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STRUCTURAL RELIABILITY OF CONJOINT MEASUREMENT IN HEALTH CARE: AN EMPIRICAL INVESTIGATION

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INTRODUCTION

Given the limited opportunity in the health care market to observe data that clearly reveal individual preferences, researchers have to rely on data relating to stated preferences rather than observed actions. In seeking measures of preference in hypothetical contexts, approaches that have commonly been used in health care include standard gamble and time trade-off (Torrance, 1986). These techniques have tended to concentrate on the elicitation of values for health states which are then used as weights for the adjustment of life years in the calculation of quality-adjusted life years (QALYs). In addition, willingness-to-pay techniques have also been used to elicit monetary valuations for health care programme benefits (for examples of contingent valuation see Donaldson et al., 1997; Diener et al., 1998; Zethraeus, 1998). An alternative approach to the elicitation of preferences for programme benefits is 'conjoint measurement' which uses peoples' statements of how they would respond to different hypothetical situations described in terms of a limited number of 'important' attributes. Respondents then provide an indication of the relative preference for each scenario using a rating, ranking or choice-based response mechanism. These techniques are increasingly being used in the health care sector (Ryan and Hughes, 1997; Bryan et al., 1998; Vick and Scott, 1999).

This paper is concerned with the structural reliability of conjoint measurement when applied in a health care setting. Structural reliability is concerned with the stability of preferences over alternative study designs. For example, reliability over data collection procedure explores the level of variation in the results of the conjoint measurement exercise when alternative data collection methods are used (see Carmone et al., 1978; Reibstein et al., 1988). The focus of this paper is reliability over the attribute set where the stability of preferences for common attributes is investigated when the nature or levels of other attributes are varied. Previous work on structural reliability has largely been in the area of marketing research and has generally found very encouraging results (Carmone et al., 1978; McCullough & Best, 1979; Malhotra, 1982; Reibstein et al., 1988). This paper reports one of the first empirical investigations of structural reliability over attribute set in a health care setting.

The clinical setting used in the research reported here was the diagnosis and treatment of knee injuries. In patients presenting with serious injuries a number of alternative diagnostic procedures exist, including arthrography, which has a high level of accuracy but is invasive and technically demanding, and arthroscopy, which also has good accuracy and additionally provides the opportunity to diagnose and treat abnormalities with a single intervention. Over recent years arthroscopy has become the diagnostic procedure of choice. However, it is an invasive and relatively high cost surgical procedure which often reveals no abnormality requiring surgical repair, and so increasingly orthopaedic surgeons are turning to magnetic resonance imaging (MRI) as a means of diagnosing knee problems. MRI is non-invasive, and has been shown to have relatively high sensitivity and specificity (Crues et al., 1987; Mink et al., 1988), thereby allowing surgery to be avoided in many cases.

METHODS

Questionnaire design and data collection

The conjoint measurement study used the pairwise choice approach to preference elicitation. Each choice included two scenarios: a conventional treatment approach to management (arthroscopy) and an approach using MRI. The attributes and levels used in the study were selected on the basis of the results of previous research (Bryan et al., 1998) and are shown in Table 1. For the conventional treatment scenario, within each choice, the surgery avoidance and cost attributes both had only one level: 100% chance of surgery and zero cost, respectively. Given that arthroscopy is routinely available on the National Health Service in the UK (without charge to the patient), cost was fixed at zero for conventional treatment in order to ensure that respondents viewed the scenarios as plausible. Further details of the conjoint measurement design are described elsewhere (Bryan et al., 1998). An example of the choices used in this study is shown in the Appendix.

In order to test for structural reliability two separate conjoint measurement exercises were designed: exercise A where scenarios were defined in terms of three attributes and exercise B where scenarios included all four attributes. This study investigated the extent to which the introduction of an additional attribute caused a ‘structural’ change in the rates at which respondents substituted between attributes that remained unchanged. The attribute excluded from exercise A was treatment time, on the basis that this factor was repeatedly shown to be significant in driving choices in earlier conjoint work (Bryan et al., 1998). In addition, it was considered feasible to construct plausible conjoint scenarios that omitted this attribute.

