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The impact of numeracy on reactions to different graphic risk presentation formats: An experimental analogue study

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Objectives. Numeracy, the ability to process basic mathematical concepts, may affect responses to graphical displays of health risk information. Displays of probabilistic risk information using grouped dots are easier to understand than displays using dispersed dots. However, dispersed dots may better convey the randomness with which health threats occur, so increasing perceived susceptibility. We hypothesized that low numeracy participants would better understand risks presented using grouped dot displays, while high numeracy participants would have good understanding, regardless of display type. Moreover, we predicted that dispersed dot displays, in contrast to grouped dot displays, would increase risk perceptions and worry only for highly numerate individuals.

Design and method. One hundred and forty smokers read vignettes asking them to imagine being at risk of Crohn's disease, in a 2(display type: dispersed/grouped dots) × 3(risk magnitude: 3%/6%/50%) × 2(numeracy: high/low) design. They completed measures of risk comprehension, perceived susceptibility and worry.

Results. More numerate participants had better objective risk comprehension, but this effect was not moderated by display type. There was marginally significant support for the predicted numeracy × display type interaction for worry about Crohn's disease, but not for perceived susceptibility to the condition.

Conclusions. Dispersed dot displays somewhat increase worry in highly numerate individuals, but only numeracy influenced objective risk comprehension. The most effective display type for communicating risk information will depend on the numeracy of the population and the goal(s) of the communication.

Communicating probabilistic risk information is a key challenge for health professionals. Effective risk communication strategies are needed, so that individuals can make informed choices about their treatments and their health-related behaviours.

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The introduction of large population screening programmes in the UK and elsewhere, such as that for bowel cancer (NHS bowel cancer screening programme, 2007) and cardiovascular disease risk assessments (Joint British Societies, 2005) means that many more individuals will receive probabilistic risk information. Moreover, new technologies, such as genetic testing for predisposition to common diseases, create further demand for effective risk communication strategies.

This study was conducted to inform the design of participant information in a trial assessing the impact of genetic risk information on behaviour change (ISRCTN 21633644). Participants in the trial undergo risk assessments for Crohn's disease. Crohn's disease runs in families, individuals with an affected first degree relative having an elevated probability of developing the condition (Lewis *et al.*, 2007). Smoking also increases the likelihood that individuals at risk develop Crohn's disease (Selby, 2003). Learning that one is susceptible to Crohn's disease, but that stopping smoking reduces this risk, may motivate smokers to quit. However, the best way to communicate the probabilities involved has yet to be determined. In previous trials assessing the impact of genetic risk information on behaviour change, participants had difficulties comprehending the risk information (Lipkus, McBride, Pollak, Lyna, & Bepler, 2004).

Graphic displays are thought to facilitate probabilistic risk communication (Ancker, Senathirajah, Kukafka, & Starren, 2006). Graphic formats may make the perception of risk information easier for individuals, so decreasing the cognitive processing demands of the information. Reducing the cognitive effort required to use information in decision-making can lead to its greater use (Hibbard & Peters, 2003), and reduce judgment errors (Feldman-Stewart, Kocovski, McConnell, Brundage, & Mackillop, 2000).

Several studies have examined which graphic formats are most effective at communicating probabilistic risk information. Based on a recent review of these (Ancker *et al.*, 2006), it was decided to use icon arrays to communicate risk information. Icon arrays portray a risk using a group of individual icons such as dots, oblongs, or human figures. Such arrays have several desirable properties for risk communication. Firstly, individuals understand probabilities better when they are presented at the discrete level, rather than as proportions or percentages (Berry, 2004). Secondly, icon arrays allow individuals to view two or more probabilities expressed in terms of a common denominator. Comparing '4 in 1,000' to '1 in 1,000' is easier than comparing '1 in 250' to '1 in 1,000' (Cosmides & Tooby, 1996; Gigerenzer & Hoffrage, 1995).

Icon displays can make part to whole relationships clearly visible. When icons are arranged as a group, the ability to estimate what proportion object A fills of the larger object B appears to be automatic (Stone *et al.*, 2003). Alternatively, icons can be arranged so that those 'affected' appear randomly scattered throughout the array. Such dispersed icon displays may help convey the randomness inherent in health risks, so increasing perceived vulnerability to the health outcome, although there is an absence of evidence to support or refute this (Baty *et al.*, 1997; Schapira, Nattinger, & McHorney, 2001). However, dispersed icon displays make it difficult for viewers to estimate the proportion affected as this can only be estimated by counting, rather than by judging the proportion of the block area.

Several studies have compared the effects of different types of icon display. Participants who viewed grouped displays were more accurate at judging the larger of two risks, at estimating the magnitude of the difference between two probabilities and at judging the magnitude of a single probability (Feldman-Stewart *et al.*, 2000). In a study

examining the ability of grouped displays, dispersed displays and bar graphs to convey breast cancer risk information, participants perceived the magnitude of a 9% risk to be higher when it was presented using a dispersed icon display than when it was presented as either a grouped icon display or as a bar graph (Schapira, Nattinger, & McAuliffe, 2006).

