The Old School, Brewhouse Hill, Wheathampstead,
Hertfordshire AL4 8AN, UK

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The use of conjoint analysis to determine the importance of factors that affect on-farm welfare of the dairy cow

LJ Angus, H Bowen, LAS Gill, TG Knowles and A Butterworth*

Clinical Veterinary Science, University of Bristol, Langford, Bristol, BS40 5DU, UK
* Contact for correspondence and requests for reprints: andy.butterworth@bris.ac.uk

Abstract

A large range of variables can affect the welfare of the dairy cow, making it difficult to assess the overall 'level of welfare' of the individual animal. Two groups of individuals completed a questionnaire based upon the 'five freedoms': 26 respondents had expertise either in the field of dairy cow welfare or as practicing veterinary surgeons, and 30 were veterinary students in their penultimate year of study. Conjoint analysis was used to calculate the average importance scores (AIS) for 34 variables presented to the respondents as 52 'model cows' in the form of grouped questions, phrases and pictures. Conjoint analysis identified the most important factors for each 'freedom': access to forage, body condition score, foot conformation, hock lesions, and the encouragement required for a dairy cow to walk into the parlour. There was a significant difference between the expert and student groups for seven out of 34 factors, which may be attributed to individual variation of opinion, knowledge, experience and expectation. The factors were ranked within each 'freedom' using the experts' AIS but it was not assumed that each freedom had equal 'weight'; therefore, the factors within each freedom were compared only with factors within the same freedom. These scores produced a weighting scale, which was applied on-farm, in a preliminary exercise comparing 'model' and 'perceived' welfare scores.

Keywords: *animal welfare, conjoint analysis, dairy cow, five freedoms, on-farm, welfare assessment*

Introduction

Dairy enterprises remain an important sector of the UK farming industry despite current economic pressure. The UK is the seventh largest milk-producing country in the world, producing more than 14 billion litres per year (Defra 2002). However, the demands made upon dairy cattle for milk production may affect the welfare and longevity of the individual animals. Although health and welfare problems, such as chronic lameness, can be controlled, prevented or even eradicated, they have often not been addressed (Hughes & Curtis 1997). One framework for assessing the welfare impact on individual animals is the use of the 'five freedoms', developed by the Brambell Committee (1965) and Webster (1986), and these established criteria for assessment of animal welfare form the core of a number of animal welfare standards (Leaver 1999; Defra 2002).

A large range of variables can affect the welfare of the dairy cow, making it difficult to assess the overall 'level of welfare' of the individual animal. Health, physiology, behaviour and production have been used as indicators of animal welfare (Brambell 1965; Ewbank 1987), and subjective states, such as pain, distress and suffering, have been related to observable factors, such as clinical disease. Measurements of plasma glucocorticoids (a measure of physiological stress), observed behaviour, incidence of clinical disease and mortality rates have also been used to assess the welfare of dairy cattle (Reinhardt & Reinhardt 1975; Loeffler 1986; Broom 1987; Hall 1989; Broom & Johnson 1993; Munksgaard & Simonsen 1996; Mench & Mason 1997; Terlouw *et al* 1997). Evaluation of the 'most important' factors affecting the ability of an individual to cope with its environment (Fraser 1995) may be important in the on-farm assessment of welfare.

This paper describes a preliminary study that uses a statistical technique — conjoint analysis — to analyse the responses of people with experience of dairy cattle welfare, and to apply these responses by weighting the factors according to the importance placed on them. Individual 'model cows' are presented to explore what the respondents feel to be potentially important — and less important — impacts on individuals, and hence potentially on the whole herd as a group of individuals. A 'herd model' could have been created as an alternative approach, but in this preliminary study, focus is placed on individual animals as 'model members of a herd'; the limitations of this approach are also discussed.

Materials and methods

Questionnaire

A literature search resulted in the creation of a list of 34 possible factors that could be considered to have potential welfare impacts on the dairy cow. This list was not exhaustive, and it is recognised that other people, and those working with cattle in other parts of the world, might

Table 1 Some examples of questions taken from the questionnaire. A total of 34 factors were phrased in 52 'model cows' using this format.

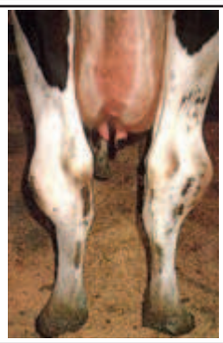
1. This cow has contact with a bull	No	Yes
2. This cow's calf was removed	<12h	24h+
11. Her water source is		
12. This cow is three months into her lactation		
17. The percentage abortion in this herd is	4%	1.5%
21. This herd has an incidence of milk fever higher than 20% per year	Yes	No
26. This cow walks into the milking parlour without encouragement	No	Yes
27. This cow has access to an undisturbed, comfortable, clean lying area	No	Yes
32. The cow's underfoot conditions:		
34. The cow's hocks:		

Table 2 An example of an orthogonal array generated using SPSS Conjoint 8.0 (SPSS 1999) for 'freedom from hunger and thirst'. The orthogonal array is a statistically suitable fraction of all possible answer combinations. In the questionnaire, 'good' = 0 and 'bad' = 1 with respect to welfare. This orthogonal array was then converted into 52 'model cow' profiles to be presented to respondents.

