Effect of Risk Communication Formats on Risk Perception Depending on Numeracy

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Objective. *To examine the influence of numeracy on interpreting various risk communication formats.* ***Design.*** *A random sample of women (N = 266) completed a questionnaire assessing numeracy and risk perception of prenatal test results and results of colon cancer screening tests. The authors examined the relationships between risk level (high v. low) and format of risk presentation (ratio, pictogram, or Paling Perspective Scale) and whether these relationships differed based on the numeracy skills of the participant.* ***Results.*** *The authors identified a significant (P < 0.001) 3-way interaction between format, risk level, and numeracy: high-numerate participants in the low-risk group perceived the test results as less risky compared with participants in the high-risk group (P < 0.001) with the Paling Perspective Scale but not with the other formats. For low-numerate participants, they did not observe differences between low- and high-risk scenarios for any of the 3 formats. The results were similar for the Down syndrome and colon cancer scenarios. Overall, the pictogram resulted in significantly lower risk ratings compared with the Paling Perspective Scale and the ratio with numerator 1 (P < 0.001).* ***Conclusion.*** *Different communication formats may produce different risk perceptions, but the effect is qualified by patients' numeracy skills.* ***Key words:*** *numeracy; risk perception; risk communication; prenatal tests; colon cancer.* ***(Med Decis Making 2009;29:483–490)***

One important goal of risk communication in the medical context is to provide laypeople with risk information obtained through screening procedures and diagnostic tests. Comprehension of risk information is a precondition of informed decision making. It requires some numerical ability.[1] People who lack numerical ability are susceptible to poor decision making because they might not understand quantitative information given by their physician.

There are several types of information and different numerical and graphical formats that can be used to convey statistical information to patients.[2] To date, there has been little research on how different formats influence laypeople's risk perception depending on their numeracy skills. The goal of our study was to examine whether 3 formats that are often used or have been proposed for communicating health risks to laypeople evoke similar risk perceptions in low- and high-numerate individuals.

FORMATS IMPROVING COMPREHENSION OF RISK INFORMATION

Research comparing various risk communication formats indicates that people understand numerical information better when it is expressed as frequencies rather than as probabilities.[3–6] These results were challenged by recent studies. In one study, participants estimated the probability that a positive screening test result meant that a baby actually had Down syndrome. The presentation of frequencies and percentages evoked few correct answers in either format.[7] In another study, participants were confronted with a hypothetical tradeoff situation in which a treatment would decrease one risk but increase another. They had to assess whether the treatment would increase or decrease the total risk. The percentage format evoked more correct answers than the frequencies format.[8]

Visual and graphical presentation of test results, as, for example, the Paling Perspective Scale and the

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pictogram, are other formats that have been recommended for improving risk communication.[2,9–12] The Paling Perspective Scale[12–14] is a graphical representation that depicts risks covering different orders of magnitude on a logarithmic scale. It differs from other graphical formats by presenting information for other risks. The presentation of comparative risk information should help patients to evaluate a particular risk. A recent study[15] compared the Paling Perspective Scale with a numerical presentation of risk comparisons. Results indicated that the provision of comparative information, and not the graphical presentation of the information, was the reason why higher risks evoked higher levels of perceived risk compared with lower risks. The evaluability hypothesis[16,17] supplies an explanation for these results. Participants may not know whether a risk presented singly is high or low. Providing information about other risks makes it easier to evaluate the magnitude of a risk. It should be noted, however, that the selection of risks might substantially influence risk perception. It is important, therefore, to at least provide comparisons between homogeneous risks that all refer to the same topic.[15]

Mathematical skills may facilitate the understanding of graphical presentations. We presume that some numeracy skills are necessary for understanding the Paling Perspective Scale, for example. Before we describe the rationale for the present study, we review the relevant research on numeracy and risk communication.