Evidence that individuals may prefer grouped displays to dispersed displays comes from a focus group study (Schapira *et al.*, 2001), in which participants disliked dispersed displays because the only way to understand the magnitude of the probability was to count the affected icons. Therefore, while dispersed icon displays may increase perceived susceptibility to a condition and so potentially promote risk-reducing behaviour (Milne, Sheeran, & Orbell, 2000), participants' difficulties understanding such displays could result in the risk information not being comprehended, and so failing to motivate risk-reducing behaviour.

Numeracy and the communication of health risk information

One individual difference likely to affect reactions to graphic displays of probabilistic risk information is numeracy, 'the ability to process basic probability and numerical concepts' (Peters *et al.*, 2006b). There is considerable individual variation in numeracy. Even within a highly educated sample, up to 20% of participants had difficulty answering simple questions, such as choosing the option that represented the highest risk from three different proportions or percentages (Lipkus, Samsa, & Rimer, 2001). Numeracy may affect reactions to risk information for several reasons. People with high numeracy are more fluent in converting percentages to frequencies and vice versa. They may also experience more affect in response to numbers conveying probabilistic risk information, and may use this affect more in guiding their decisions (Peters *et al.*, 2006b). Affect can influence decision-making by serving as information (Clare, Gasper, & Garvin, 2001), individuals basing their decisions on how the alternatives make them feel. Alternatively, the extent and valence of affect can alter how the information is processed and thus influence decisions (Nabi, 1999; O'Keefe, 2002; Peters, Lipkus, & Diefenbach, 2006a).

Evidence suggests that numeracy may moderate reactions to probabilistic risk information and to graphic displays of such information. In a study of women's ability to apply information regarding the benefits of mammography to their estimated lifetime risk of breast cancer, women with high numeracy were more accurate in applying the risk reduction information, whereas less numerate participants overestimated the benefits of mammography to their lifetime cancer risk (Schwartz, Woloshin, Black, & Welch, 1997). Another study found that participants perceived risks of breast cancer as greater when presented with dispersed, compared to grouped, displays, but that this effect was more pronounced for individuals with low numeracy (Schapira *et al.*, 2006).

In presenting risk information to motivate behaviour change, the communication has two goals: to enable individuals to understand the size of the risk estimates provided; and to alter participants' perceived susceptibility to the condition in order to motivate risk-reducing behaviour change. Compared to grouped displays, dispersed displays may increase individuals' appreciation of the role of chance in whether adverse health outcomes occur and this may increase perceived susceptibility to these outcomes. However, because dispersed displays are harder to comprehend, this effect may be limited to numerate individuals.

The present study

The present study uses vignettes to investigate smokers' reactions to risk information about the likelihood of developing Crohn's disease, and how these reactions differ according to icon display type and participants' numeracy. The likelihood of developing Crohn's disease conditional on continued smoking was varied systematically, to examine the effects of display type at different levels of risk magnitude. We examine participants' subjective and objective understanding of the risk estimates contained in the vignette, their perceived likelihood of, and their worry about, developing Crohn's disease. Individual's appraisals of susceptibility to a health event are likely to be related to their levels of worry as worry can be regarded as an affective perception of likelihood (Klein & Stefanek, 2007). However, perceived likelihood and worry are only moderately correlated (Lipkus *et al.*, 2000), and both may make separate contributions to predicting motivation for health behaviours. As numerate individuals may be more subject to extracting affect from probabilistic risk information, they may experience more worry about their risk of Crohn's disease for a given risk magnitude than less numerate individuals. This may be moderated by display type. Dispersed displays, which highlight the role of chance in whether one develops Crohn's disease, may produce more affect. However, this effect may be restricted to more numerate participants, as it requires the ability to extract meaning from the more complex, dispersed display.

Hypotheses

- (1) Understanding of risk estimates
 - Grouped displays are easier to process than dispersed displays, leading to better understanding of risk estimates, an effect that will be stronger for people with low numeracy.
- (2) Perceived susceptibility to Crohn's disease
 - Higher magnitude risk estimates will lead to greater perceived susceptibility to Crohn's disease.
 - Dispersed displays will result in participants reporting greater perceived susceptibility to Crohn's disease than grouped displays, but this effect will be weaker for people with low numeracy.
- (3) Worry about developing Crohn's disease
 - Higher magnitude risk estimates lead to greater worry about developing Crohn's disease.
 - Dispersed displays will result in participants reporting greater worry about developing Crohn's disease than grouped displays, but this effect will be weaker for people with low numeracy.

Methods

Design

Participants were randomly allocated to read one of six vignettes, asking them to imagine being given information about their risk of Crohn's disease, in a 2(display type: dispersed or grouped) × 3(risk magnitude: 3, 6, or 50%) design. This study is part of a broader study that also examined the effects of risk provenance (genetic test vs. family history only). The results of the risk provenance manipulations are presented in a separate paper (Wright, Takeichi, Whitwell, Hankins, & Marteau, 2008).