Profile	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P	Q	R
Water	1	0	1	1	1	1	0	0	1	0	0	0	1	0	0	0	0	1
Trough	0	1	1	0	1	1	0	0	0	1	0	1	0	1	1	0	1	1
Condition	1	0	0	1	0	1	0	1	0	1	0	1	0	1	0	1	0	0
Feed	1	0	0	0	0	0	0	0	1	1	1	1	0	0	1	1	1	1

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Table 3 An example of one of the 52 'model cows' created, in the format presented to respondents. This 'model cow' is profile 'A' from Table 2.

COW 1	Case A
At any one time 10% of the herd are able to drink water	No
Her water source is...	
This cow is three months into her lactation	
To reach the feed trough to be able to eat, this cow has to wait	20 min

consider other additional factors to be important. The factors were separated into groups that the authors felt to be identifiable with each of the five freedoms. Indirect assessment methods were used where direct assessment of the factor was not appropriate. For example, body condition score was used to indicate the level of nutrition, but it is recognised that body condition score can reflect the combined effects of a number of factors on the animal. Herd statistics, such as the number of mastitis cases per year per one-hundred cows, were used as a quantifiable method of assessing the level of a problem within a herd to help identify the risk for an individual.

A non-leading phrase or question was created for each factor. Each question had two possible answers (factor levels) arrived at by research from the relevant literature. The answers were designed so that one was perceived as 'good' and the other as 'bad' with respect to the welfare of the dairy cow. For each 'freedom', between four and nine questions were grouped together into blocks; some examples of the questions are given in Table 1. These questions covered all of the 34 factors and were selected using the orthogonal array programme described below, and arranged as groups of 'model cows': 12 'freedom from discomfort' 'model cows' (8 factors); 8 'freedom from fear and distress' (4 factors); 8 'freedom from hunger and thirst' (4 factors); 12 'freedom from pain, injury and disease' (9 factors); and 12 'freedom to express normal behaviour' (9 factors). This gave a total of 52 'model cows' for the respondents to score, with a visual analogue line provided for each 'model cow'. There was no indication in the questionnaire that the questions were grouped into 'freedoms'.

Figure 1

The visual analogue scale. Respondents marked the 100 mm line with a cross to correspond with their perception of the welfare for each 'model cow' profile.

Conjoint analysis

Conjoint analysis is a decompositional or attribute-free technique that infers the importance of attributes used by an observer in decision making without asking the respondents to rate attributes directly (Hair *et al* 1998). A statistical package, SPSS Conjoint 8.0 (SPSS 1999), was used to produce a statistically suitable fraction of answer combinations: the 'orthogonal array' (Table 2). Grouped questions determined by the orthogonal array were presented to respondents as 'model animals.' An example of one 'model' is given in Table 3, this example using 4 questions (factors). The use of an orthogonal array produces some 'model cows' where information appeared contradictory, for example a cow showing poor foot conformation but no reluctance to walk. Respondents were asked to consider all of the factors presented, despite potential contradictions.

Two groups of respondents completed the questionnaire, which incorporated a brief explanation, instructions and an example 'model cow' profile. The first group included people with experience either as practicing veterinary surgeons working with dairy cattle, or individuals with expertise in the field of animal welfare (in particular, dairy cow welfare). Of these, 16 people used a questionnaire sent to them on CD-ROM and viewed on computer, and 10 people completed it using a printed booklet. The second group consisted of 30 Bristol veterinary students in their penultimate year of study who viewed the questionnaire, projected onto a screen from a computer. This group was considered to be aware of the factors affecting the welfare of dairy cows but considered to be naïve — when compared with the expert group — because of their lack of on-farm experience. The decision to use two groups, one of 'experts' and one of 'non-experts' was based on a wish to keep the comparators simple for this preliminary study.

A 100 mm visual analogue scale (Figure 1) was chosen for scoring responses as it produced almost continuous data with 1 mm increments giving a range of 100 possible scores. The responses were measured, in mm, from poor welfare (0) toward good welfare (100) and were retained for statistical analysis.

Statistical analysis

Conjoint analysis uses the ordinary least-squares estimation method (Rice 1988) to calculate utility scores for each individual, average scores for each group of respondents, and, from a combination of these scores, the relative importance of each factor.

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Table 4 The on-farm checklist used to validate the modelled welfare scores (MWS) against the perceived overall welfare scores (POWS).

