Conjoint Analysis Method That Minimizes the Number of Profile Cards

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Abstract. Conjoint analysis is an effective method for use in deciding on a product concept. However, when numerous items are being surveyed, the number of profile cards shown to survey respondents increases and responding becomes more difficult. This makes it necessary to restrict the number of items being surveyed. This paper proposes a method of analysis that makes it possible to use a lower number of profile cards than that provided by the orthogonal design of experiment even when a large number of items is being surveyed. An Internet survey of 1,600 consumers using this method indicated that it generated identical analytical results to those produced when the orthogonal design of experiment was used.

Keywords: conjoint analysis, industrial design, incomplete rank ordered data.

1 Introduction

Conjoint analysis is a survey and analysis method which seeks to determine which product concepts will appeal to consumers by studying the degree to which they like or dislike entire products and then estimating the utility of each individual element making up that product[1],[2],[3]. In conjoint analysis, elements which determine the value of a product are termed "attributes," and concrete expressions of the conditions of these attributes are termed "levels." Concepts, which are combinations of single levels for each of the elements, are termed "profile cards." When consumers decide that they prefer a specific profile card, there is a trade-off between attributes, and this clarifies the criteria used by consumers when they select a product. However, when the number of surveyed attributes and levels in conjoint analysis increase, the number of profile cards also increases, making it difficult for subjects to provide answers. This makes it necessary to restrict the number of surveyed items.

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Table 1. Attributes and levels of hypothetical product plan for a digital camera & survey results

Attribute	Level		Part-worth utility		Attribute importance	
			16 cards	10 cards	16 cards	10 cards
Pixel count	3MP		-1.203	-1.030	59.64%	58.03%
	5MP		1.203	1.030		
Zoom	3x zoom		-0.890	-0.784	32.64%	33.61%
	8x zoom		0.890	0.784		
Memory card	SD card		0.465	0.443	4.72%	5.03%
	Memory stick		0.038	0.035		
	CompactFlash		-0.012	-0.070		
	xD-Picture card		-0.490	-0.407		
Battery	Lithium rechargeable battery		-0.036	0.015	0.05%	0.01%
	AA dry battery		0.036	-0.015		
Design	G		-0.069	-0.070	2.94%	3.32%
	J		-0.030	-0.067		
	L		0.420	0.403		
	W		-0.321	-0.266		
Constant			8.500	5.419		

2 Method of Minimizing Number of Profile Cards

Theoretically, the minimum number of profile cards that can be projected for conjoint analysis is the total number of levels minus the number of attributes, plus one. In addition, there are cases in conjoint analyses in which multicollinearity arises due to the rank deficiency of the design matrix, making analysis impossible. Because of this, even in the case of the theoretically supposable minimum number of profile cards, it would also be necessary to consider ensuring that the rank of the design matrix does not drop below the level given by the subtraction of the number of attributes from the total number of levels.

The formulation of a collection of cards such that, when any two attributes are randomly selected, all the combinations of the levels of those attributes appear uniformly, is an ideal condition in terms of achieving minimal bias in the levels combined as cards. This makes it possible to maximize the accuracy of estimation of part-worths, but the number of cards increases greatly[4]. It is difficult to balance minimization of the number of cards and minimization of bias in the levels; however, an increase in the number of cards increases the burden on respondents, and consistency or repeatability in answers is lost. It would be desirable to minimize any decline in reliability due to such loss, in addition to the incidence of analytic errors due to bias in the presented product concept.

Conjoint analysis allocates levels to cards with a lack of interaction between attributes as a precondition. Assuming sufficient attention to this point, when attributes and levels are studied, this problem can be dealt with by ensuring that when any two attributes are randomly selected, all the combinations of the levels of those attributes appear as uniformly as possible, under the principle that statistical independency (slightly weaker than orthogonality), rather than orthogonality, is ensured between the attributes. In concrete terms, the constraints for the solution of the optimization problem for the minimization of the number of cards are:

1. Number of cards = Total number of levels – Number of attributes +1
2. Guarantee of statistical independency between attributes
3. The theoretical maximum rank of the design matrix = Total number of levels – Number of attributes

Under these constraints, the optimization problem is solved by means of iteration so as to ensure, to the degree possible, that all of the combinations of the levels for any two randomly selected attributes will appear uniformly. Specifically, after cards are formulated using the L2-L7 and other orthogonal arrays, a card is randomly removed, and the statistical independency of the attributes is checked by means of a test for independence using the Akaike information criterion (AIC) and a test, using the ratio of the singular values of the matrix, is conducted to ensure that there is no deficiency in the maximum theoretical rank. Cards continue to be removed in turn until the minimum number of cards is reached. Following this, the levels of each attribute are interchanged while checks of independency and rank-deficiency are run. The formulation of the cards is optimized by conducting this procedure sequentially until each level of the attributes appears most uniformly.