NUMERACY AND COMPREHENSION OF RISK COMMUNICATION FORMATS

Numeracy is defined as the ability to process basic probability and numerical concepts.[1,18] People differ substantially in numerical abilities, and many people are innumerate.[19,20] Highly numerate individuals were found to be more likely to pay attention to numbers, to better comprehend numbers, to draw more precise affective meaning from numbers and to be less influenced by framing effects than low-numerate individuals.[1] The higher the numeracy skills, the more consistent were risk judgments for both probability and frequency presentation formats indicating the risk of having breast cancer.[21] Although all women tended to overestimate their risk of having breast cancer, women with high numeracy skills overestimated their risk less than innumerate women.[22]

Due to the difficulties in comprehending numbers, it recently has been suggested that graphical displays be used when presenting risk information to low-numerate individuals.[2] Few studies have examined the influence of numeracy on the comprehension of graphical formats, however. A comparison between the ratio format with numerator 1 and the magnifier scale—a graphical format that features a magnifying glass to represent probabilities between 0 and 1% on a logarithmic scale—showed that low-numerate individuals were better able to comprehend the graphical than the numerical format.[23] In another study, low-numerate individuals were found to have difficulties in comprehending graphical displays. Low-numerate individuals were less able than high-numerate individuals to recall information about risks with high probabilities presented textually or in pictographs; they were also less able to comprehend risk information displayed in survival curves.[24] To improve risk communication with low-numerate individuals, some researchers have recommended that as little information as possible be presented, with symbols used to qualify outcomes as good or bad with regard to a particular criterion. This should make important numbers easier to evaluate and reduce cognitive effort.[25,26]

RATIONALE FOR THE STUDY

The evaluation of different risk communication formats is a difficult task. In some studies, participants using different formats (e.g., frequencies and probabilities) had to solve mathematical tasks, and the number of correct answers was used as the evaluation criterion (e.g., see Gigerenzer and Hoffrage[3]). Other studies used the number of missing answers as an indicator of comprehension.[23] In the present study, we focus on the influence of communication formats on risk perception. Although it is not possible to determine whether a certain format evokes the ''true'' level of concern, a test can be conducted on whether various levels of risk evoke different levels of perceived risks. Employing a random sample of the general population, the 1st goal of the present study was to examine the influence of numeracy on the perception of risks that are presented as probabilities, as pictograms or in the Paling Perspective Scale. In our previous study,[15] we found that university students differentiated across risk levels when presented with the Paling Perspective Scale but not when presented with ratios or pictograms. Because university students can be assumed to have high numeracy skills, we expect the same results for high-numerate individuals in the present study. The Paling Perspective Scale provides comparative risk information that

presumably allows high-numerate individuals to better evaluate a particular risk. Inasmuch as ratios and pictograms do not provide comparative risk information, high-numerate individuals may not know whether a risk presented singly is high or low. Accordingly, when the Paling Perspective Scale is used, we hypothesized that high-numerate individuals with high risks would produce higher perceived risk levels compared with high-numerate individuals with low risks. In line with previous research, we did not expect such an effect for probability information or for the pictogram.

For low-numerate individuals, we hypothesized that risk comparison, as it is used in the Paling Perspective Scale, would not improve the risk judgments. Comparing a risk with other risks is a complex task. It requires cognitive effort and an ability to abstract that low-numerate individuals are probably not able to supply. For these individuals, we therefore expected that lower and higher actual risks would not result in different levels of perceived risks for the Paling Perspective Scale. We expected a similar result for the other 2 formats. Because of the lack of comparative risk information, low-numerate individuals may not know whether a risk presented singly is high or low when they are presented with the pictogram or the ratio format.

The 2nd goal of the present study was to examine which of the 3 formats leads to greater perceived risk across risk levels. Our previous study[15] provides empirical evidence that pictograms decrease risk perception. People mainly look on the nonhighlighted part of the pictogram representing persons that are not at risk. This part is usually much larger than the part with the highlighted objects representing persons at risk. As a result, pictograms may lead to a lower estimation of risks compared with other formats.

METHODS

Study Design

We examined the relationships between risk level (high v. low) and format of risk presentation (ratio, pictogram, or Paling Perspective Scale) and whether these relationships differed based on the numeracy skills of the participant for 2 clinical issues: Down syndrome and colon cancer. We presented all participants with information about the 2 scenarios: test results for delivering a child with Down syndrome and test results for having colon cancer. Prenatal screening and screening tests for colon cancer are frequently conducted in Switzerland. We could assume that our participants were familiar with Down syndrome and colon cancer. Thus, each participant received information about both scenarios. To control for sequence effects, within each condition the order of the 2 scenarios was systematically varied.