Question asked (factor)	Negative response (0)	Positive response (100)
1. The opportunity for contact with a bull is	Poor	Good
2. The calves are removed	Later	Sooner
3. The level of assisted calving is	High	Low
4. There is space for this cow to groom itself when housed	No	Yes
5. Duration of forage access	Long	Short
6. There is space for this cow to exercise	No	Yes
7. The incidence of left displaced abomasum is	High	Low
8. This cow is subject to natural lighting patterns	Unnatural	Natural
9. The level of abnormal behaviour seen is	High	Low
10. There is enough water trough space for 10% of the herd to drink at one time	No	Yes
11. The condition and accessibility of the water trough is	Bad	Good
12. The condition score of the cow, with respect to the stage of lactation, is	Poor	Good
13. The duration of waiting to get to the feed trough is	Long	Short
14. The prevalence of lameness within the herd is	High	Low
15. Foot conformation is	Poor	Good
16. Stockmanship awareness of the health status of the herd is	Poor	Good
17. The abortion rate of the herd is	High	Low
18. Cows show reluctance to walk	Yes	No
19. The incidence of mastitis is	High	Low
20. Udder cleanliness is	Poor	Good
21. The incidence of milk fever is	High	Low
22. Teat lesions are present on	All cows	No cows
23. Amount of bullying seen between cows is	High	Low
24. Cows are herded with dogs	Always	Never
25. The approach distance (distance to the cow reached before signs of aversion are shown) is	Long	Short
26. Amount of encouragement required to walk into the parlour	High	Low
27. There is access to an undisturbed, comfortable, clean, lying area	Never	Always
28. Cleanliness of the cows' legs	Poor	Good
29. Number of cows that have difficulty rising	All cows	No cows
30. Position of shelter, with respect to prevailing wind, is	Poor	Good
31. Udder conformation is	Poor	Good
32. Underfoot condition are	Poor	Good
33. Number of cows with everted teats	All cows	No cows
34. Number of cows with hock lesions	All cows	No cows
35. Overall impression of welfare on the farm	Poor	Good

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Table 5 Using 'freedom from hunger and thirst' as an example, the table shows how the average importance scores (AIS) were used to weight the on-farm scores made by the assessors at audit, to calculate the modelled welfare score (MWS).

Factor	AIS (%)	On-farm score	MWS (= AIS × On-farm score)
Water trough space	17.9	45	805.5
Water trough condition	23.0	22	506.4
Condition score	29.7	54	1601.1
Feed trough space	29.4	27	794.6
Total	100		3707.7

The majority of the 'model cow' profiles presented to the respondents were used to calculate the relative importance of each factor. In initial trial simulations, holdout (standard model cases) 'calibration profiles' were used to check the accuracy of the calculated utility values and importance scores and these holdouts did not show disagreement with the main profiles. Because of the large number of 'model cases' presented to respondents (n = 52), and because the holdout calibration indicated agreement with the 'model cases', holdouts were not presented in the final list of questions. An independent-samples *t*-test (Petrie & Watson 2000) was applied to determine whether there was a statistically significant difference in the individual importance scores between veterinary students and experts.

It was noted that some individuals' responses produced utility scores that were in opposition to those of the majority. The percentage of these 'reversals' was calculated for each factor, and results were compared between the students and the experts using a non-parametric signed-rank Wilcoxon test (Petrie & Watson 2000). This provided a method of assessing how consistently the questions were interpreted.

Validation method

In order for the importance scores of the expert respondents' data to have practical value, they were converted into a scoring system that could be implemented on-farm. The 34 factors incorporated in the questionnaire may, or may not, contribute to the welfare of the dairy cow. Conjoint analysis of the expert data determined the different importance values ascribed by the respondents for each factor. The average importance scores (AIS), calculated by conjoint analysis for each 'factor', were recorded as percentages and used as weightings. The factors were developed into an on-farm checklist (Table 4), which was scored by an expert using the 100 mm visual analogue scale (Figure 1), from bad (0) to good (100). This validation was carried out on four farms. For each factor the distance marked on the line was measured, giving the on-farm score. To calculate the modelled welfare score (MWS), the AIS was used to 'weight' the on-farm score as shown using Table 5 and the following example.

The maximum possible score for this 'freedom' = Σ [AIS × highest possible on-farm score (= 100)] for each factor. The MWS for this 'freedom' = Σ (AIS × on-farm score): maximum possible score = 3707.7/10 000 = 37%. The overall MWS for a farm was the average of the validated welfare scores for each 'freedom'.

The last question in the questionnaire completed by an expert asked for a single 'perceived overall welfare score' (POWS): a summary 'gut feeling' for the overall welfare score of the general welfare of the dairy cows on that particular farm, and at that particular visit. This score was compared with the modelled welfare score using the Pearson product moment correlation coefficient (Petrie & Watson 2000).

Results

The analogue scale scores were recorded for the expert and student groups. Conjoint analysis was performed to calculate the AIS. Figures 2 to 6 indicate, for each 'freedom', the AIS and standard error of the means (SEM) for these groups.