Scenarios for both exercises were defined on the basis of a fractional factorial design (main effects only) using the SPEED software package (Hague Consulting Group, 1989). Exercise A involved 12 choices and exercise B 14 choices. In line with a previous conjoint study (Propper, 1991), and to avoid respondent fatigue, two versions of the questionnaire were developed (Questionnaires 1 and 2) such that each respondent was posed half of the choice set for each exercise. Thus, respondents were presented with a questionnaire containing two conjoint measurement sections (A and B). Section A contained the 6 choices relevant to exercise A and section B contained 15 choices, 7 of which were relevant to exercise B (the other 8 choices in section B provided data for a separate study, not reported as part of this paper).

As part of the design of the conjoint study, three 'dominated' choices were included in each questionnaire (one in section A and two in section B) as tests of internal consistency. A dominated choice has at least one attribute at a better level and no attribute at a worse level, compared to the alternative. The questionnaire also asked general questions concerning a range of respondent characteristics: age, sex, experience of knee injuries and treatments, whether they have private health insurance, time spent in sports activities and level achieved (e.g. national representation), and previous participation in a similar conjoint exercise. Some of the students included in the survey took part in an earlier conjoint study.

Following piloting on a convenience sample of university staff, the main questionnaire was administered to undergraduate Sports and Exercise students at Birmingham and Brunel Universities. This target group was chosen since it has been established in previous work that the level of participation in sport and the prevalence of knee injuries are both high in this student population, making them a group with relevant experience. The Birmingham students were sent the questionnaire, with a covering letter, through the internal mail. Non-responders at approximately 2 weeks were sent a single reminder. Entry into a prize draw was offered as an incentive to respond. For logistic reasons the same distribution method was not possible for the Brunel students who completed the questionnaire within a lecture. Questionnaires 1 and 2 were randomly distributed to individuals within each sample.

Data analysis

Prior to estimation of utility models, the choice patterns for each respondent were investigated to establish first whether they 'passed' the internal consistency check and second, whether lexicographic preferences were exhibited. The framing of the conjoint exercise allowed two possible forms of lexicographic response: by attribute (i.e. choices being driven by the levels of a single attribute) or by technology (i.e. choices consistently for either conventional treatment or MRI).

In line with similar conjoint studies, the utility models were estimated using random effects probit regression (Vick and Scott, 1998; Ryan, 1999) where the dependent variable is binary (value 0 for conventional treatment; 1 for MRI). The random effects approach was chosen as this treats the individual effects as being uncorrelated with the other independent variables, and allows adjustment for the panel nature of the data (Greene, 1997).

The assessment of structural reliability involved a comparison of the random effects probit models for exercises A and B. The functional forms for the two models are given below.

Model A

$$y_{ijqA} = \forall_{0A} + \forall_{1A}(a_{jA} - a_{iA}) + \forall_{3A}(k_{jA} - k_{iA}) + \forall_{4A}(c_{jA} - c_{iA}) + v_{ijqA} + u_{qA}$$

Model B

$$y_{ijqB} = \forall_{0B} + \forall_{1B}(a_{jB} - a_{iB}) + \forall_{2B}(t_{jB} - t_{iB}) + \forall_{3B}(k_{jB} - k_{iB}) + \forall_{4B}(c_{jB} - c_{iB}) + v_{ijqB} + u_{qB}$$

where i is the left-hand scenario within a choice;

j is the right-hand scenario within a choice;

i,j = 1, ... , n, the number of conjoint choices posed;

q = 1, ..., n, the number of respondents to the survey;

y = the difference in random utility between the two scenarios presented within a choice;

a, t, k, c = the levels for the treatment, time, knee problem resolution and cost attributes respectively;

$\forall_0$ ... $\forall_4$ = the model coefficients;

v_{ijq} = is the random error term due to differences amongst observations, and

u_q = is the disturbance due to differences amongst respondents resulting from measurement error.

Model A used data from section A choices only and Model B data from the relevant 7 choices of section B. All models were specified with a constant term in order to investigate the presence of a systematic tendency to choose left or right, which in this context might indicate an underlying preference for one of the technologies (Ryan & Hughes, 1997). Given that each attribute has quantitative levels where the direction of preference is clear, it is possible to predict the expected signs on each attribute coefficient. The *a priori* expectation was that the coefficients on the cost and time attributes would be negative (e.g. smaller costs would be preferred over larger costs) and the coefficients on the avoidance of surgery and knee problem resolution attributes would be positive (e.g. a higher chance of resolution would be preferred to a lower chance).