Vignettes

To reflect potential clinical applications of genetic testing for Crohn's disease, each vignette asked participants to imagine that they had a sibling with Crohn's disease, and provided information about the condition's symptoms. Participants imagined undergoing a risk assessment, to ascertain their own risk of developing Crohn's disease. They were then presented with their hypothetical risk assessment results. To understand the probabilities involved, participants imagined 1,000 smokers with the same result, who also had sibling with Crohn's disease. Depending on the magnitude condition, participants were told 30 (3% risk), 60 (6% risk), or 500 (50% risk) of the 1,000 people were expected to develop Crohn's disease. This was illustrated in a 40×25 array of dots. In the grouped display conditions, a triangular section, starting at the bottom right-hand corner of the array, of the same number of dots as people expected to develop Crohn's disease, was coloured in. In the dispersed display conditions, the same number of dots was coloured as in the grouped display conditions, but the coloured dots were dispersed throughout the entire display. In all conditions, participants were informed that stopping smoking could halve their risk, and this was illustrated. Finally, participants learnt that in the general population about one in 1,000 people are expected to develop Crohn's disease. The full vignettes are shown in the Appendix.

Measures

Objective risk comprehension was assessed by asking participants: 'Which of the three sets of risk figures you were given was the biggest risk and which was the smallest risk?' with the options 'my chances of developing Crohn's disease', 'my chances of developing Crohn's disease if I stopped smoking', and 'the general population chance of Crohn's disease'. In all conditions, the correct responses were that the general population chance of Crohn's disease was the smallest and the chance of developing Crohn's disease was the biggest.

Subjective ease of understanding was assessed using a single item, 'How easy did you find it to understand the information we gave you about the chances of developing Crohn's disease?' rated 1: 'very difficult' - 7: 'very easy'.

Perceived susceptibility to Crohn's disease was assessed using three items, reflecting different aspects of perceived susceptibility (Weinstein, 1998). *Susceptibility conditional on continued smoking* was assessed using 'If you continue to smoke, how likely do you think it is that you will develop Crohn's disease?' rated 1: 'not at all' - 7: 'extremely likely'. *Susceptibility conditional on quitting smoking* was assessed using 'If you stop smoking, how likely do you think it is that you will develop Crohn's disease?' rated 1: 'not at all' - 7: 'extremely likely'. *Susceptibility relative to other smokers* was assessed using 'Compared to other smokers the same age as you, what do you think your chance of developing Crohn's disease is?' rated: 1: 'a lot more', 2: 'more', 3: 'average', 4: 'less', 5: 'a lot less'.

Worry about developing Crohn's disease was assessed using 3 items ($\alpha = .96$) (Cameron & Diefenbach, 2001): 'To what extent are you worried about getting Crohn's disease?', 'To what extent are you concerned about getting Crohn's disease?', and 'To what extent are you afraid of getting Crohn's disease', all rated 1: 'not at all' - 7: 'extremely'.

Numeracy was assessed using eight items developed by Lipkus and his colleagues (2001).

Demographic information and smoking behaviour

Participants were asked their age, gender, and educational qualifications. Nicotine dependence was assessed using the Heaviness of Smoking Index (HSI; Heatherton, Kozlowski, Frecker, Rickert, & Robinson, 1989).

Participants

The Research Ethics Committee of a UK university approved the study. One hundred and forty adult smokers, who did not have Crohn's disease, were recruited from a market research agency's nationally representative internet panel. Panel members complete surveys in return for 'points' that are exchangeable for consumer goods. Participants received 10 'points' (approximate monetary value £1). This sample size is sufficient to detect medium-sized (0.5 *SD*) main effects and interactions with a type I error rate of 0.05 and a type II error rate of 0.8.

Sixty-one (43.6%) men and 79 (56.4%) women participated. Their mean (*SD*) age was 44.3 (13.5) years. Twelve (8.6%) had no formal educational qualifications, 30 (27.9%) had qualifications usually completed at age 16 (GCSEs/O Levels), 34 (24.3%) had qualifications usually completed at age 18 (A Levels or further education qualifications) and 46 (32.9%) had a University degree. Nine participants had other qualifications. Their mean (*SD*) HSI score was 2.6 (1.6), indicating a moderate level of nicotine dependence.

Procedure

Panel members were e-mailed a URL that linked to the survey. Participants first completed the demographic and smoking behaviour items. Next, they read one of the six vignettes, randomly allocated by the website software. Participants then completed the main questionnaire, which began by assessing risk perceptions, then worry, perceived ease of understanding, objective understanding, and finished with the numeracy items. While responding to the questionnaire, participants could choose to view the risk information again, in a separate window.

Analyses overview

The effects of display type and numeracy on subjective ease of understanding were assessed using ANOVA. The effects of display type and numeracy on objective risk comprehension were assessed using logistic regression (Jaccard, 2001). The interaction term's ability to significantly contribute to the prediction of risk comprehension was tested using a hierarchical regression strategy. For the perceived risk measures and worry, the effects of display type, risk magnitude, numeracy and their interactions were examined using ANOVA. Significant interactions were probed using simple main effects analysis, employing a Sidak adjustment for multiple comparisons. As dichotomizing scales to create a two level factor may yield misleading results (MacCallum, Zhang, Preacher, & Rucker, 2002), we did not dichotomize the numeracy scale using a median split on the total scores. Instead, we subjected the items to psychometric analysis, and then used the best discriminating item as a marker of numeracy.

Results

Numeracy levels in this sample

Table 1 shows the proportions of participants answering each numeracy item correctly. The median score was seven, as it was in Lipkus *et al.*'s (2001) sample.