Differences in the responses of the students and the veterinarians were apparent; Figure 3 shows the differences between these groups for the factors described in Table 3. To determine whether there was a statistically significant difference in the individual importance scores between veterinary students and experts, an independent-samples *t*-test was used. The factors indicated in Table 6 showed significant differences in AIS between expert and student groups, whilst the remaining 27 factors were not significant at confidence level $P < 0.05$.

A signed-rank Wilcoxon test (Petrie & Watson 2000) was performed to compare the consistency in interpretation of the questions between the experts and students. This compared the percentage of 'reversals' for each group and showed that there was no significant difference between the groups within each 'freedom'.

The overall MWS for each of four farms was compared with the POWS (Table 7). To determine whether there were significant differences, the scores were analysed using the Pearson product moment correlation coefficient (Petrie & Watson 2000), and showed a correlation coefficient of 0.988, significant with $P < 0.05$ (two-tailed). This suggested that the MWS score for each farm closely matched the POWS. Because the on-farm scores and the POWS were collected at the same time, they could not be considered as independent, and this is recognised as a limitation. It is also apparent that an increased sample size and an increased number of farms would be required in order for us to consider the results of this part of the study anything other than preliminary.

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Table 6 Factors given significantly different average importance scores by student and expert groups, analysed using an independent-samples *t*-test. **P* < 0.05, ***P* < 0.01.

'Factor'	Question	Significance (two-tailed)
Expression of normal behaviour	Contact with a bull	**0.005
	Calf removal from dam	*0.001
Fear and distress	Walking into parlour without encouragement	*0.049
Discomfort	Udder conformation	*0.048
	Underfoot conditions	*0.033
	Everted teats	*0.029
	Hock lesions	*0.001

Table 7 Perceived overall scores (POWS) were given to each farm by assessors as a 'gut feeling' of dairy cattle welfare standards on a particular farm, and on the particular visit. The modelled welfare scores (MWS), which were calculated using the method described in the text, are also shown.

Farm	POWS	MWS
1	75	69
2	82	76
3	63	66
4	38	52

Discussion

Discussion of experts' results

The following discussion is broken down into areas corresponding to the responses to each of the groups of questions for the 'five freedoms'.

Freedom to express normal behaviour

Please refer to Figure 2. Conjoint analysis of expert scores showed 'access to forage', 'space to groom' and 'space to exercise' to be of highest importance, with an AIS of 14.58, 13.08 and 12.70 respectively. The SEM values 2.07, 1.81 and 1.87 respectively, were low indicating low variation in scores between individuals. The importance ascribed to 'space to groom' and 'space to exercise' may have indicated a perceived high importance for adequate room for normal movement (Webster 1993; Leaver 1999).

Time spent eating has also been shown to contribute to dairy cow welfare (Fraser & Broom 1997; Lindstrom & Redbo 2000). In this section of the questionnaire, questions concerning 'access to forage' were intended to explore issues of oral satisfaction. Respondents were unaware of the division of the questionnaire into the 'five freedoms' and so may, for example, have considered this question to represent 'nutrition'.

'Left displaced abomasum incidence' was scored as the least important factor (AIS 7.90, SEM 1.31) but had 19.2% reversals, indicating a high variation in opinion, which suggests that this factor was seen as being irrelevant or having been misplaced in this section, or that the question had been misinterpreted. The fact that the analysis enabled 'faulty', or inappropriately chosen factors to be identified was, the authors believe, a strength of the technique, as large numbers of reversals of opinion regarding a factor make it essential either to reconsider the use of this factor, or to trigger close inspection of the way that the 'question' was used to examine the use of a given factor. A number of respondents identified 'left displaced abomasum' as not 'fitting' well into the group of factors that also included factors such as 'space to exercise', 'assisted calving incidence' and 'natural light patterns'. Where best to 'place' factors in a grouped study of this type is one of the elements of design that this preliminary study has explored and highlighted, and the authors believe that the grouping and design of factor questions is an area that should be explored further in subsequent studies using this technique.

A cow's natural behaviour is interrupted if she requires assistance during calving (Kilgour & Dalton 1984). Assisted calving was ranked eighth out of the nine factors relating to 'freedom to express normal behaviour' (AIS 10.33, SEM 1.40). This may reflect the experts' experience and perhaps a general acceptance that assisted calving is part of established agricultural practice.

The range of SEM for these nine factors was low (1.13–2.16) indicating that the respondents provided comparatively consistent scores.

Freedom from hunger and thirst

Please refer to Figure 3. The most highly ranked factors for this 'freedom' were 'feed trough space' (AIS 29.43, SEM 4.63) and 'condition score' (AIS 29.65, SEM 4.68). The large SEMs (4.63–4.68) indicated a wide spread of scores, perhaps representing difficulties in interpreting the 'condition score' photographs used, the quality of which was limited by print and size.

