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Cognitive structural models: The perception of risk and prevention in coronary heart disease

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This paper examines the relationship between causal models and the assessment of actions in a naturalistic domain. Two studies used a novel network diagram technique to elicit individual causal models of the factors affecting the risk of coronary heart disease. The same individuals also rated the effectiveness of different preventive actions. In their diagrams, individuals depicted the causal interrelationships between various factors and estimated the strength of the connecting paths. Total path strength accounted for two-thirds of the variance in ratings of preventive actions. A number of methodological issues were also explored, which supported the utility of the technique. Consensual models allowed a ready comparison between groups of subjects and showed the importance of distinguishing the presence of paths from the strengths of those paths. The studies support the value of the technique in analysing individual differences in the way people represent complex causal structures; various extensions and applications are also proposed.

The idea that individuals construct models of reality (Craik, 1943) in order to think about possible actions in the world has proved useful in cognitive psychology in understanding inferential reasoning and discourse (Johnson-Laird, 1983; Johnson-Laird & Byrne, 1991). Yet ways of examining the relationship between a model and action remain underdeveloped. Experimentally, provision of a suitable model has been found to help individuals learning to operate a device (Kieras & Bovair, 1984) and in influencing solutions to problems in electricity (Gentner & Gentner, 1983). However, such research has not specifically attempted to elicit the nature of the models used. In certain other technical domains, the reverse approach has been adopted: the nature of mental models has been inferred from thinking-aloud protocols (e.g. Bainbridge, 1989) but such a method is indirect and time consuming.

In contrast, social psychological research arising out of the desire to understand how people understand social phenomena (Heider, 1958; Kelley, 1983; Weiner, 1986) has focused on the nature of the model rather than ensuing action. Such a focus has either established the relative salience of different causes for different groups (e.g. Furnham, 1982, 1992) or has identified the network structure of causal beliefs from aggregated data (e.g. Lunt, 1989, 1991).

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A central aim of the present research is to examine the connection between a causal model and the assessment of actions in a naturalistic domain. In order to do so it is necessary to choose an area which is suitably complex and about which individuals have sufficient knowledge, to choose a suitable measure of action, and to develop a method suited to the elicitation of causal models from individuals.

We examined individuals' causal models of the risk factors for coronary heart disease (CHD) and related these to their judgements of preventive actions. CHD is the single largest cause of death in the UK and the main risk factors that can be influenced are known. These include cigarette smoking, exercise, diet, high blood cholesterol, and high blood pressure (Curtis, Eames, Ben-Shlomo, Marmot, Mohan & Killoran, 1993). Understanding the nature of public beliefs of risk factors and prevention is important to the design of communication programmes aimed at altering actions (Eadie & Davies, 1992). While questionnaires provide a way to assess *knowledge* of specific factors, a technique which provided a representation of the *causal structure* of beliefs might be of practical benefit.

In one possible technique (Lunt, 1989, 1991), subjects assess the causal relationship between pairs of factors presented in a matrix and a causal network is constructed from aggregated data. Since the analysis is of aggregated data, the technique can only provide a consensual model of causal structure in which a path is either represented or not; additionally there are theoretical problems in deciding on an appropriate threshold for the inclusion of paths. Furthermore, the technique does not allow the disentanglement of the presence of a path and the strength of that path. The present technique solves all these problems.

Rather than have individuals carry out the forbidding task of completing a matrix we instead asked them directly to construct a network diagram. Of the various forms of external representation (see Twyman, 1979), diagrams offer a usable form for representing the interconnection of causes, and researchers sometimes construct such diagrams from thinking-aloud protocols in order to display interconnectedness (e.g. Hoc, 1989). The experience of statisticians and researchers who use 'path analysis' models suggests that these network diagrams are a very natural, intuitive method of representing complex causal pathways (see Loehlin, 1992, for an introduction to path analysis and structural models).

Indeed, prior research showed that individuals readily drew diagrams indicating their view of the interrelationship of factors in increasing or decreasing the risk of CHD (Green, 1993). In such a diagram a factor may have either a direct path, an indirect path or both a direct and an indirect path to CHD. The diagram represents what individuals spontaneously consider to be the critical pathways. The present paper extends this technique by requiring subjects to state the strength of each causal path. We call these diagrams cognitive structural models in order to emphasize the formal similarity to covariance structural models, and to stress their origins in individual cognitions rather than in data *per se*. They are examples of a kind of dynamical model in Johnson-Laird's typology of mental models (Johnson-Laird, 1983).

The main aim of Expt 1 was to elicit individual causal models using the technique in order to examine the relationship between these models and the ratings of the effectiveness of various actions in reducing CHD risk. Any relationship should be revealed by a positive correlation between total path strength for each factor (direct and indirect paths) and the ratings. We also aimed to construct a consensual model that distinguished between paths and path strengths.