Our study involved experimental allocation of risk level and risk presentation format. For each scenario, we provided participants either a high- or a low-risk level. The risk levels were high or low only relative to the other level within a scenario, not in an absolute sense. Thus, a low-risk level within the colon cancer scenario might be a high risk in the absolute sense. Each risk level was provided using 1 of the 3 formats. Participants were randomly assigned to 1 of these 6 conditions.

The dependent variable was the subjectively perceived risk. We also sought to determine whether the relationships between these variables differed based on the participant's numeracy.

Subjects

We drew random samples of persons from the telephone book in both a medium-sized and a small Swiss city. We asked female respondents to participate in a study about physician-patient communication. Inasmuch as prenatal diagnosis is regularly used for females but not for males, only females participated in the study. Interviews were scheduled with female persons between the ages of 18 and 75 years. When several women in a household met the specified criterion, we then randomly determined the person to be selected for the interview. The response rate was 42% ($N = 266$).

Interviews and Materials

Face-to-face interviews were conducted to make sure that each participant answered by herself and that participants solved the tasks in the order required by our design.

Presented with the Down syndrome scenario, all participants read the following text: ''We describe a fictitious scenario about a woman. Sandra is pregnant. Her gynecologist uses a blood test to assess whether her child might have Down syndrome.'' Participants in the ratio with numerator 1 format and high-risk group read the following risk information: ''The physician informs Sandra as follows: Based on the test, the probability of having a Down syndrome

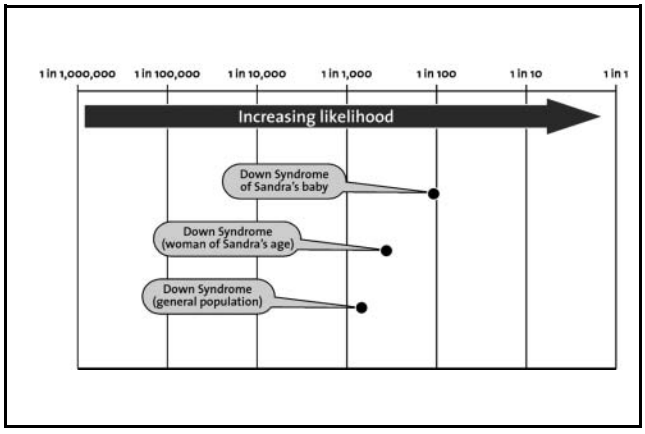

Figure 1 Paling Perspective Scale used for the presentation of the Down syndrome scenario (high risk level).

child is 1:112.'' In the low-risk group, a test result for Sandra with a risk of having a Down syndrome child of 1:909 was described. For the graphical presentation, the Paling Perspective Scale and pictograms were used. The Paling Perspective Scale is shown in Figure 1. The following risks were shown in the graphical display: Sandra's risk of having a Down syndrome baby, the risk for a woman of Sandra's age of having a Down syndrome baby, and Down syndrome in the general population. The size of the picture in the questionnaire was 15×8 cm. In the pictogram version, 1000 persons were depicted; 9 persons with Down syndrome were highlighted in black in the high-risk group, and 1 person with Down syndrome was highlighted in black in the low-risk group. The size of the pictogram was 14.5×10 cm.

Presented with the colon cancer scenario, all participants read the following text: ''We describe a fictitious scenario about a woman. Her physician uses a screening test to assess whether Daniela might have colon cancer.'' Participants in the ratio with numerator 1 format and high-risk group read the following risk information: ''The physician informs Daniela as follows: Based on the test, the probability of having colon cancer is 1:6.'' In the low-risk group, a test result for a woman with the risk of having colon cancer of 1:48 was described. In addition to Daniela's risk of having colon cancer, the following 2 comparative risks were shown in the Paling Perspective Scale: the risk for a woman of Daniela's age of having colon cancer, and the risk of colon cancer in the female population. The size of the picture in

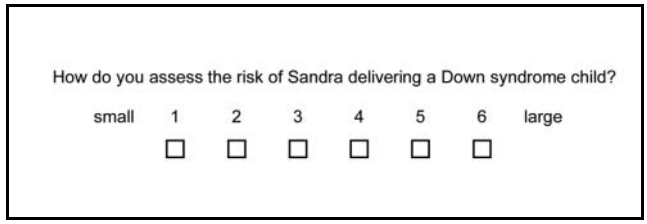

Figure 2 Rating scale for assessing risk perception.

the questionnaire was 15×8 cm. In the pictogram version, 1000 persons were depicted; 167 persons with colon cancer were highlighted in black in the high-risk group, and 21 persons with colon cancer were highlighted in black in the low-risk group. The size of the pictogram was 14.5×10 cm.