For the test of structural reliability, the null hypothesis was of no differences between attribute coefficients, that is:

$\forall_{0A} = \forall_{0B} = 0$

$\forall_{1A} = \forall_{1B} = 0$

$\forall_{3A} = \forall_{3B} = 0$

$\forall_{4A} = \forall_{4B} = 0$

For the three attributes in both models and the constant term, comparison was made of the coefficient values: if the 95% confidence intervals overlap this was taken to suggest no significant difference. Any such differences observed between models were taken to indicate structural unreliability of the conjoint measurement technique in this context. The two models were also compared using the ‘dummy variable approach’ (Gujarati, 1988) whereby data from both exercises A and B were ‘pooled’ and the following model (Model P) estimated. This approach is equivalent to a multi-step Chow test procedure.

Model P

$$y_{ijqP} = \forall_{0P} + \forall_{1P}(a_{jP} - a_{iP}) + \forall_{2P}(t_{jP} - t_{iP}) + \forall_{3P}(k_{jP} - k_{iP}) + \forall_{4P}(c_{jP} - c_{iP}) + \forall_{5P}D_{ij} + \forall_{6P}[D_{ij}(a_{jP} - a_{iP})] + \forall_{7P}[D_{ij}(k_{jP} - k_{iP})] + \forall_{8P}[D_{ij}(c_{jP} - c_{iP})] + v_{ijqP} + u_{qP}$$

where D_{ij} = 0 for observations from exercise A, and 1 for observations from exercise B; and

for all observations from exercise A, $(t_{jP} - t_{iP}) = 0$, since information on treatment time was not included in the scenario descriptions.

Assuming $E(v_{ijqP}) = 0$ and $E(u_{qP}) = 0$, estimating Model P is equivalent to estimating two individual models since

$$E(y_{ij} \mid D_{ij}=0) = \forall_{0P} + \forall_{1P}(a_{jP} - a_{iP}) + \forall_{2P}(t_{jP} - t_{iP}) + \forall_{3P}(k_{jP} - k_{iP}) + \forall_{4P}(c_{jP} - c_{iP})$$

$$E(y_{ij} \mid D_{ij}=1) = (\forall_{0P} + \forall_{5P}) + [(\forall_{1P} + \forall_{6P})(a_{jP} - a_{iP})] + \forall_{2P}(t_{jP} - t_{iP}) + [(\forall_{3P} + \forall_{7P})(k_{jP} - k_{iP})] + [(\forall_{4P} + \forall_{8P})(c_{jP} - c_{iP})]$$

The difference in the models for the two exercises is, therefore, indicated by the statistical significance of the differential constant ($\forall_{5P}$) and the differential slope coefficients ($\forall_{6P}$, $\forall_{7P}$, $\forall_{8P}$). The null hypothesis of no difference is:

$\forall_{5P} = 0$

$\forall_{6P} = 0$

$\forall_{7P} = 0$

$\forall_{8P} = 0$

RESULTS

Response and sample characteristics

Data were collected on a total of 176 students (132 from Birmingham University and 43 from Brunel) representing a response rate of 34% for Birmingham and 100% for Brunel (given the captive nature of the sample). The level of completion of the questionnaires was very high: data were missing for only 18 choices (from a total of 2288 presented), 12 of which were from a single respondent.

Table 2 provides an overview of the nature of the sample. Given an undergraduate student population the age distribution of the group was as expected (mean 20.97 years; SD 3.56 years) and in line with previous research, many respondents (41%) had experienced a knee injury that required the attention of a doctor.

Response patterns

The number of respondents whose choices suggested lexicographic preferences for each attribute or technology is shown in Table 3. The level of exposure to choices where it was possible to express a lexicographic response varied between attributes. For example, in Questionnaire 1 there were 10 choices that had an alternative with a lower level for the cost attribute, whereas for the avoidance of surgery attribute there were 9 choices that had an alternative with a higher level for that attribute. Since the time attribute only formed part of the scenarios in section 2 of the questionnaires, the exposure to such choices was clearly more limited and so the apparently large number of lexicographic respondents for the time attribute is misleading. Given the differential exposure across attributes, it is not possible to conclusively identify lexicographic response patterns using the data collected in this survey.

Whilst some respondents appear to have chosen in line with variation in the levels of a single attribute, none of the respondents always chose a single technology, either MRI or conventional treatment. This provides an indication that respondents were engaging in trading behaviour as they considered the choices posed. In terms of the level of inconsistency in responses, a total of 20 respondents ‘failed’ the inconsistency check by choosing a non-dominant alternative in at least one of the relevant questions.