'Water trough condition' and 'water trough space' were ranked below feed factors (AIS 23.02, SEM 2.49; AIS17.89, SEM 2.65 respectively). This was perhaps unexpected, because a 600 kg cow yielding 30 kg milk per day, fed on concentrates and silage, requires approximately 70 kg water per day (Leaver 1999). Phrasing the question in a different

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way, for example "this cow has access to water twice daily/constantly", may have affected the importance scores that resulted. This example demonstrates that the way in which a question is phrased can have a very significant effect on the value or weight ascribed by the respondent.

Freedom from pain, injury and disease

Please refer to Figure 4. 'Foot conformation' and 'reluctance to walk' were ranked first and third of nine factors (AIS 15.07, SEM 2.34; AIS 12.74, SEM 3.36 respectively). Lameness is a common cause of poor welfare (Webster 1993; Whay *et al* 2002).

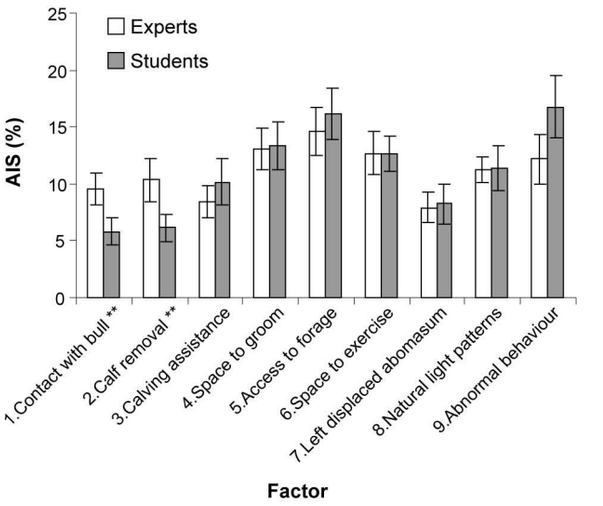
'Lameness prevalence' (percentage incidence) was included as an indication of the risk of that cow suffering from lameness. The use of a herd statistic may have caused underestimation of the significance of this factor because it does not directly reflect the effect on the individual. The AIS for this question was 10.62 (SEM 2.40), which appeared contradictory in view of the other factors indicating lameness, which were scored more highly ('foot conformation': AIS 15.07, SEM 2.34; 'reluctance to walk': AIS 12.74, SEM 3.36). Identifying the impact on the individual cow may have clarified the question, for example "in a year this cow experiences three episodes of lameness". The presence of 'teat lesions' was considered to be the second most important factor (AIS 14.09, SEM 2.30).

Stockmanship contributes to production and welfare (Webster 1988). In the questionnaire the issue of the stockman's response to a sick animal was represented by a photograph of a cow with congestive heart failure, stretching to cough, with the question "this cow is examined and treated today/tomorrow". The AIS for this question was 11.09 (SEM 1.58) and was ranked fifth of nine factors. The use of a photograph without additional information may not have been sufficient for the respondent to assess 'stockmanship', and this highlights the difficulties inherent in simplifying complex information to a single, stationary image. Stockmanship is one factor in a huge number of interlinked factors that affect the animal, and so the limitations of attempts to address stockmanship by use of independent examples of factors is apparent from this example.

The importance ranking of 'incidence of mastitis' was low (AIS 10.23, SEM 1.63). The type of mastitis was not specified by the question. Acute *Escherichia coli* mastitis may or may not be seen as more of a welfare issue than mild contagious mastitis (Webster 1993).

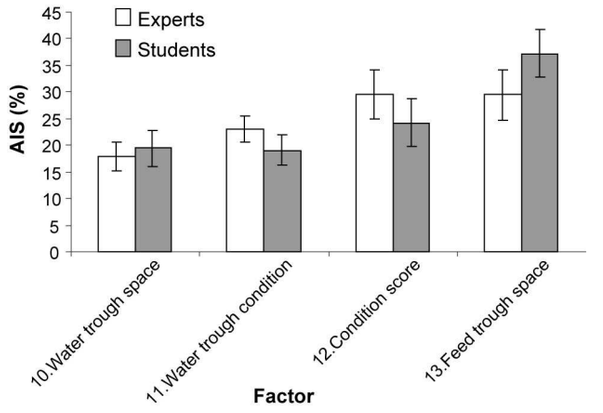
'Abortion percent' was ranked low (AIS 6.56, SEM of 1.2). Abortion was included because a high percentage may be an indication of, for example, infection, poor nutrition or stress. It may be that abortion is influenced by too many variables for it to be a useful measure of specific welfare issues. The upper limit of > 9% (an average of 4%; Murray 1990) may not have been high enough to trigger welfare concern to the respondent. A 'reversal' of 19.2% may reflect inconsistency of interpretation of this question.