Table 1. Proportion of correct responses to the numeracy scale made by the 140 participants, in relation to the findings of Lipkus *et al.* (2001)

Item	Percentage (N) answering correctly (N = 140)	Percentage of participants answering correctly in Lipkus <i>et al.</i> 's (2001) study
Which of the following numbers represents the biggest risk of getting a disease: 1 in 100 risk of getting a disease/1 in 1,000 risk of getting a disease/1 in 10 risk of getting a disease	58.6 (82)	78.2
Which of the following numbers represents the biggest risk of getting a disease: 1% risk of getting a disease/10% risk of getting a disease/5% risk of getting a disease	76.4 (107)	83.6
If person A's risk of getting a disease is 1% in 10 years, and person B's risk is double that of A's, what is B's risk?	85.7 (120)	90.5
If person A's chance of getting a disease is 1 in 100 in 10 years, and person B's risk is double that of A's, what is B's risk?	77.1 (108)	86.6
If the chance of getting a disease is 10%, how many people would be expected to get the disease out of 100?	88.6 (124)	80.8
If the chance of getting a disease is 10%, how many people would be expected to get the disease out of 1,000?	87.9 (123)	77.5
If the chance of getting a disease is 20 out of 100, this would be the same as having a ___% chance of getting the disease	76.4 (107)	70.4
The chance of getting a viral infection is .0005. Out of 10,000 people, about how many of them are expected to get infected?	50.7 (71)	48.6

However, the participants performed differently on the items, being less likely to correctly answer items 1–4, but more likely to correctly answer items 5–7 and somewhat more likely to answer item eight correctly. Psychometric analysis¹ of the scale revealed that the first item had the highest variance ($SD = 0.49$) and a good item-total correlation ($r = .62$). This item also had the second highest difficulty score (0.59) (where difficulty is defined as the mean item score and thus, for a dichotomous item, the proportion of participants getting it right), the highest discrimination value (0.83) (Allen & Yen, 1979), indicating that it was the best item for discriminating between the top third and bottom third of total scores on the numeracy measure, and a very good value for Ferguson's delta for discrimination (0.97) (Hankins, 2007). Therefore, participants who answered this item correctly were treated as having higher numeracy, while those who did not were considered to have lower numeracy.

¹ Full details of the psychometric analysis of the numeracy scale are available from the first author upon request.

The high and low numeracy groups did not differ in terms of mean age, nicotine dependence, the proportions of men and women they contained or in terms of highest educational qualification. This latter finding echoes Lipkus *et al.*'s (2001) observation that even individuals with university-level education may not be highly numerate.

Effects of display type and numeracy on subjective ease of understanding

Mean subjective ease of understanding scores were high across all groups, ranging from 5.3 ($SD = 1.8$) in the dispersed display, low numeracy condition to 5.7 ($SD = 1.4$) in the grouped display, high numeracy condition. Neither display type ($F(1, 136) = 0.05$, $p = .82$, partial $\eta^2 < .001$), numeracy ($F(1, 136) = 1.15$, $p = .29$, partial $\eta^2 = .008$) nor their interaction ($F(1, 136) = 0.35$, $p = .55$, partial $\eta^2 = .003$) significantly influenced subjective ease of understanding.

Effects of display type and numeracy on objective risk comprehension

Table 2 shows the results of the logistic regression predicting risk comprehension. The percentages of participants responding correctly are shown in Table 3 and illustrated in Figure 1. Adding the display type \times numeracy interaction term to the model predicting correct comprehension did not improve its fit at a statistically significant level, $\chi^2(1) = 1.55$, $p = .21$. Display type did not significantly influence the odds of participants having correct objective risk comprehension. The coefficient for numeracy in Table 2 means that the odds of having good objective understanding for high numeracy individuals are nearly four times the odds of having good comprehension for low numeracy individuals. This effect is conditioned on the moderator variable (display) being equal to zero, and so applies only to participants who viewed a grouped display. If the display variable is recoded, with zero corresponding to the dispersed display condition, then the odds ratio for numeracy is 10.2. This indicates that when individuals saw a dispersed display, the odds of participants with high numeracy responding correctly were 10 times the odds of participants with low numeracy responding correctly. The coefficient for the interaction term reflects the ratio of these two odds ratios. That the interaction coefficient is not significant indicates that this ratio of ratios does not differ significantly from one. In summary, while numeracy influences objective risk comprehension, display type does not moderate its impact.

Table 2. Logistic regression predicting objective risk comprehension

	Odds ratio	95% C.I. for odds ratio		<i>p</i>
		Lower	Upper	
Display type	0.442	0.152	1.284	.134
Numeracy	3.830	1.301	11.280	.015
Display type \times numeracy	2.663	0.567	12.517	.215
Constant	1.077			.847

Note. Dummy variable coding was as follows: Display type: grouped = 0, dispersed = 1; Numeracy: low numeracy = 0, high numeracy = 1.

Table 3. Proportions of participants correctly responding to the risk comprehension item, by numeracy and display type

Numeracy	Display type		Response	
			Correct	Incorrect
Lower	Dispersed	<i>N</i>	10	21
		%	32.3	67.7
	Grouped	<i>N</i>	14	13
		%	51.9	48.1
Higher	Dispersed	<i>N</i>	34	7
		%	82.9	17.1
	Grouped	<i>N</i>	33	8
		%	80.5	19.5

The effects of display type, risk magnitude and numeracy on risk perceptions and worry

Table 4 shows mean scores by experimental group for perceived susceptibility and worry. Table 5 details the ANOVA results for these variables.