A further aim was methodological, namely to examine whether the network representation is affected by the number and nature of the factors which have to be considered. As the number of factors increases subjects are faced with a need to manage complexity. They may do so by reducing the complexity of their representation. Experiment 1 employed a factorial design which varied the number of relevant and the number of irrelevant factors (contexts) in order to examine the impact of such variations on the representation of a common set of core factors (high cholesterol; eating fatty foods; taking exercise; and eating oat bran). Such a manipulation has a further advantage: it also allows us to check whether merely representing a factor in a diagram affects the ratings of effectiveness. We demonstrate that to a large extent neither the representation of a subset of a complex model nor the ratings of effectiveness are affected by such variations.

The technique also permits a comparison of the representations of different subject groups. Experiment 2 compared the causal models of a group of junior medical students with non-medical students. We expected that the strength of paths in the model would predict the rated effectiveness of actions as before but anticipated certain differences in the models; in particular it was hoped that medical students would be more aware of the important influence of diabetes on the risk of CHD. Such a demonstration would support the value of the technique in identifying differences in the causal models of different groups.

EXPERIMENT 1

Method

Subjects

Subjects were 100 applicants for undergraduate places in the Psychology Department of University College London.

Design

Subjects were assigned at random to one cell (context) of a 2 × 2 between-subjects design (see Table 1). All subjects assessed the four 'core' factors of high cholesterol level; eating fatty foods; taking exercise; and eating oat bran. One dimension of the 2 × 2 factorial design varied the number of additional relevant factors according to the presence or absence of three factors: high blood pressure; smoking cigarettes; and having diabetes. The second dimension examined the effect of the presence or absence of three irrelevant factors: being short-sighted; living in the inner city; and holidaying by the sea. (Our use of the terms relevant and irrelevant principally reflects contemporary medical wisdom concerning the factors; we neither expected nor found that all subjects agreed with this classification.)

To summarize, subjects in context 1 (additional relevant and irrelevant factors) considered 10 factors; subjects in context 2 (additional relevant but no irrelevant factors) considered seven factors; subjects in context 3 (irrelevant but no additional relevant factors) considered seven factors; and subjects in context 4 (no additional relevant or irrelevant factors) considered four factors.

Table 1. The context conditions of Expt 1 and the factors specified

Context 1 Additional relevant and irrelevant factors	Context 2 Additional relevant factors	Context 3 Irrelevant factors	Context 4 No other factors
Core factors			
Oat bran	Oat bran	Oat bran	Oat bran
Exercise	Exercise	Exercise	Exercise
Fatty foods	Fatty foods	Fatty foods	Fatty foods
High cholesterol	High cholesterol	High cholesterol	High cholesterol
Additional factors			
Diabetes	Diabetes		
Smoking	Smoking	None	None
High blood pressure	High blood pressure		
Irrelevant factors			
Living in the inner city		Living in the inner city	
Being short sighted	None	Being short-sighted	None
Holiday by the sea		Holiday by the sea	

Procedure

Subjects were run in two groups and were informed, in advance, that the task played no role in determining an offer of a place. They were debriefed after the study.

Subjects were asked to draw a diagram indicating how, in their view, a set of factors affected the risk of CHD. They were to write CHD in the middle of the page and then to draw each factor in an oval and indicate its relationship to another factor(s) with a headed arrow, labelled with one of the designated terms (no relation; reduces risk of; increases risk of; causes). The relationship between a factor and CHD could be direct, indirect or both direct and indirect. A schematic overhead slide, which bore no factor names but labelled all the links, was presented as an example. After five minutes subjects checked that they had represented each factor and labelled each of the paths.

Subjects then assessed the strength of association of each factor–relation by choosing a number between zero and 100. Zero meant no association, that is, no causal relation (or a purely random association), between the factor and CHD or some other factor. In contrast, 100 meant an invariable relation. As an example, they were reminded that steam rises from boiling water; there is an invariable relation between the two, and hence the factor–relation would be rated as of strength 100.

For each factor–relation or path in their model, subjects then wrote a single number indicating the strength of the association. An overlay on the previous transparency was used as illustration. Although asking subjects who say there is no causal effect of some factor to put a strength of zero on that path produced some redundancy, we thought this procedure preferable because it would limit the number of subjects inadvertently omitting path strengths.