Figure 2



Average importance scores (AIS) with standard error of the mean (SEM) bars for expert and student respondent groups for 'freedom to express normal behaviour'. **Significant difference ($P < 0.005$) between experts' and students' average importance scores.

Figure 3



Average importance scores (AIS) with standard error of the mean (SEM) bars for expert and student respondent groups for 'freedom from hunger and thirst'.

Freedom from fear and distress

Please refer to Figure 5. 'Walking into the parlour without encouragement' had the highest importance (AIS 31.83, SEM 4.94). This question incorporates numerous factors of the cows' environment considered to be important, such as familiarity with the milking routine, stockman personality, lameness, bullying and hunger (if the cows are fed in the parlour) (Reinhardt 1973; Seabrook 1987). From conjoint analysis it is not possible to identify which of these factors are affecting the respondents' welfare score. The high SEM indicates that there is variation in importance scores based on this factor.

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'Last to feed and being last in the parlour' was ranked of lowest importance of the four factors (AIS 17.56, SEM 3.4). Bullying on-farm is likely to increase when there is pressure on resources (eg competition for feed trough space, cubicles) (Webster 1993). There is overlap with factors incorporated under different 'freedoms' in the questionnaire (eg time spent waiting at the feed trough). The low AIS for this factor is relative to other factors considered within this 'freedom' and may not reflect the overall importance of bullying. 'Last to feed and being last in the parlour' had the highest 'reversal' percentage of all questions (30.8%), which may indicate variation in opinion of the importance of bullying or misinterpretation of the question. In general the SEMs for the factors within this 'freedom' were high (3.40–5.20).

Freedom from discomfort

Please refer to Figure 6. The presence of 'hock lesions' was ranked highest of the nine factors within this 'freedom' (AIS 18.84, SEM 3.00). In this section there is possible interdependence of factors; for example, 'hock lesions' may indicate absence of 'access to an undisturbed, comfortable, clean lying area'. This may have affected experts' importance scores. Conjoint analysis is most accurate when factors are independent of each other (SPSS 1999). When used to assess welfare in this study, some interdependence of factors was inevitable.

'Udder conformation' and 'everted teats' were ranked second and third respectively (AIS 14.40, SEM 2.07; AIS 2.21, SEM 2.21 respectively). Poor udder conformation is an important predisposition to both lameness and mastitis (Blowey 1985; Webster 1986).

Lower ranking factors included 'prevailing wind' and 'underfoot conditions' (AIS 9.60, SEM 1.86; AIS 9.51, SEM 1.40 respectively). Discomfort may be the end result of combinations of factors covered under other 'freedoms'. For example, lameness causes the dairy cow discomfort and could have been included in this 'freedom', but instead was considered under 'freedom from pain, injury and disease'.

Comparison of experts' and students' results

Analysis of an independent signed-ranks *t*-test (Petrie & Watson 2000) showed that seven of the 34 total factors in the questionnaire were ranked with significant difference between experts and students.

Within 'freedom to express normal behaviour' students ranked 'access to a bull' with AIS 5.80 (SEM 1.20). This was significantly different ($P = 0.005$) from the expert group, which ranked the same factor with AIS 9.53 (1.41). Students ranked 'time of calf removal' (AIS 6.13, SEM 1.2) of significantly lower importance ($P = 0.001$) than the expert group (AIS 10.33, SEM 1.85). This may reflect students' relative inexperience in comparison to experts. For both of these factors there was a high incidence of 'reversals' by students and experts (23.3% and 20.0% respectively). This may reflect inconsistencies in interpretation of these questions. Average importance scores of students and experts were statistically in agreement for the factors 'forage access' and 'space to exercise' ($P = 0.592$, $P = 0.209$ respectively).

There were no significant differences in the ranking of factors within 'freedom from hunger and thirst' and 'freedom from pain, injury and disease' between students and experts. A higher SEM within some factors might have been expected for the student group because of inexperience (eg interpretation of condition score pictures, awareness of lameness prevalence values); however, this was not proven to be the case.

Within 'freedom from fear and distress' students ranked 'walking into the parlour without encouragement' as the second most important out of the four factors considered (AIS 28.34, SEM 5.10). Experts ranked this factor of significantly higher importance than the student group (AIS 31.82, SEM 4.68) ($P = 0.049$). For 'freedom from fear and distress' both expert and student groups showed high SEMs (students 3.36–5.65, experts 3.40–5.20). This finding supports the hypothesis that this 'freedom' is the most subjective and has the greatest variability between respondents' opinions.

Within 'freedom from discomfort', the factors 'udder conformation', 'everted teats', 'underfoot conditions' and 'hock lesions' were given AIS values that were significantly different between experts and students ($P = 0.048$, $P = 0.029$, $P = 0.033$, $P = 0.001$ respectively). These differences may reflect variation in opinion, possibly because of the lack of clinical experience of students and hence differences in interpretation of the questionnaire.

