perception in those scenarios, when probability information is identical across scenarios. Additionally, Study 2, examined how presentation format influences responses to this probability information.

Our prior beliefs questionnaire found that participants perceive lung cancer more negatively than car crashes: judging it more lethal and having consequences that are more difficult to live with. These beliefs map onto higher risk perception ratings for cancer than car crash. While we might expect such differences between events that differ in the degree of dread they engender (Slovic, 1987; Slovic, Flynn & Layman, 1991; Sandman, 1989, cited in Slovic et al., 2004) we should acknowledge that participants' beliefs may reflect reality (lung cancer may well be more lethal than car crashes) or quite reasonable personal utilities (people may prefer to live with the consequences of a car crash than those for lung cancer). Thus, there is nothing irrational about observing higher ratings for risk perception for lung cancer when risk is defined by perceived risk and safety, and the importance of managing risk.

However, we did see a difference between the lung cancer and car crash scenarios that is not so easily justified on the basis of objective differences or subjective utilities. Participants showed less sensitivity to probability information for the cancer scenario. This is similar to the *insensitivity-to-probability* effect, whereby people ignore or underweight probability information when making decisions about affect-rich stimuli (Hsee & Rottenstreich, 2004; Pachur et al., 2014; Petrova, Van de Pligt, & Garcia-Retamero, 2014; Rottenstreich & Hsee, 2001). However, the difference between scenario types in this regard was not consistently large. There could be several reasons for this: we used a relative risk format for the probability information (which had not been used before) and it may be that our two scenarios were not substantially different in the level of affect they elicit.

Importantly, Study 2 finds evidence that presentation format may moderate the degree of (in)sensitivity to probability information that people show. The patterns of risk perception responses were more closely aligned with the presented pattern of relative risk values for graphical and tabular formats (which presented multiple items of information), than for written formats that provided only one item of information. There was also some suggestion that insensitivity to probability information was more pronounced in the written format. Taken together, a format which allows people to see the patterns associated with the statistical data (either graphically or tabular) more clearly may help people grasp "gist" knowledge (Reyna, 2008; Reyna & Brust-Renck, 2014) which anchors their perceptions at an appropriate level. Our findings here should be taken with caution given the underpowered nature of Study 2 in detecting a three-way interaction, however similar relationships have been proposed (Lipkus & Hollands, 1999) and found for graphical displays (Leonhardt & Keller, 2018) and visual aids (Petrova et al., 2018). Thus, it may be that any format that presents the information simultaneously in an organized form aids risk communication. These findings have an intriguing parallel with data from Traczyk and Fulawka (2016) who found that participants with higher levels of numeracy were less susceptible to showing insensitivity to probabilities in the presence of choice-irrelevant affect. For choice relevant affect, we found that making numeric information easier to comprehend has the same effect as having better numeric skills.

Our findings have two inter-related implications for risk communication and assessment. First, while it is difficult to judge the appropriateness of any single risk assessment (not least because we asked participants for *subjective/personal* evaluations), insensitivity to probability information speaks to the appropriateness of the *relation between* assessments. If people are insensitive to event probabilities, it is likely that the evaluations of risks that differ only in their probabilities are more similar than they "should" be. Thus, relative to the evaluation of low-probability risks, people place insufficient importance on managing higher-probability risks; or, equivalently, relative to the evaluation of high-probability risks people give too much importance to managing lower-probability risks. Under such circumstances, at least one of these two evaluations seems inappropriate. Given the common tendency to overweight small probabilities (i.e., give relatively greater weight to rare outcomes in evaluations and decisions; Kahneman & Tversky, 1979; Prelec, 1998; Tversky & Kahneman, 1992), we think it more common that risk assessments/perceptions for low-probability events are overly negative, than that those for higher-probability events are overly positive. Therefore, anything that reduces insensitivity to probabilities provides an opportunity to make *sets* of risk assessments/perceptions more appropriate, which should encourage better resource allocation when managing multiple risks. Our data suggest that presenting information relevant to multiple assessments simultaneously (e.g., in tables or graphs) is one way to ameliorate insensitivity to probability—even when only one assessment is made.

Second, a common criticism of using relative frequency to communicate risk is that it generates unnecessary concern about extremely rare adverse events (Gigerenzer, 2002; Gigerenzer, Wegwarth, & Feufel, 2010). Learning that something "doubles your risk of death" seems shocking; but less so if one hears that the increase in probability is from 0.00001 to 0.00002. Arguably, a key problem with relative risk formats is that they isolate or decontextualize the relevant fact. Thus, one way to think about graphical and tabular formats is that they instate (some) context; providing points of comparison when evaluating something that increases the risk of an adverse outcome by (say) 20% or 40%. In keeping with this, when our participants had contextual information (in tables or graphs) they gave less negative evaluations for the "low risk" relative frequencies. The option to provide context through tables or graphs is valuable because sometimes it is difficult to specify the baseline risk as a probability (e.g., when many other relevant factors are unknown) and therefore relative risk is the main risk measure available.