For perceived risk conditional on continued smoking, the predicted main effect of risk magnitude was not significant. Instead, a significant risk magnitude \times numeracy interaction was observed. When numeracy was low, risk magnitude did not affect risk perceptions (simple main effect (SME) of magnitude at low numeracy, $F(2, 128) = 1.267$, $p = .285$, partial $\eta^2 = .019$). However, when numeracy was higher, risk magnitude influenced perceived risk more strongly, although the SME was only marginally significant ($F(2, 128) = 2.369$, $p = .098$, partial $\eta^2 = .036$). Sidak-adjusted pairwise comparisons showed that, among individuals with high numeracy, those in the 50% risk condition perceived greater susceptibility than those in the 3% risk condition.

For risk relative to other smokers, there was a marginally significant main effect of numeracy: participants with high numeracy perceived themselves as more at risk of

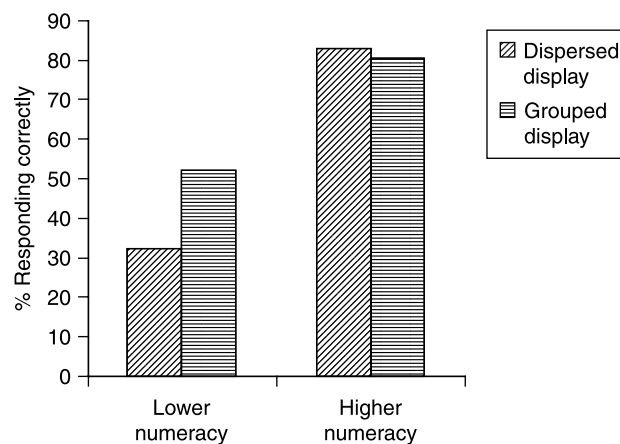
**Figure 1.** Proportions of participants providing a correct response to the objective risk comprehension item, according to numeracy and display type.

Table 4. Perceived susceptibility and worry (mean (SD)), according to display type, risk magnitude, and numeracy level

Variable	Numeracy	Display	3%	6%	50%
Risk conditional on continued smoking (1–7)	Lower	Dispersed	4.00 (1.70)	3.75 (1.76)	3.89 (1.27)
		Grouped	5.00 (1.26)	4.11 (1.76)	3.67 (0.89)
	Higher	Dispersed	3.64 (1.15)	4.42 (1.16)	4.53 (1.36)
		Grouped	3.67 (1.33)	3.69 (1.44)	4.40 (1.35)
Risk conditional on quitting smoking (1–7)	Lower	Dispersed	2.80 (1.23)	2.67 (1.23)	2.33 (1.00)
		Grouped	3.33 (0.82)	2.56 (1.13)	2.58 (1.62)
	Higher	Dispersed	2.71 (0.91)	2.75 (0.75)	2.87 (1.30)
		Grouped	2.56 (1.20)	2.54 (0.88)	2.60 (1.07)
Risk relative to other smokers (rated 1: a lot more – 5: a lot less)	Lower	Dispersed	2.90 (1.10)	2.42 (0.79)	3.11 (0.33)
		Grouped	2.17 (0.98)	3.22 (1.20)	3.00 (0.74)
	Higher	Dispersed	2.64 (0.50)	1.92 (0.79)	2.40 (1.06)
		Grouped	2.78 (1.17)	2.92 (0.86)	2.50 (0.97)
Worry (1–7)	Lower	Dispersed	2.93 (2.14)	3.22 (1.52)	3.59 (2.32)
		Grouped	4.06 (2.34)	3.67 (1.31)	3.75 (1.22)
	Higher	Dispersed	3.57 (1.79)	3.75 (1.63)	4.40 (1.69)
		Grouped	3.31 (1.77)	3.74 (1.60)	3.20 (1.79)

Crohn's disease relative to other smokers (mean = 2.53, where low scores indicate greater perceived risk) than did participants with low numeracy (mean = 2.80). There was also a significant risk magnitude \times display type interaction. SMEs analysis showed that display type did not significantly influence relative risk perceptions for participants in the 3% group (mean relative risk = 2.77 for dispersed display, 2.47 for grouped display, SME of display $F(1, 128) = 1.09, p = .30$, partial $\eta^2 = .008$) or those in the 50% group (mean relative risk = 2.76 for dispersed display, 2.75 for grouped display, $F(1, 128) < 0.001, p = .984$, partial $\eta^2 < .001$). However, participants who received a 6% risk estimate, and saw a dispersed display had significantly stronger relative risk perceptions (mean = 2.17, where low scores indicate greater perceived risk) than those viewed the same risk magnitude illustrated by a grouped display (mean = 3.07, SME of display $F(1, 128) = 11.03, p = .001$, partial $\eta^2 = .079$).

Perceived susceptibility conditional on quitting was not significantly predicted by any of the factors in the model, or their interactions.