The Wilcoxon signed-rank test (Petrie & Watson 2000) showed no significant difference in the number of reversals within each 'freedom' between the student and expert groups. This suggests that both groups interpreted the questions within 'freedoms' in approximately the same way. This may suggest that questions were set at an appropriate level for both students and experts to answer.

In general, one might believe that students' perception of welfare could differ from that of experts as a result of greater emphasis placed on animal welfare in the veterinary curriculum in recent years. However, the findings of this preliminary study suggests that the differences between students and experts were not as great as might have been expected: only seven of the 34 factors showed significant difference ($P < 0.05$). Experts' experience in advising farmers and treating disease may explain the comparative differences.

Comparison of the modelling method and an on-farm overall welfare assessment

Use of Pearson's product moment correlation coefficient (Petrie & Watson 2000) indicated that there was a strong positive correlation between the 'perceived overall welfare score' (POWS) and the 'modelled welfare score' (MWS) (correlation coefficient 0.988, $P < 0.05$) (Table 7). This indicated that scores from the modelling exercise correlated positively with general welfare scores assigned by experts during on-farm welfare assessment. This suggests that the

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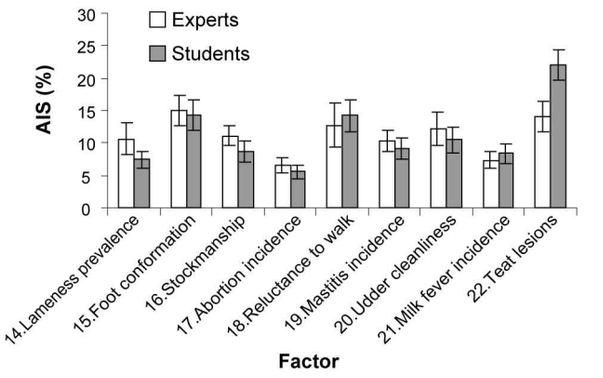
weightings derived from conjoint analysis may be comparable to the importance scores given by experts at on-farm assessment. On-farm assessment for this preliminary study was carried out on only four farms; therefore, further work would be required to consolidate these early findings. Evaluation of the validated welfare scores given by many assessors on the same farm could indicate whether the use of conjoint analysis in this way would be appropriate for use in objective on-farm welfare assessment.

This was a preliminary study and the method would need refinement before further application. However, there was positive feedback from the respondents regarding the use of photographs to illustrate points. Static images and phrases provide only limited information, which could be improved by the use of video clips and sound. Additional text provided to 'explain' the background to a photograph might have improved the respondents' ability to interpret photographs, and this finding is a valuable one — that pictures alone, without supplementary information, may not provide sufficient information for an informed decision. The use of photographs was found to be least appropriate for 'freedom to express normal behaviour', perhaps because it is difficult interpret 'behaviour' without reference to movement and changes in posture or activity. Some respondents may have found cases within this 'freedom' more difficult to assess for this reason. Respondents commented that 'model animals' with large numbers of factors were more difficult to assess with the same accuracy in comparison to those 'model animals' with fewer factors. Consideration was given when designing the questionnaire to group the factors together following the structure of the the 'five freedoms'. Some factors may contribute to more than one 'freedom'; for example, experts placed 'difficulty in rising' with low rank within 'freedom from pain, injury and disease' but if this factor had been included under 'freedom to express normal behaviour' it may have been ranked with different relative importance.

Although every effort was made to include factors that were deemed important, the list was not considered exhaustive. It was also recognised that each stakeholder (including farmer, stockman, vet, ethologist, welfare biologist, ruminant physiologist etc) would have a view on the inclusion of certain measures, and that only a very wide consultation, and a critical and rigorous analysis of the measures proposed, could give assurance that most variables had been covered. It was the authors' view that, in this preliminary study, an exhaustive list of variables was not required to demonstrate the potential of the technique. Further studies would be required to explore the potential of this technique to tease apart the weighting given to variables by differing groups of stakeholders. The questionnaire focussed on dairy cattle welfare issues on-farm, but factors compromising welfare during transport, at cattle markets and at slaughter are of importance; however, their inclusion was beyond the restricted scope of this questionnaire.