After four minutes subjects checked that they had written a number between zero and 100 on each path and turned the page. They were then asked to imagine that they were advising a person, whose habits they did not know, on how to reduce the risk of CHD. They were asked to rate each of 10 listed actions on a scale from zero to 10 in terms of their effectiveness in reducing risk, where zero means totally ineffective and 10 means maximally effective. The 10 actions identified related to the complete set of 10 factors (see Table 1). The actions were: reduce blood pressure; stop smoking; control diabetes; eat oat bran; move to the country; take more exercise; wear glasses; reduce cholesterol; holiday by the sea; eat less fat. All subjects rated all 10 actions, irrespective of the factors they had been asked to represent in their network.

Results and discussion

Figure 1 shows an example diagram, redrawn so that the placing of items is easier to read, but retaining the causal interconnections, which is the focus of our analysis.

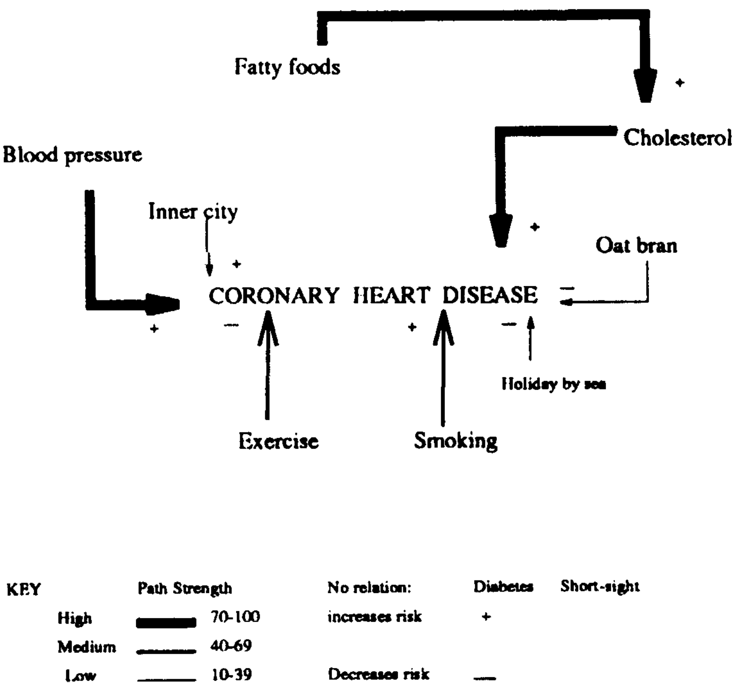

Figure 1. Shows a typical cognitive structural model drawn by a subject (in this case a non-medical student in context 1).

The relationship between the cognitive structural model and ratings of effectiveness. Our first question concerned the relationship between a person's causal diagram of the risk factors and their ratings of the effectiveness of actions to reduce risk. To be included in the analysis, subjects had to have provided strength estimates for all paths in their causal diagrams. For contexts 1 to 4, the respective numbers of subjects meeting this requirement in each context were 21, 22, 24 and 24.

The degree of association between a factor and CHD was computed by summing all relevant paths for that factor. So, for instance, suppose a person envisaged that 'eating oat bran' exerted a direct effect on CHD by a path of strength 40 out of 100 (.40); additionally assume there was an indirect effect via cholesterol, with the paths from oat bran to cholesterol and cholesterol to CHD having strengths of 30/100 (.30) and 70/100 (.70). The strength of the indirect path is then $.7 \times .3 = .21$, and the total strength of association (direct + indirect) is therefore $.40 + .21 = .61$. The analysis is therefore formally identical to a path analysis, taking subjects' ratings of strength of association as equivalent to standardized path coefficients.

In computing the correlation between the strengths of the causal paths from a factor to CHD and the ratings of action we can only consider those factors which were represented. For subjects who represented the four core factors ($N = 91$), the average correlation between the strength of a path in the cognitive structural model and the rated effectiveness of an action was .68 (SE = .04) accounting for 46 per cent of the variance in rating scores of those factors. For the two groups representing seven factors ($N = 43$), the average correlation was .74 (SE = .04), which explains 55 per cent of the rating variance. For the group ($N = 21$) which represented all 10 factors, the average correlation was .80 (SE = .04), accounting for 65 per cent of the variance of the rating scores. Overall, these data indicate a strong relationship between causal structure and ratings of effectiveness of actions. Before considering the consensual representation based on the diagrams we consider some methodological questions.

Representation of the core factors. Each factor was categorized as possessing either a direct path to CHD, an indirect path to CHD, both a direct and an indirect path to CHD or no path to CHD (none). These data are presented in Table 2.

Three of the four core factors were depicted by almost all subjects as affecting the risk of CHD; for the fourth factor of 'eating oat bran', the majority of subjects (75 per cent; 75/100) envisaged a path. Subjects, it will be recalled, were required to label each path using one of the designated terms such as 'increases risk of' or 'causes'. It was expected that if subjects used the label 'cause' they would use it to label paths with the highest strength. In fact, the label 'cause' was used by only 53 subjects but 45 applied it to the one path with the highest strength ($z = 2.20, p < .025$; one-tailed sign test). For purposes of analysis, paths labelled as causing some outcome (e.g. the path from fatty foods to high cholesterol), or increasing the risk of it, were treated in the same category.