Following the presentation of the Down syndrome scenario, subjectively perceived risk was measured with the question ''How do you assess the risk of Sandra delivering a Down syndrome child?'' Participants could answer on a scale ranging from 1 (small) to 6 (large). This rating scale is illustrated in Figure 2. After the colon cancer scenario, subjectively perceived risk was measured with the question ''How do you assess the risk of Daniela having colon cancer?'' Participants could answer on the same rating scale (Figure 2).

Numeracy was assessed using the 7 items of the numeracy scale developed by Lipkus and colleagues.[20]

Statistical Analyses

We conducted an analysis of variance (MANOVA) with risk perception as dependent variable, scenario as within-subject factor, and risk level, format, and numeracy as between-subject factors. Differences between the formats were tested using Tukey's HSD test. Simple t tests were used for planned comparisons on whether low- and high-numerate individuals differentiated between low- and high-risk levels within each scenario. The α error was set at 0.05.

Sample Size and Power Analysis

A priori, we calculated the required sample size using G*Power 3.0.10.[27] Assuming an effect size of $f(V) = 0.25$, an α level of 0.05, and a power of $(1-\beta) = 0.80$, we obtained a required sample size of $N = 279$.

RESULTS

Description of Demographics and Numeracy of Participants

The mean age of the participants was 47.7 years (SD = 15.2 years). The self-reported education level ranged from primary school (3.8%, $n = 10$), lower secondary school (5.6%, $n = 15$), upper secondary vocational school (42.9%, $n = 114$), and upper secondary university preparation school (23.7%, $n = 63$), to university (21.8%, $n = 58$); 6 persons failed to provide education information.

The mean numeracy score was 4.8 (SD = 2.0; $Md = 5$) of 7 possible items ($\alpha = 0.77$). Because the distribution was highly skewed, we performed a median split on the measure. Although we are aware that dichotomous splits are associated with problems such as loss of power, the lack of symmetry in the numeracy measure justified the median split.[28] Forty-eight percent ($n = 129$) of the participants were classified as low numerate (0 to 5 correct items) and 52% ($n = 137$) as high numerate (6 or 7 correct items).

Differences in Risk Perception between Scenarios and between Risk Levels

Participants perceived Sandra's risk of delivering a Down syndrome baby lower ($M = 2.48$) than Daniela's risk of having colon cancer ($M = 3.45$, main effect: $F_{1,254} = 113.52$, $P < 0.001$). Participants also perceived the risk higher in the high-risk conditions ($M = 3.19$) compared with the low-risk conditions ($M = 2.75$, main effect: $F_{1,254} = 8.18$, $P < 0.001$).

Differences in Risk Perception between Formats

The pictogram ($M = 2.08$) resulted in significantly lower risk ratings compared with the other formats (main effect $F_{2,254} = 38.21$, $P < 0.001$, Tukey's HSD test $P < 0.001$). The Paling Perspective Scale ($M = 3.53$) and the ratio with numerator 1 ($M = 3.28$) were not significantly different (Tukey's HSD test $P > 0.40$).

Differences in Risk Perception between Risk Level and Format and Numeracy Skills

We found different risk perception patterns for high- and for low-numerate individuals. Table 1 shows the means.

Down syndrome scenario. Low-numerate individuals did not differentiate between high- and low-risk levels of Sandra having a Down syndrome baby when presented with the ratio format ($t_{42} = -0.17$; $P = 0.87$), the pictogram ($t_{48} = .39$; $P = 0.70$), and the Paling Perspective Scale ($t_{41} = 0.000$; $P = 1.00$). High-numerate individuals did not differentiate between high- and low-risk levels when presented with the ratio format ($t_{42} = 1.54$; $P = 0.12$). When presented with the pictogram, they significantly differentiated between high- and low-risk level ($t_{37} = -2.28$; $P = 0.03$), perceiving the high-risk level as lower risk and the low-risk level as higher risk. For the Paling Perspective Scale, we observed the expected pattern in the high-numerate group. Participants in the low-risk group perceived the test results as less risky compared with people in the high-risk group ($t_{44} = 4.08$; $P < 0.001$), perceiving the high-risk level as higher risk and the low-risk level as lower risk.