Model estimation

The random effects probit models are presented in Table 4. Model A indicates that responses were significantly influenced by variation in the levels of all three attributes ($p<0.001$). The signs of all attributes are as expected: the negative sign on the cost coefficient indicates that higher levels of cost for MRI, relative to arthroscopy, were associated with a significantly higher probability of choosing the arthroscopy scenario. The constant term is also significant, with a positive coefficient, suggesting a systematic tendency for respondents to choose the MRI option, others things being equal. One interpretation of this finding is an underlying preference for MRI over conventional treatment. The model estimated using data from section B, where the attribute 'time involved in the treatment process' was included in the scenario description, found that responses were not significantly influenced by variation in the chance of avoiding arthroscopy (p=0.72). However, all three of the other attributes had coefficients that were significantly different from zero with the expected signs. Again the constant term was also significant, with a positive coefficient.

The simple comparison of Models A and B suggests a mixed picture concerning structural reliability. The coefficients on two of the three common attributes (knee problem resolution and cost) are very similar between models and have overlapping confidence intervals. On the other common attribute (avoidance of surgery), whilst the coefficient values have overlapping confidence intervals, they are wide with only a small overlap. However, the coefficients on the constant term in the two models are significantly different: the absolute value of the coefficient in Model B is more than twice that of Model A and the confidence intervals do not overlap.

The pooled data model (Model P) is also presented in Table 4 and provides support for the results obtained from the simple comparison of models. Both the differential constant ($\forall_{5P}$) and one of the differential slope coefficients ($\forall_{6P}$) are statistically significant, strongly indicating that the models for the two exercises are different. However, the instability is limited to the constant term and a single model attribute (i.e. avoidance of surgery).

DISCUSSION

The conjoint measurement results imply that respondents engaged in the exercise and that their choices were significantly influenced by variation in the treatment duration, the resolution of the knee injury and the cost of treatment attributes. It was inconclusive, overall, that variation in the level of the process attribute (i.e. likelihood of avoiding surgery) was associated with high levels of utility. However, the results provide some evidence that preferences for the option described as the ‘new technology’ (i.e. MRI) were strong – one interpretation is that this was perceived as better in ways not captured by scenario descriptions. These findings are in broad agreement with those of previous research in this area (Bryan et al., 1998).

Given the potential for error in conjoint measurement, especially since it is not possible to include all relevant characteristics of a technology or service in conjoint scenarios, this study explored the structural reliability of the conjoint method to variation in the attribute set. The particular strength of this study is that the two conjoint models are directly comparable since they use data from the same respondents collected at the same point in time. Therefore, any differences between the models cannot result from differences in the characteristics of respondents between exercises A and B, and given that the two exercises were completed on the same occasion there was no variation in the level of relevant experience between administrations. One of the limitations of the study is that different data collection methods were employed at the two data collection sites. However, given that the convergent validity comparison was within individuals, it is not clear how any bias could have been introduced through the variation in data collection procedures.

Unlike much of the previous research in this area (Carmone et al., 1978; McCullough & Best, 1979; Malhotra, 1982; Reibstein et al., 1988), a mixed picture was found. The results relating to the stability of two of the coefficients on the attributes that formed an integral part of the scenario descriptions (i.e. cost and the chance resolution of the knee problem) were encouraging. However, the result for the stability of the constant coefficient in the models was less encouraging. One interpretation of this difference in constant coefficients is a significantly stronger underlying preference for MRI in section B compared to section A. However, this interpretation is implausible given that the comparison is within respondents and both exercises were completed on the same occasion. Another possible explanation is respondent fatigue or boredom. If, as respondents progressed through the questionnaire, they experienced increasing fatigue, as seems plausible given that a total of 21 choices were posed, and this was associated with a tendency to choose the right-hand option (i.e. the MRI scenario) then the constant term would be larger in Model B, since section B (where scenarios included 4 attributes) always came after section A (where scenarios contained 3 attributes). The bias potentially introduced through respondent fatigue might have been lessened if the ordering of sections A and B had been alternated, such that half of the respondents received a questionnaire where section B followed section A and the other half a questionnaire where A followed B. This design was not employed since there was a concern that respondents would have difficulty in considering choices involving scenarios with only three attributes if they had already been presented with choices described in terms of four attributes.