For worry about developing Crohn's disease, the interaction between display type and numeracy attained marginal statistical significance and is illustrated in Figure 2. Inspection of means suggested that, in line with predictions, dispersed displays caused more worry for highly numerate participants than for less numerate participants, while the difference between more and less numerate participants viewing a grouped display was smaller, and in the other direction. However, neither of the SMEs was statistically significant (SME of numeracy for dispersed displays: $F(1, 128) = 2.47, p = .118$, partial $\eta^2 = .019$; SME of numeracy for grouped displays: $F(1, 128) = 0.814, p = .369$, partial $\eta^2 = .006$).

Discussion

This study examined the effects of numeracy and display type on reactions to risk information about Crohn's disease. The first hypothesis was that grouped displays would be

Table 5. Results of risk magnitude \times display type \times numeracy ANOVAs on risk perceptions and worry

Variable	Effect	df^a	F	p	Partial η^2
Risk conditional on continued smoking	Magnitude	2	0.102	.903	.002
	Display type	1	0.044	.834	<.001
	Numeracy	1	0.002	.964	<.001
	Magnitude \times display type	2	0.877	.418	.014
	Magnitude \times numeracy	2	3.331	.039	.049
	Display type \times numeracy	1	1.842	.177	.014
	Magnitude \times display type \times numeracy	2	0.608	.546	.009
Risk conditional on quitting	Magnitude	2	0.625	.537	.010
	Display type	1	0.001	.977	<.001
	Numeracy	1	0.043	.837	<.001
	Magnitude \times display type	2	0.251	.778	.004
	Magnitude \times numeracy	2	1.049	.353	.016
	Display type \times numeracy	1	1.194	.277	.009
	Magnitude \times display type \times numeracy	2	0.194	.824	.003
Risk relative to other smokers	Magnitude	2	0.304	.738	.005
	Display type	1	1.554	.215	.012
	Numeracy	1	2.948	.088	.023
	Magnitude \times display type	2	5.132	.007	.074
	Magnitude \times numeracy	2	2.059	.132	.031
	Display type \times numeracy	1	1.761	.187	.014
	Magnitude \times display type \times numeracy	2	0.457	.634	.007
Worry about Crohn's disease	Magnitude	2	0.248	.781	.004
	Display type	1	0.020	.887	<.001
	Numeracy	1	0.170	.681	.001
	Magnitude \times display type	2	0.886	.415	.014
	Magnitude \times numeracy	2	0.109	.897	.002
	Display type \times numeracy	1	3.002	.086	.023
	Magnitude \times display type \times numeracy	2	0.254	.776	.004

^a $df_{\text{error}} = 128$ for all analyses.

easier to understand than dispersed displays, an effect that would be particularly pronounced for individuals with low numeracy. The results for subjective understanding did not support this hypothesis. Responses to the subjective understanding measure may be affected by social desirability bias, participants being unwilling to admit to comprehension difficulties. Also, the item asked about understanding of the risk information in general terms, rather than specifically about understanding of the probabilities. Even participants who had difficulty understanding the numerical risk estimates may have felt that, overall, they understood the vignette well, and responded accordingly. Future studies should frame subjective ease of understanding questions to be more specific regarding the part(s) of the risk information about which participants should rate their subjective comprehension.

The results for objective risk comprehension also failed to support the hypothesis. Less numerate participants were less likely to correctly answer the objective risk comprehension item, but this effect was not modified by display type. Neither display type enabled less numerate participants to understand the risk information as well as did more numerate participants. The ability of other display types to facilitate probabilistic

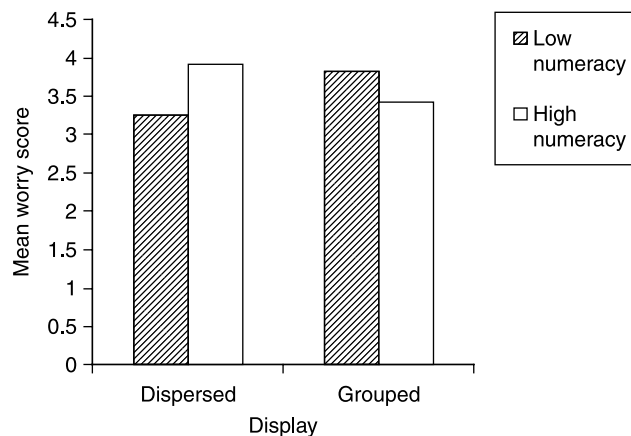


Figure 2. Mean worry scores, according to numeracy and display type.

risk comprehension in individuals with low numeracy requires investigating. The discrepancy in the effect of numeracy between subjective and objective risk comprehension echoes previous findings that participants' subjective levels of confidence in their ability to use medical statistics were only weakly correlated with their objective understanding (Woloshin, Schwartz, & Welch, 2005).

For perceptions of susceptibility to Crohn's disease, two effects were predicted. The first was an interaction between display type and numeracy, dispersed displays resulting in greater perceived susceptibility than grouped displays, but this effect being weaker for less numerate participants. However, this interaction was not significant for any of the perceived susceptibility variables. It appears that when grouped and dispersed icon displays are presented alongside written descriptions of the probabilities, neither type of display influences risk perceptions. There was limited evidence that numeracy alone influenced perceived susceptibility. More numerate participants reported greater risk relative to other smokers than did less numerate participants. However, this difference was only marginally statistically significant. More numerate participants may have been more able to use the probabilities presented in the vignettes to guide their responses to the susceptibility items than were less numerate participants. Given that all participants were told that their risks were greater than that of the general population, perceiving higher susceptibility relative to others seems a rational response by numerate participants to the vignette probabilities.