Both these implications make sense in light of research on *evaluability* (Hsee, 1996, 1998) which suggests that decision attributes that are difficult to evaluate have limited impact on the decision (Hsee & Zhang, 2010). For example, some attributes of an option are much easier to evaluate when two options (having different values for that attribute) are presented together (joint evaluation) rather than separately (single evaluation). Thus, one interpretation of Study 2 is that the graphical and tabular formats provide context, making it easier to evaluate the probability information, and so increases the weight given to this probability information. Indeed, Hsee and Zhang (2010) proposed that probability weighting should be more linear (i.e. more sensitive to probabilities for most of the 0–1 range) in joint evaluation; though we believe this has only been confirmed in one paper (Hsee, Zhang, Wang, & Zhang, 2013). Thus, we have provided important new data relevant to this proposal.

5. LIMITATIONS AND FUTURE RESEARCH

Although within-subjects designs can be more powerful, they are susceptible to order effects. The potential impact of such order effects was reduced in three ways. First, by keeping stimuli from the same experimental set separate (i.e., by including filler items). Second, by randomizing the order of risk scenario presentation for each participant. Third, by using a visual-analogue scale instead of a numerical scale—making anchoring on previous responses less likely.

While we did not measure age and gender, we know that our recruitment methods produce a sample that was predominantly female and young adult. While these findings may be applicable across genders, such effects may be enhanced in one gender. Indeed, Murray and McMillian (1993) identified that while cancer is identified as the most feared disease, taken separately, women were more fearful of cancer than men.

Our findings illustrate some factors (e.g., affective content, format) that can result in different reactions to the same relative risk. This has parallels in research into reactions to information about absolute risk, where reference points or other aspects of context can result in different interpretations of the same objective probability (Windschitl, Martin, & Flugstad, 2002; Windschitl & Weber, 1999). Future research could directly examine whether a common set of factors affect the interpretation of absolute risk and relative risk, and whether susceptibility to such effects is a stable individual trait. Although we believe our findings are valuable, extending research on the insensitivity-to-probability effect to relative risk and different formats of presentation and showing consistent findings across two experiments, questions remain as to the generalizability or boundary conditions of the insensitivity-to-probability effect. This is evidenced by a recent failure to replicate one of Rottenstreich and Hsee (2001) key findings in a large-scale pre-registered replication (Klein, Vianello, & Hesselman, 2018). Indeed, data from our lab leads us to conjecture that the insensitivity-to-probability effect may only be apparent under specific conditions: we found no evidence of the effect in the data we collected alongside Study 2 in which we changed the type of cancer and accident in the scenarios (see Supporting Information).

Related to this, we believe that little is known about which component(s) of affect might be critical to the insensitivity-to-probability effect. For example, in our validation study, we used a measure of "dread" to assess the affect associated with car crash and lung cancer. Such a measure has been argued to reflect a more affective evaluation of risk rather than a cognitive one (Loewenstein et al., 2001) and has been shown to correlate well with implicit measures of affect (Dohle, Keller, & Siegrist, 2010). However, other measures of affect could have been chosen (e.g., worry, vividness). To assist with assessing the robustness of the insensitivity to probability effect for outcomes evoking different degrees of affect, we recommend that future research employs a range of measures of affect to determine whether specific components of affect are particularly important for the effect.

Finally, alternative explanations for the effects that we found remain a possibility. While we were able to check that these scenarios differed in affect, it is difficult to identify two events which differ *solely* on their levels of affect. For instance, these events may differ in whether a natural comparison baseline exists (e.g., 0 cigarettes in the case of smoking, with no obvious baseline for car travel). This may then affect risk perceptions because sensitivity to outcomes often decreases the further one gets from a reference point (Kahneman & Tversky, 1979). Alternatively, or additionally, the absolute risk may be different (or perceived to be different) between our scenarios, which could—in turn—affect the interpretation of relative risks. Therefore, important questions remain, and we see our results as *beginning the* exploration of the sensitivity to probability information expressed as relative risk, and how this might be affected by presentation format.

6. CONCLUSION

Our results support the proposal that for highly emotive risk events, perceptions of the risk are not only higher, but can show less sensitivity to probability information. Further, format appears to moderate this, with perceptions less in line with probability information in a written format that presents only one item of information at a time. These findings on format may be important for two reasons. First, most work on the insensitivity-to-probability effect focusses on such single-item probability formats (Rottenstreich & Hsee, 2001). However, it is important to investigate these effects in other formats and for other risk events to understand under what conditions such insensitivity is seen. Second, although sometimes one cannot avoid emotional terminology, Study 2 illustrates how graphical or tabular displays might be used to reduce insensitivity to probability information in such cases.

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Affiliations have changed for both authors since initial data collection. Data for Study 1 was collected while both authors were working in the Department of Psychology at the University of Essex, while Study 2 was conducted while both authors were working at the Department of Psychology at King's College London.

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