The finding of instability in the constant term coefficient raises important questions about the appropriateness of labelling scenarios in conjoint measurement exercises (Dowie, 1998). The motivation for labelling here was principally to ensure high levels of respondent engagement in the conjoint tasks. The expectation was that choices involving scenarios labelled as a specific technology would be viewed as more realistic by respondents, resulting in more considered responses to conjoint questions. A strong underlying technology-specific preference was not expected, *a priori*, on the basis that the results of the two conjoint studies conducted in the piloting phase (Bryan et al., 1998) did not strongly indicate the presence of such preferences. Without any additional information, the only reasonable basis for a pure technology preference is the additional (unstated) attributes that respondents may have attached to the technology label, constructed either from the separate technology descriptions (which were provided as part of the introductory material in the questionnaire) or from previous experience or knowledge. It would have been interesting to explore further the reasons for such preferences using qualitative techniques, as advocated recently by Dolan et al. (1999) and Coast (1999), but such additional work was not feasible in this study. Given the ambiguity of the basis for such preferences it is unsurprising that they were found to be unstable in response to changes in the structure of the conjoint exercise. This finding supports the conclusion that labelling of scenarios in conjoint measurement in health care should be avoided; a position also advocated by Dowie (1998, p5):

“if people have preferences about being cut open, or taking drugs daily – as they are fully entitled to – then these relate to the *consequences* of the process and can and should be identified and measured as such, not smuggled in under a respondent-supplied option/process preference."

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Table 1: Attributes and levels used in the conjoint study

Attributes	**Levels**
Cost to individual (£)	0, 200,400,600
Chance of avoiding surgery (%)	0, 20,40
Time from initial visit to end of treatment (weeks)	6,12,18,24
Chance of the knee problem being resolved (%)	60,70,80,90

Table 2: Sample characteristics

	Number (%)
Male	87 (49)
Previous knee Injury	72 (41)
Previous knee MRI scan	17 (10)
Previous knee arthroscopy	13 (7)
Private medical insurance	49 (39)
More than 15hrs per week sports training	23 (13)
County level sports representation	57 (33)
International level sports representation	12 (7)
Took part in similar study	39 (30)

Table 3: Number of respondents exhibiting complete lexicographic preferences

Attribute	Number (%)
Questionnaire 1	
Cost	5 (6)
Avoidance of surgery	3 (4)
Duration of treatment	72 (86)
Chance of resolution of knee injury	2 (2)
Always choose conventional treatment	0 (0)
Always choose MRI	0 (0)
Questionnaire 2	
Cost	1 (1)
Avoidance of surgery	1 (1)
Duration of treatment	7 (8)
Chance of resolution of knee injury	6 (7)
Always choose conventional treatment	0 (0)
Always choose MRI	0 (0)

Table 4: Random effects probit models

	Model A		Model B		Model P	
Attributes	Coefficient	95% CI	Coefficient	95% CI	Coefficient	95% CI
Constant	0.3699*	0.1414 to 0.5983	0.9061*	0.6999 to 1.1123	0.8366*	0.6349 to 1.0384
$(a_j - a_i)$	0.0151*	0.0082 to 0.0219	0.0016	-0.0070 to 0.0101	0.0007	-0.0080 to 0.0093
$(t_j – t_i)$	-	-	-0.0823*	-0.0974 to -0.0673	-0.0799*	-0.0948 to –0.0650
$(k_j - k_i)$	0.0544*	0.0486 to 0.0603	0.0516*	0.0445 to 0.0588	0.0519*	0.0441 to 0.0596
$(c_j - c_i)$	-0.0034*	-0.0040 to -0.0029	-0.0037*	-0.0044 to -0.0031	-0.0037*	-0.0043 to –0.0030
D_{ij}	-	-	-	-	-0.4512*	-0.7382 to –0.1643
$[D_{ij}(a_{jP} - a_{iP})]$	-	-	-	-	0.0137**	0.0023 to 0.0250
$[D_{ij}(k_{jP} - k_{iP})]$	-	-	-	-	0.0020	-0.0079 to 0.0119
$[D_{ij}(c_{jP} - c_{iP})]$	-	-	-	-	0.0002	-0.0006 to 0.0011
n (data)	1049		1221		2270	
n (groups)	176		175		176	
Chi^2	371		454		822	
P	<0.001		<0.001		<0.001	

* Indicates statistical significance at the 0.01 level.

** Indicates statistical significance at the 0.05 level.

APPENDIX

Example of a choice used in the study:

Choice 2	Conventional treatment	MRI
Cost to you personally	£0	£200
Chance of avoiding surgery	0%	20%
Time from initial visit to end of treatment	12 weeks	12 weeks
Chance of the knee problem being completely resolved	90%	70%

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