Colon cancer scenario. Low-numerate individuals did not differentiate between high- and low-risk levels of Daniela having colon cancer when presented with the ratio ($t_{42} = 0.34$; $P = 0.73$), the pictogram ($t_{48} = 1.93$; $P = 0.06$), and the Paling Perspective Scale ($t_{41} = -0.14$; $P = 0.89$). High-numerate individuals did not differentiate between high- and low-risk level when presented with either the ratio format ($t_{42} = -0.04$; $P = 0.97$) or the pictogram ($t_{37} = 0.70$; $P = 0.49$). Presented with the Paling Perspective Scale, they significantly differentiated between high- and low-risk levels ($t_{44} = 6.49$; $P < 0.001$), perceiving the high-risk level as higher risk and the low-risk level as lower risk. This 3-way interaction between format, risk level, and numeracy was significant ($F_{2,254} = 8.61$, $P < 0.001$).

These observed risk perception patterns for low-numerate and high-numerate individuals were the same for the Down syndrome and the colon cancer scenario, as the nonsignificant 4-way interaction between scenario, format, risk level, and numeracy indicates ($F_{2,254} = 2.06$, $P = 0.13$). The same results were obtained when the order of the scenarios was statistically controlled for by including it in the ANOVA as a 4th between-subject factor.

DISCUSSION

In risk communication, the use of graphical presentation formats, such as pictograms or the Paling Perspective Scale, has often been recommended for improved risk comprehension, especially of

Table 1 Means (Standard Deviations) to the Questions ''How Do You Assess the Risk of Sandra to Deliver a Down Syndrome Child?'' and ''How Do You Assess the Risk of Daniela to Have Colon Cancer?''

		Risk Format		
Numeracy	**Risk Level**	**Ratio**	**Pictogram**	**Paling Perspective Scale**
Down syndrome				
Low numeracy	Low risk	2.74 (SD = 1.45) $n = 23$	1.70 (SD = 1.49) $n = 23$	3.00 (SD = 1.27) $n = 22$
	High risk	2.67 (SD = 1.39) $n = 21$	1.85 (SD = 1.50) $n = 27$	3.00 (SD = 1.48) $n = 21$
High numeracy	Low risk	2.05 (SD = 1.07) $n = 21$	2.23 (SD = 1.72) $n = 22$	2.30 (SD = 1.33) $n = 23$
	High risk	2.70 (SD = 1.64) $n = 23$	1.24 (SD = 0.56) $n = 17$	4.09 (SD = 1.62) $n = 23$
Colon cancer				
Low numeracy	Low risk	3.78 (SD = 1.51) $n = 23$	1.96 (SD = 1.19) $n = 23$	3.68 (SD = 1.25) $n = 22$
	High risk	3.95 (SD = 1.77) $n = 21$	2.67 (SD = 1.39) $n = 27$	3.62 (SD = 1.60) $n = 21$
High numeracy	Low risk	4.19 (SD = 1.25) $n = 21$	2.32 (SD = 1.43) $n = 22$	3.04 (SD = 1.33) $n = 23$
	high risk	4.17 (SD = 1.61) $n = 23$	2.59 (SD = 0.80) $n = 17$	5.43 (SD = 1.58) $n = 23$

Note: 1, small; 6, large.

low-numerate individuals.[2,10] Empirical support for this recommendation has been lacking, however. In addition, many studies in risk communication have employed student or convenience samples. One should be cautious in generalizing findings from these studies.

The Influence of Risk Communication Formats on Risk Perception for High-Numerate and Low-Numerate Individuals

The 1st goal of the present study was to examine the influence of numeracy on the perception of risks that are presented as a ratio, pictogram, or Paling Perspective Scale. For the Paling Perspective Scale, we hypothesized that informing high-numerate participants about a high-level risk would result in higher risk ratings compared with a low-level risk. In line with our hypothesis, high-numerate individuals reacted differently to lower risks compared with higher risks when they were presented with the Paling Perspective Scale but not when they were presented with the other formats. Low-numerate individuals showed similar risk ratings in the high- and the low-risk conditions in all 3 presentation formats, indicating that they did not fully understand these risk formats.