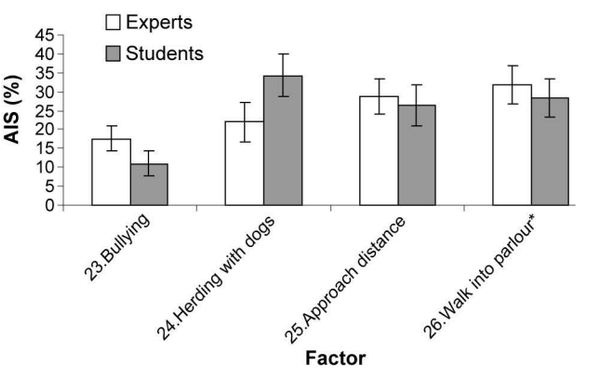
Some experts questioned whether some factors were welfare issues (eg 'abortion percentage'). Additionally, the fact that

Figure 4



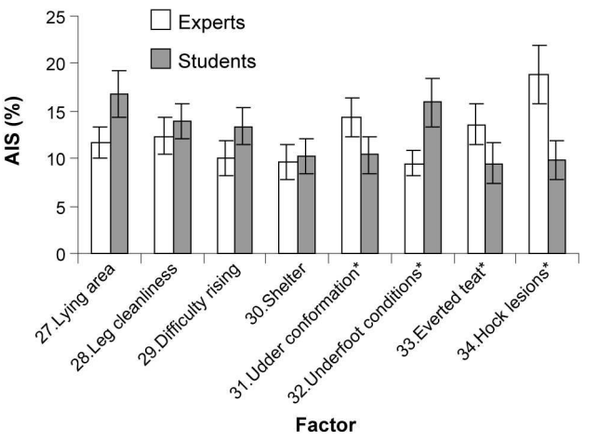
Average importance scores (AIS) with standard error of the mean (SEM) bars for expert and student respondent groups for 'freedom from pain, injury and disease'.

Figure 5



Average importance scores (AIS) with standard error of the mean (SEM) bars for expert and student respondent groups for 'freedom from fear and distress'. *Significant difference ($P < 0.05$) between experts' and students' average importance scores.

Figure 6



Average importance scores (AIS) with standard error of the mean (SEM) bars for expert and student respondent groups for 'freedom from discomfort'. *Significant difference ($P < 0.05$) between experts' and students' average importance scores.

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some factors affect individuals (such as 'condition score' and 'reluctance to walk'), whilst others affect the whole herd (such as 'trough space' or 'abortion percentage') was perceived by some respondents as a complex approach. The authors' rationale for mixing individual, group, and 'herd statistic' factors was that this is the approach that any auditor or assessor of a framing system would take. He or she would use all available data to build up a picture of the farm's function including farm records, objective observation of housing and feed space, and observation of the animals themselves during the inspection. The use of individual 'model animals' did not simply model the impacts on a single individual animal, but was used to explore the effect of a range of factors that could affect both individuals and individuals as 'representatives' of a whole herd, as a means of exploring the combined welfare impact of a number of factors.

It should be noted that the questions were phrased to find out the respondents' view of their importance in the assessment of welfare, rather than a statement of their assumed importance. The conjoint analysis described in this study has not permitted comparison of the importance of factors between 'freedoms'; each 'freedom' has been considered independently. Relative importance of factors could be determined only by directly comparing one against another.

One disadvantage of conjoint analysis is that the method can compile responses to only a limited number of factors (in general fewer than 10) at one time. This means that comparisons between the results for different groupings of factors (in this case, the groups of factors brought together under the 'freedom' groupings) cannot be made. Within the scope of this preliminary study it is not possible to explore the complex interactions between factors, and the significance of the 'weighting' of groups of factors; however, this study does start to make the limitations, and hence the possible restriction of use, of this technique apparent. Further use of this type of analysis may be of value in determining which welfare issues are considered to be important to consumers, researchers and legislators (Main *et al* 2003).

Conclusions and animal welfare implications

This preliminary study has shown how conjoint analysis may be used to obtain weighting scores for factors that affect the welfare of dairy cows. The study has highlighted some advantages and disadvantages of the technique, and lessons learnt from this initial trial may be of value in further studies that use this, or similar methods, to increase the understanding of observer preference and weighting in animal welfare decision making. One apparent disadvantage is that factors from different 'freedoms' cannot be directly compared, and hence the possible effects of a strong factor from one area 'compensating' for a weak factor from another area cannot be assessed. However, the nature of conjoint analysis means that, within the freedoms, strong and weak factors do influence each other, as it is the interaction of the weighting that creates the overall welfare score, which the respondent records.

Reliable 'tools' for on-farm welfare assessment may help in the 'auditing' of improvements (or worsening) of the impact of on-farm factors on animals. Inspection and certification bodies, retailers, farmers and researchers may wish to validate the measures they use to assess welfare. Studies such as this suggest that there may be value in using statistical methods, such as conjoint analysis and interpretation of expert responses, to help point us to useful tools, and to combine the effects of multiple factors that may affect welfare into 'scores'. This paper does not attempt to address the complex issues of aggregation of welfare measures into 'scores'. A significant EU-wide five-year study — 'Welfare Quality' — started in May 2004 and aims to bring together animal welfare scientists from across Europe to provide consensus regarding on-farm assessment methods. It is possible that statistical methods such as conjoint analysis may be used to determine whether the tools proposed have practical value, and, in the final analysis, whether on-farm assessment can make a difference to the welfare of the individual animal and to animals at the group and herd level.

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