Two factors were held to reduce the risk of CHD (eating oat bran and taking exercise) and two factors were held to increase the risk of CHD (eating fatty foods and a high level of cholesterol). Most paths between the core factors and CHD involved a direct relationship (75 per cent; 276/370). For the factor 'eating fatty foods', in contrast, 82 per cent of paths (81/99) included an indirect causal path through 'high cholesterol'.

The data of the four context groups, defined according to the number of relevant and irrelevant factors presented to them, were compared by means of a log-linear model, using the program GLIM 3.77 (Healy, 1988). The log-linear model consisted of a five-way analysis comprising the type of core factor (oat bran, exercise, etc.), the number of relevant and irrelevant factors presented, and the presence of direct and indirect paths in the model. In the first stage of the analysis, the design model was fitted. It consisted of 27 degrees of freedom accounted for by the combination of the following terms: (relevant*irrelevant + direct*indirect)*type where * indicates interactions. This model was highly significant but of no substantial interest. The next stage fitted the interactions of the relevant*irrelevant*direct*indirect terms. These interactions were significant ($\chi^2(9) = 21.72, p < .001$).

Scrutiny showed that the most significant term was the fourth order interaction itself. This interaction can be seen in the totals given in Table 2. In context 1 (where subjects were required to represent many relevant and many irrelevant factors), only

Table 2. Nature of paths connecting core factors to coronary heart disease as a function of context in Expt 1

Path type	None	Direct	Indirect	Both
Direct	−	+	−	+
Indirect	−	−	+	+
Context 1. Additional relevant factors and irrelevant factors				
Oat bran	5	13	6	1
Exercise[a]	0	20	4	0
Fatty foods[a]	0	7	14	3
Cholesterol	0	22	2	1
Total	5	62	26	5
Context 2. Additional relevant factors only				
Oat bran	7	5	10	3
Exercise	0	17	4	4
Fatty foods	0	2	12	11
Cholesterol	1	22	1	1
Total	8	46	27	19
Context 3. Irrelevant factors only				
Oat bran	5	5	9	6
Exercise	2	17	1	5
Fatty foods	0	4	11	10
Cholesterol	0	25	0	0
Total	7	51	21	21
Context 4. No other factors				
Oat bran	8	7	4	6
Exercise	0	21	3	1
Fatty foods	0	4	13	8
Cholesterol	0	25	0	0
Total	8	57	20	15

[a] One subject omitted to represent this factor.
Note. + and −, in this and subsequent tables, indicate that direct and indirect paths are present or absent respectively.

five of the 98 paths (5 per cent) were both direct and indirect whereas in the other contexts, the proportion ranged from 15 per cent to 21 per cent. It is likely that the number of factors to be considered is the critical variable rather than the relevance of the factors. Subjects in context 3 (few relevant, many irrelevant) performed in the same way as subjects in context 2 (many relevant, few irrelevant) and both groups of subjects had been required to consider seven possible risk factors.

Apart from that fairly small interaction, there was no evidence of an effect of context on the representation of the causal paths for the core factors. Indeed, the remaining interaction terms in the model (relevant*irrelevant*direct*indirect*type) were not significant ($\chi^2(27) = 29.93$, n.s.).

Representation of additional factors. Table 3 displays path data for those additional factors which were presented in contexts 1 and 2. As previously, when subjects envisaged that the factor affected risk, they labelled the paths in the same way. All additional factors were held to increase the risk of CHD.

Table 3. Nature of paths connecting additional factors to coronary heart disease as a function of context in Expt 1

Path type	None	Direct	Indirect	Both
Direct	−	+	−	+
Indirect	−		+	
Context 1				
Diabetes[a]	15	9	0	0
Smoking[b]	2	14	6	1
Blood pressure	0	25	0	0
Total	17	48	6	1
Context 2				
Diabetes	15	7	2	1
Smoking	1	11	6	7
Blood pressure	1	24	0	0
Total	17	42	8	7

[a] One subject omitted to represent this factor.
[b] Two subjects omitted to represent this factor.

Analysis using a suitable log-linear model showed that these additional factors were represented in the same way in the two contexts. To summarize, the number of factors represented hardly affected the nature of the causal paths depicted for either the set of core factors or the additional relevant factors.

The ratings of effectiveness and the effects of context. A further subsidiary interest was the extent to which prior representation of a factor affected the rating of its effectiveness. Table 4 displays the mean ratings of effectiveness of the different actions in reducing the risk of CHD, and compares these ratings across the four contexts by means of a one-way ANOVA.