The predicted main effect of risk magnitude on perceived susceptibility was not significant for any of the susceptibility items. However, there was a significant interaction between risk magnitude and numeracy on perceived susceptibility conditional on continued smoking, the type of susceptibility perception probably most likely to be affected by the risk information presented. More numerate participants appeared to be influenced by the risk magnitudes presented in the vignettes, while less numerate participants were not. Therefore, the lack of significant main effects of risk magnitude may be due to there being considerable variance in the extent to which more and less numerate participants' susceptibility perceptions were influenced by the vignette probabilities, with this variance then resulting in the main effect of risk magnitude not being statistically significant.

There was also a significant interaction between risk magnitude and display on susceptibility relative to other smokers, display type only making a difference to relative

risk individuals in the 6% group. From a psychological standpoint, it is unclear as to why display type only influenced relative risk for this particular risk magnitude. Further work should explore the effects of display types at different levels of risk magnitude.

Finally, for worry about Crohn's disease, two effects were predicted. The first was an interaction between display type and numeracy, dispersed displays resulting in greater worry than grouped displays, but this effect being weaker for less numerate participants. This interaction was marginally significant. As predicted, the dispersed displays were associated with greater worry in more numerate participants than in less numerate participants. However, contrary to prediction, grouped displays were associated with greater worry in less numerate participants, although the absolute magnitude of this difference between the two numeracy groups was not as pronounced as that for dispersed displays. Given that the interaction between numeracy and display type was only marginally significant, it requires replication. However, we might consider these findings reason to build tentatively on Peters *et al.*'s (2006b) suggestion that highly numerate individuals are more sensitive to the affective meaning of probabilistic risk information, to also suggest that highly and less numerate individuals' ability to extract affective meaning from probabilistic risk information may vary according to how that information is presented.

The predicted significant main effect of risk magnitude on worry was not observed. Although there was a linear increase in mean worry scores across the three levels of risk magnitude, the differences were small. Emotional responses to vignettes may be less strong than those to real-world health risk information. Future studies should investigate whether the effects of display type, risk magnitude and numeracy on worry are stronger in clinical contexts.

Strengths and limitations of the current study and recommendations for further research

This is one of the first studies to examine whether numeracy moderates cognitive and emotional responses to risk estimates presented using different graphical formats. The study benefits from using a sample with a wider range of educational backgrounds than has hitherto been the case (Lipkus *et al.*, 2001) and so the results may better generalize to patient populations. While the smoking behaviour of participants in this study was very similar to that of British smokers in general (Goddard, 2006), the internet-based recruitment strategy may have disproportionately excluded socially deprived individuals. Future research should attempt to examine the relationship between numeracy and reactions to graphical displays of probabilistic risk information in such populations.

Using vignettes allowed participants to be allocated to different risk magnitudes, regardless of their smoking behaviour, so removing one potential confound in studies of reactions to health risk information (Croyle, Sun, & Hart, 1997). However, vignettes are obviously only representations of real-life situations, albeit representations intended to focus attention on the experimental constructs of interest. The extent to which these results generalize to individuals receiving probabilistic risk information in clinical contexts remains to be seen.

There are several issues with the measures employed in this study. Items assessing worry were not conditional on continued smoking. Although worry is often assessed in this manner (Cameron & Diefenbach, 2001), measurement error may have been inadvertently introduced into the worry measure, some participants reporting lower levels of worry about Crohn's disease because they planned to quit smoking in the near

future, but others reporting worry about developing Crohn's disease contingent on continued smoking. We operationalised numeracy using the item that best discriminated individuals with high and low total numeracy scores in our sample. This introduces a small additional degree of measurement error into the analyses, which may be partly responsible for the lack of significant effects of numeracy. However, many of the effect sizes associated with numeracy were small, and unlikely to attain statistical significance in this sample, even if numeracy was measured more precisely. A further limitation was that, to reduce response burden, many constructs were assessed using single items. Further studies should use multiple items to assess both risk perceptions and risk comprehension. Finally, we operationalised perceived susceptibility in several different ways and performed ANOVAs on each item, potentially inflating the family wise type I error rate. Therefore, some of the significant effects observed may be due to type I error. However, if future studies replicate these findings, we would be more confident in our conclusions.

How should probabilistic risk information be displayed?

Dispersed displays did not consistently increase perceptions of susceptibility to Crohn's disease. There was only marginally significant evidence that they caused greater worry than grouped displays in more numerate participants. Therefore, any benefit of display type for motivating behaviour change may be limited to numerate individuals. Display type also failed to facilitate risk comprehension. Given these findings, further research is required before we can confidently recommend a particular display type for communicating probabilistic risk information. In particular, the triangular grouping of icons in this study differs from the linear grouping of icons used in other studies (Feldman-Stewart *et al.*, 2000). Pilot work suggested that individuals preferred this triangular grouping, but further research should compare these two types of grouped displays.