The Paling Perspective Scale[12–14] has been proposed as a means of enabling laypeople to better understand the risks they are faced with. The rationale is that it may be easier to evaluate a risk when comparative risk information is given. Results of the present study suggest, however, that this only applies to high-numerate individuals, not to low-numerate individuals. Our results suggest that low-numerate people did not fully understand the Paling Perspective Scale.

The Paling Perspective Scale uses a logarithmic scale to depict comparative risk information. Our previous study indicated that participants did not use the logarithmic scale to rate the risk.[15] We obtained similar results when we compared the Paling Perspective Scale with a list providing comparative risk information. It seems unlikely, therefore, that the logarithmic scale is the reason why low-numerate individuals did not differentiate between high- and low-risk levels. In addition, the magnifier scale employing a logarithmic scale[23] was found to be used by low-numerate individuals in the same way as by high-numerate individuals. Further research evaluating risk communication formats that provide comparative information as a table is needed to qualify this conclusion.

Unexpectedly, in the Down syndrome scenario high-numerate individuals underestimated the high-risk level compared with the low-risk level when they were presented with the pictogram. It seems that the nonhighlighted part of the pictogram attracted attention to a greater extent when high-risk level was presented compared with low-risk level. We assume that this is an accidental effect. There is no plausible explanation for this result. Accordingly, the colon cancer scenario did not evoke the same risk perception pattern.

In sum, the evaluation of risk communication formats is difficult because it is not possible to determine whether a certain format evokes the ''true'' or ''accurate'' level of concern. Nevertheless, a test can be conducted as to whether different levels of risk

evoke different levels of perceived risk. The present study showed that different levels of risk evoked different levels of perceived risk only when the Paling Perspective Scale was used and only when it was presented to high-numerate individuals. The use of the other 2 presentation formats did not evoke different levels of perceived risk in either high- or low-numerate individuals. These findings should be taken into account when designing risk communication tools.

The Influence of Communication Formats on Risk Perception

The 2nd goal of the present study was to examine which of the 3 formats leads to greater perceived risk across risk levels. The results indicated that the pictogram resulted in significantly lower risk perceptions compared with the other formats. This result is in line with our hypothesis. The reason for this effect is not well understood. We assume that people might look on the nonhighlighted part of the pictogram longer because the nonhighlighted part is larger and might therefore attract attention to a greater extent compared with the highlighted part. According to Stone et al.,[29] this might be due to a foreground v. background perception rule. Given a very small ratio of foreground to background, the graphical representation heightens people's perception of the background. Further studies could examine our assumption in more detail by employing the eye tracker method to follow the eye movements of participants when looking at a pictogram.

Our results show that if it is the goal of risk communication to correct exaggerated health concerns, the pictogram can be used. A physician using the pictogram should be aware, however, that it clearly reduces risk perception. We observed very low-risk ratings even for the high-risk cancer scenario, much lower than for the other 2 formats.

Limitations of the Study

Some limitations of the present research should be addressed. We examined a random sample of women. We can think of no reason, however, why low-numerate males should interpret the Paling Perspective Scale differently from low-numerate females. Another limitation is that we used hypothetical test outcomes. This was constant for all participants, however, and thus cannot be the reason for the significant effects that we observed.

CONCLUSION

Results of the present research indicate that physicians are faced with an even more difficult task than previous studies suggested. Different communication formats not only result in different risk perceptions, but the effect is qualified by patients' numeracy skills. This suggests that there will be no perfect risk communication format that physicians can apply in all situations. Physicians may ask patients how good they are with numbers[24] and then structure their risk communications accordingly. Results of the present study indicate that low-numerate persons have difficulties in using risk comparison information. Verbal explanations of how the graphical representation should be understood could be useful. Future studies should address the question of whether verbal explanations may enable low-numerate persons to better understand risk comparisons.

Another clear outcome of the present research is that risk communication effects should not be examined using only well-educated persons. Numeracy skills are also important for the interpretation of certain graphical presentation formats, as the present study shows. It is important, therefore, that risk communication recommendations be based on data from random samples.

An important goal of future research should be the development of risk communication formats that can be easily understood by low-numerate persons. Some researchers have argued that information should be given an affective value in order to enable low-numerate persons to understand risk information, for example, by employing symbols.[25,26,30] A problem associated with this approach is that use of symbols might shape patients' decisions in a paternalistic manner rather than help them to make independent, informed decisions.

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