Actions associated with factors relevant to CHD (core and additional: the first seven rows of Table 4) were rated as more effective than those deemed irrelevant to CHD (the last three rows of that table). The two exceptions were 'controlling diabetes' and 'eating oat bran', both of which were considered to be relatively ineffective ways of reducing the risk of CHD.

Analyses of variance for each factor showed that context exerted no statistically reliable effect in any of the cases. Partition of the effects in the one marginally significant case showed that subjects who represented the causal role of blood pressure rated its reduction somewhat more highly ($t(1,87) = -2.65$, $p < .01$) without correction for repeated testing. No other contrasts or interaction contrasts

Table 4. The rated effectiveness of action (standard deviations in parentheses) and the F ratios of the context effects in Expt 1

Actions	Mean effectiveness ratings	Context effect
Eat oat bran	3.51 (2.12)	$F(3,87) = 1.51$
Take exercise	7.16 (1.82)	$F < 1$
Eat less fat	7.76 (1.77)	$F < 1$
Reduce cholesterol	8.26 (1.56)	$F(3,87) = 1.15$
Control diabetes	3.16 (2.94)	$F(3,87) = 1.24$
Stop smoking	7.13 (2.29)	$F < 1$
Reduce blood pressure	7.48 (1.80)	$F(3,87) = 2.50, p = .065$
Move to country	2.36 (1.80)	$F < 1$
Holiday by sea	1.62 (1.62)	$F(3,87) = 1.35$
Wear glasses	0.08 (0.34)	$F(3,87) = 1.05$

were reliable. In short, the ratings of the effectiveness of different actions in reducing the risk of CHD were generally unaffected by whether or not the person had previously been required to consider the causal role of that factor.

A consensual cognitive structural model. The data allowed us to construct a consensual cognitive structural model. The network diagram is relatively sparsely interconnected. Of the 110 possible direct paths between each factor and CHD or between each factor and any other, only 59 paths were represented by at least one person and only 34 were mentioned by more than five people (i.e. 10 per cent or more of a given sample). Figure 2 presents the paths depicted by 10 per cent or more of the subjects in the various conditions, and indicates the range of path strengths. (It includes subjects who represented each presented factor and provided strengths of association for each path.)

As expected, the number of subjects representing a path and the strengths assigned to that path are relatively distinct properties. There are paths with high strength that are represented by few people (e.g. cholesterol to blood pressure) and paths of high strength represented by many people (e.g. cholesterol to CHD). In overview, many subjects (82 per cent; 75 out of 91) represented a strong connection between eating fatty foods and high cholesterol and most subjects (95 per cent; 86 out of 91) represented a strong link between high cholesterol and CHD. Eating oat bran was considered by less than half the sample to reduce the risk of either CHD or high cholesterol level and its effect in either case was not considered to be particularly strong. Cholesterol and blood pressure act as mediating causal factors for other risk factors such as eating fatting foods, exercise and smoking.

EXPERIMENT 2

The second study assessed the relationship between the causal models and the ratings of effectiveness on a group of medical students, whose knowledge of CHD might be