Finally, the current study focused on a situation where the goal was to increase perceptions of susceptibility. The optimal display to employ when probabilistic risk communications are intended either to promote informed choices between treatment options, or to reduce over-exaggerated perceptions of susceptibility, remains an empirical question. Health professionals wishing to communicate probabilistic risk information to their patients need to consider the target population and the goal(s) of the communication when deciding which graphical display to employ.

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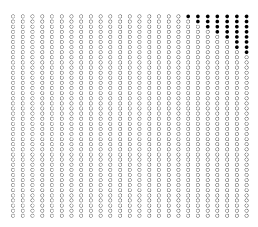
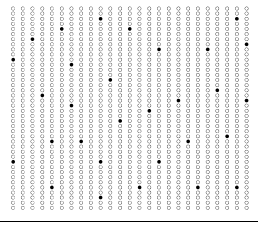
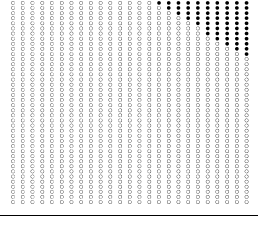
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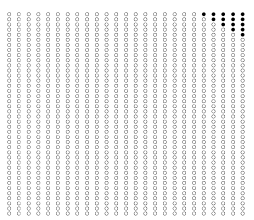
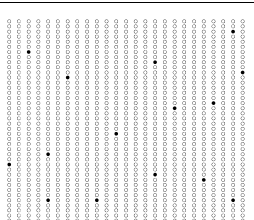
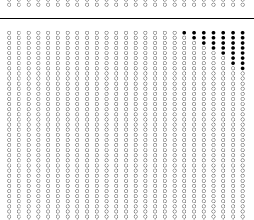
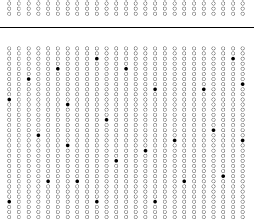
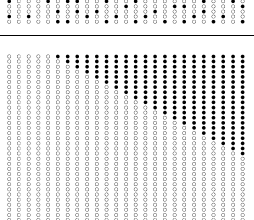
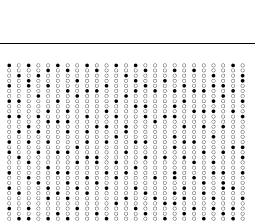
Appendix. The vignettes used in the study

	Gene positive	Gene negative	Family history
Introduction	Picture yourself in the situation described below. Try to imagine as clearly as possible how you would think and feel if you were actually in the situation		
Disease information	Imagine that you have a sister or brother who has Crohn's disease <ul style="list-style-type: none"> • Crohn's disease affects the gut • It tends to run in families and is more common in smokers • Symptoms include abdominal pain, diarrhoea, fever, loss of appetite, and weight loss. There is no cure for the disease. The symptoms can be treated by medication but most patients will in time need surgery • The symptoms are so serious that some people with Crohn's disease cannot work or go out 		
Scenario	Your doctor offers you a risk assessment, using a genetic test to find out your risks of developing Crohn's disease	(identical to that used in gene positive condition)	Your doctor offers you a risk assessment, using the information about your family history to find out your risks of developing Crohn's disease
Test result	You agree to have this genetic test Your doctor tells you that the result of your genetic test shows that you have a version of a gene that increases your risk of developing Crohn's disease	Your doctor tells you that the result of your genetic test shows that you do not have a version of a gene that increases your risk of developing Crohn's disease	Your doctor tells you your risk of developing Crohn's disease from your risk assessment based on your family history
Risk estimate*	3% 6% 50%	3% 6% 50%	3% 6% 50%

*The details of this element of the vignette are shown in the next table.

Details of how the different risk estimates were communicated

Risk magnitude	3%	6%	50%
	To understand your risks Imagine 1000 people: <ul style="list-style-type: none">• With the same genetic test result, and• Who smoke, and• Who have a brother or sister with the disease		
	30 out of these 1000 people are expected to develop Crohn’s Disease. This is shown in the picture below	60 out of these 1000 people are expected to develop Crohn’s Disease. This is shown in the picture below	500 out of these 1000 people are expected to develop Crohn’s Disease. This is shown in the picture below
Your chance of Crohn’s Disease			
	Your doctor informs you that if you stop smoking your risk would be cut in half to 15 per 1000. This is shown in the picture below	Your doctor informs you that if you stop smoking your risk would be cut in half to 30 per 1000. This is shown in the picture below	Your doctor informs you that if you stop smoking your risk would be cut in half to 250 per 1000. This is shown in the picture below

Your chance of Crohn's Disease if you stopped smoking						
	In the general population about 1 in 1000 people are expected to develop Crohn's Disease. This is shown in the picture below.	In the general population about 1 in 1000 people are expected to develop Crohn's Disease. This is shown in the picture below.	In the general population about 1 in 1000 people are expected to develop Crohn's Disease. This is shown in the picture below.	In the general population about 1 in 1000 people are expected to develop Crohn's Disease. This is shown in the picture below.	In the general population about 1 in 1000 people are expected to develop Crohn's Disease. This is shown in the picture below.	In the general population about 1 in 1000 people are expected to develop Crohn's Disease. This is shown in the picture below.
The general population chance of Crohn's Disease	