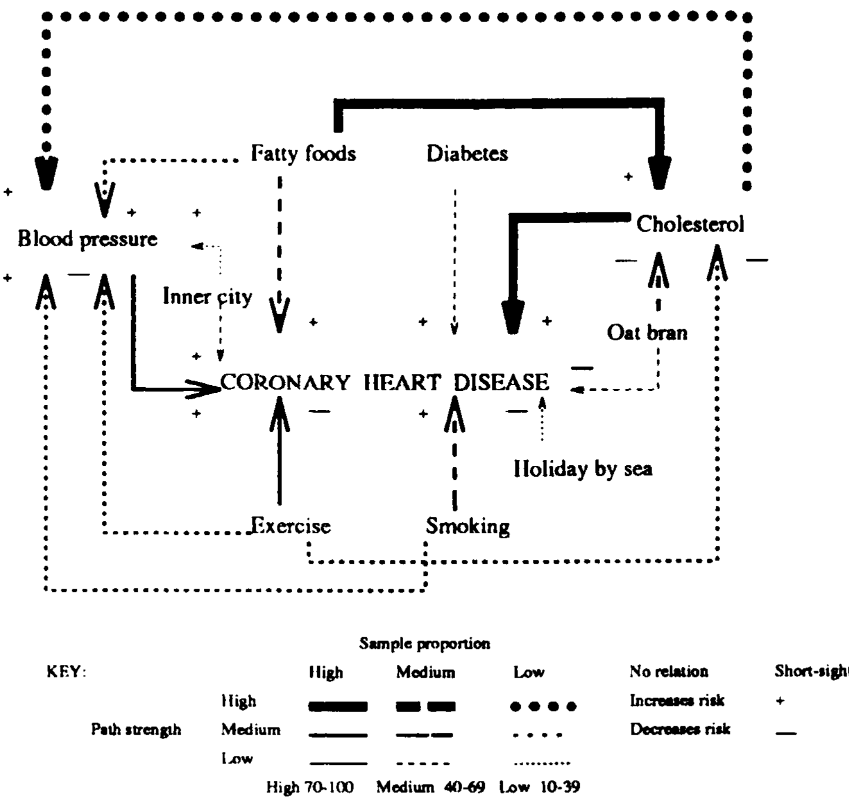

Figure 2. The consensual cognitive structural model for the non-medical students.

expected to be somewhat greater than that of the students in Expt 1. We concentrated on the representation of the full set of relevant factors (core and additional) and examined, as before, the extent to which the pattern of relations was influenced by the presence of further irrelevant factors In addition, we compared the medical students' performance with the non-medical subjects of Expt 1 and constructed a consensual model.

Method

Subjects

Twenty-four medical students in the second year of their preclinical training at St Mary's Hospital Medical School, London.

Design

Subjects were assigned at random to either context 1 (additional relevant factors and irrelevant factors) or context 2 (additional relevant factors only). Eleven subjects were run in context 1 and 13 in context 2.

Procedure

Subjects were run in a single group; otherwise the procedure and instructions were identical to those of Expt 1.

Results and discussion

The relationship between the cognitive structural model and the ratings of effectiveness. Analysis was as in Expt 1. For the four core factors (24 subjects), the mean correlation of total path strength and effectiveness ratings was .58 (SE = .10). For the seven core and additional factors (24 subjects), the correlation was .61 (SE = .08) and for all 10 factors in context 1 (11 subjects), the correlation was .82 (SE = .04). The variance explained was, respectively, 34 per cent, 37 per cent and 67 per cent. These data support the findings of Expt 1.

The representation of core and additional factors. The paths connecting the core and additional factors to CHD were categorized as before and the data are presented in Tables 5 and 6. As previously, subjects agreed on the labelling of the paths.

Table 5. Nature of paths connecting core factors to coronary heart disease as a function of context in Expt 2

Path type	None	Direct	Indirect	Both
Direct	−	+	−	+
Indirect	−		+	
Context 1				
Oat bran	0	2	9	0
Exercise	0	7	2	2
Fatty foods	0	2	6	3
Cholesterol	0	9	2	0
Total	0	20	19	5
Context 2				
Oat bran	4	3	5	1
Exercise	0	8	1	4
Fatty foods	0	1	8	4
Cholesterol	0	10	3	0
Total	4	22	17	9

The nature of the connections between a core factor and CHD varied. A single direct path was the modal way of representing the relationship between exercise and CHD and also between high cholesterol level and CHD. In contrast, eating fatty foods and eating oat bran were more frequently shown to affect the risk of CHD indirectly, usually by reducing the risk of high cholesterol levels. Analysis of these data using the log-linear model from Expt 1, suitably modified, showed that the presence of irrelevant factors did not alter the pattern of direct and indirect paths.

Table 6. Nature of paths connecting additional factors to coronary heart disease as a function of context in Expt 2

Path type	None	Direct	Indirect	Both
Direct	−	+	−	+
Indirect	−		+	
Context 1				
Diabetes	3	5	3	0
Smoking	0	8	0	3
Blood pressure	0	11	0	0
Total	3	24	3	3
Context 2				
Diabetes	2	5	4	2
Smoking	1	1	6	5
Blood pressure	0	13	0	0
Total	3	19	10	7

Likewise, analysis of the data for the additional relevant factors showed that the path structure was similar for the two contexts, though we note that somewhat more subjects (85 per cent, 11/13) linked smoking to CHD indirectly in context 2 than in context 1 (27 per cent, 3/11). Overall, however, neither the representation of the core factors nor the representation of the additional factors was affected by the context in which these factors appeared.

The ratings of effectiveness and the effects of context. As in Expt 1 we examined whether prior representation of a factor affected the ratings of effectiveness. Table 7 presents the mean ratings of effectiveness averaged over the two contexts. (Means for the non-medical students in the same two contexts in Expt 1 are presented for later comment.)

Table 7. The rated effectiveness of actions (standard deviations in parentheses) for medical students (Expt 2) and the relevant set of non-medical students (Expt 1)

Actions	Medics	Non-medics	Group effect
Eat oat bran	4.37 (2.04)	3.24 (2.105)	$t = 2.19, p < .05$
Take exercise	7.08 (1.89)	7.22 (1.68)	$t < 1$
Eat less fat	7.75 (2.03)	8.06 (1.66)	$t < 1$
Reduce cholesterol	8.29 (1.81)	8.29 (1.81)	$t < 1$
Control diabetes	5.75 (2.86)	2.50 (2.87)	$t = 4.57, p < .001$
Stop smoking	8.04 (2.37)	7.40 (2.29)	$t = 1.12$
Reduce blood pressure	8.33 (1.97)	7.98 (1.53)	$t < 1$
Move to country	2.88 (2.11)	2.60 (1.97)	$t < 1$, n.s.
Holiday by sea	2.25 (1.96)	1.74 (1.68)	$t = 1.16$
Wear glasses	0.04 (.20)	0.06 (.31)	$t < 1$

In all cases, medical students rated the effectiveness of actions based on the set of relevant factors more highly than those based on the set of irrelevant factors. Context exerted no effect on the ratings of effectiveness: no contrasts were statistically significant (t test, $p > .1$ in all 10 cases).

The consensual cognitive structural model for medical students. The consensual model for the medical students is summarized in Fig. 3. As in Expt 1, the number of subjects depicting a path and that path's mean strength are distinct properties of the model: for instance, the path from cholesterol to CHD is represented by most subjects (88 per cent, 21/24) and has high strength (mean = 75.9), whereas the path from fatty foods to blood pressure is represented by few subjects (13 per cent, 3/24) but also has relatively high strength (mean = 66.7, i.e. at the top end of the medium strength category in Fig. 3). Cholesterol and blood pressure act as intervening factors for fatty foods, exercise, smoking and diabetes.

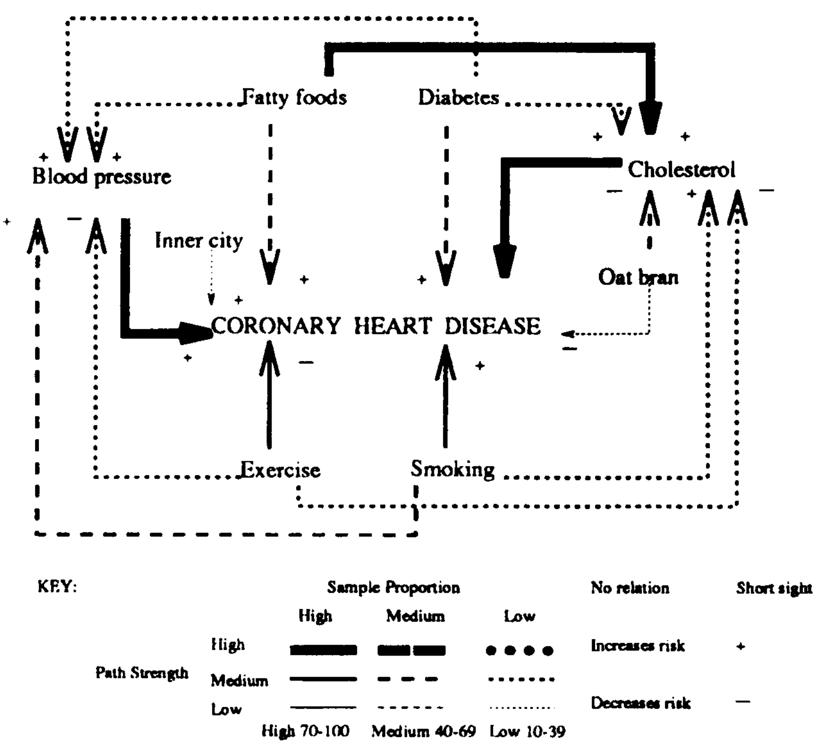

Figure 3. The consensual cognitive structural model for the medical students.

A comparison of the data for medical and non-medical students. Log-linear analyses were carried out on the representation of paths in the two common contexts. For the core factors, there were no differences between the two groups. For the additional factors, the only effect involving group showed that medical students represented more direct paths in their models ($\chi^2(3) = 13.17$, $p < .01$). This was because more of them showed diabetes having a direct effect on CHD.

Analyses of the ratings of effectiveness (see Table 7) showed that only two of these comparisons were significant, viz. eating oat bran and the control of diabetes. Medical students rated both actions as more effective, especially in the case of diabetes where there was an average difference of 3.25 scale points between the two groups.

Comparison of the consensual models. This comparison was made both for the nature of the paths and the path strengths. It would be expected that differences in causal representation should lead to differences in the ratings of effectiveness. The two groups differed in the presence or absence of paths only for the effect of diabetes: five medical students (21 per cent) showed a path from diabetes to cholesterol compared with one non-medical student (2 per cent) ($\chi^2(1) = 4.4$, $p < .05$). Also, more medical students linked diabetes and CHD, 79 per cent (19/24) having direct or indirect paths, compared with 44 per cent (19/43) of non-medical students ($\chi^2(1) = 6.32$, $p < .025$). Furthermore, path strengths from diabetes to CHD were higher for the medical students (50.2 vs. 37.6, $t = 1.57$, $p = .063$, one-tailed test). This is consistent with medical students rating the control of diabetes as more effective in reducing the risk of CHD.

The groups also differed only on path strength for two factors. Medical students showed a higher mean path strength from smoking to CHD (84.1 vs. 63.8; $t = 2.26$, $p < .025$, two-tailed) and also had a higher mean path strength for 'holiday by the sea' to CHD (medical mean = 22.8, non-medical mean = 9.1; $t = 3.47$, $p < .005$). Although the ratings of effectiveness were consistent with such differences they were not significantly different (see Table 7).

All the above factors show general evidence of a difference in causal representation leading to a difference in rated effectiveness of actions. In one further case, this relationship did not obtain. As note above, medical students rated oat bran to be a more effective reducer of CHD risk (Table 7) but there was no concomitant difference between the groups in either the proportion of subjects representing paths or in the mean strength of paths from oat bran to CHD.

GENERAL DISCUSSION

The aim of these studies was to examine the relationship between individual causal models of a phenomenon and their assessments of action bearing on that phenomenon. It was possible to examine the relationship between the causal model of the factors affecting the risk of CHD and ratings of effectiveness of actions designed to reduce the risk of it, since subjects had also estimated the strength of each path in their causal diagrams. For subjects representing all 10 factors, the total path strength yielded strong positive correlations with the ratings of effectiveness (averaging .80 in Expt 1 and .82 in Expt 2). In the best case then, total path strengths accounted for two-thirds of the variance of the rating scores. Differences in path strengths also accounted for most of the differences in ratings between the groups of subjects in Expts 1 and 2.

The studies show substantial agreement across subjects in the major pathways affecting the risk of CHD. Hence they provide a view of the social representation of knowledge, and in particular of the ways in which variables are held to interact causally. High blood pressure was held to increase the risk of CHD by practically every subject. Exercise was held to reduce the risk of CHD directly for around 80 per cent of subjects and to act indirectly via reducing the risk of high cholesterol and blood pressure by about 20 per cent of subjects. Eating fatty foods increased the risk of CHD both directly (46 per cent of the sample) and indirectly via cholesterol levels for over 80 per cent. Cholesterol and blood pressure acted as intervening factors.

The technique also seems to be a useful way to capture differences in the causal beliefs of different groups. Preclinical medical students considered that diabetes plays a more important, and more complex, role in affecting risk than non-medical students though they had not been specifically taught about it. Non-medical subjects seem to have little insight into its role.

Network diagrams of the type explored here, while easy to construct, might be constrained by the number of factors which subjects are required to represent. Broadly speaking, however, the nature of the networks for common factors remained similar under changes in the number of factors represented. It was also true that the act of representing a path from a factor to CHD did not generally affect the ratings of actions associated with that factor. Expt 1 provided only one exception and, although of lower power, Expt 2 provided none. These results suggest that individuals may be able to construct diagrams involving a very large number of factors by interrelating smaller scale networks.

The results of this study invite further questions. What other factors are involved in determining subjects' ratings of effectiveness? *A priori* there is no reason to assume that perceptions of relative risk determine the recommended actions. Some actions might be recommended because they are considered to be achievable (e.g. having a holiday by the sea). The current studies suggest an interesting line of further research: namely to explore those instances where there is a discrepancy between the model and recommendation of actions.

Conceptually, the causal structure of risk factors and the path estimates provided a measure of a subject's assessment of risk. The ratings task measured the relative importance of different actions in reducing risk. Such ratings are not the same, of course, as the actions that subjects would in fact take if they considered themselves at risk. There is a need to explore the relationship between risk assessment and risk preference in this kind of context (for this general contrast see Cohen, Dearnaley & Hansel, 1956; see also Harvey, 1994). Can cognitive structural models be used to estimate the actions that individuals would be likely to chose to avoid or to minimize risk?

The present technique lends itself to a number of applications and extensions. With respect to the present case study, network diagrams might play a useful role both in medical education and in the assessment of knowledge. They might also provide a useful aid in doctor–patient communication. Does a more appropriate model lead to more appropriate action? But the technique is more general. Individuals may use a network to represent their causal understanding of some device or their understanding of some event or process. Since it is externalized it can allow other individuals to comment and to debate its adequacy. Such diagrams might then play a role in understanding individuals' perceptions of mishap. They should allow one to predict which actions individuals would take to undo or to avoid mishap (cf. Kahneman & Miller, 1986).

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