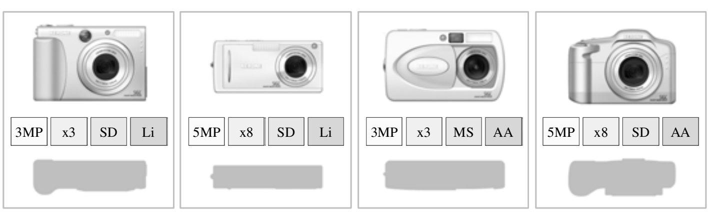

Fig. 1. Examples of profile cards

3 Verification of Effectiveness of Plan

In order to determine whether conjoint analysis using the minimum number of cards would be effective in an actual survey, a conjoint analysis of an Internet survey of consumers regarding a hypothetical product plan for a digital camera was conducted[5]. This experiment employed the attributes and levels shown in Table 1. For the sake of comparison, two surveys were prepared: Survey A, using 16 cards formulated using the orthogonal design of experiment; and Survey B, using 10 cards, minimized by means of the algorithm discussed above. 1,600 respondents who intended to purchase a digital camera were randomly assigned the surveys (800 subjects for each survey). The cards formulated using the orthogonal design of experiment were generated using SPSS ORTHOPLAN. Sixteen cards were output, with no designation of holdout cards or simulation cards. The profile cards used in Surveys A and B are respectively shown in Tables 2 and 3. Figure 1 shows examples of the profile cards that were shown to respondents. 1,600 responses were received for the survey. Responses in which there were no gaps in the rank of preference, duplications, etc. were taken as valid, and all other answers were judged invalid. 1,386 valid answers were received, representing 86.6% of the total. For each survey, the figures were:

- Survey A (16 cards): 609 (76.1%)
- Survey B (10 cards): 777 (97.1%)

The error rate for Survey A was 23.9%, while it was only 2.9% for Survey B. Assuming that there was no difference in attitude between the respondents for the two surveys, the difference can be ascribed solely to the number of cards, and we can say that the difference in error rates originates in the number of cards. This suggests that reducing the number of cards reduced the burden on respondents.

The average response times for valid responses in each survey were:

- Survey A (16 cards): 17.96 min (SD=9.76, SE=0.40)
- Survey B (10 cards): 16.05 min (SD=9.26, SE=0.33)

There is a difference of 1 minute and 27 seconds in the times. A t-test of the response times for the two surveys [F(1384)=1.946, t(1384)=-2.845, p=0.005] shows a statistically significant difference between them, at a significance level of 1%.

Table 2. Profile cards formulated using orthogonal design of experiment

Card number	Pixel count	Zoom	Memory card	Battery	Design
1	5MP	×8	CompactFlash	Lithium rechargeable batteries	L
2	3MP	×8	xD-Picture Card	AA dry batteries	G
3	3MP	×3	CompactFlash	AA dry batteries	W
4	3MP	×8	CompactFlash	Lithium rechargeable batteries	J
5	5MP	×3	xD-Picture Card	Lithium rechargeable batteries	J
6	5MP	×8	SD card	AA dry batteries	J
7	5MP	×3	CompactFlash	AA dry batteries	G
8	3MP	×8	SD card	AA dry batteries	L
9	5MP	×8	Memory stick	Lithium rechargeable batteries	G
10	5MP	×8	xD-Picture Card	AA dry batteries	W
11	3MP	×3	Memory stick	AA dry batteries	J
12	3MP	×3	SD card	Lithium rechargeable batteries	G
13	3MP	×3	xD-Picture Card	Lithium rechargeable batteries	L
14	5MP	×3	SD card	Lithium rechargeable batteries	W
15	5MP	×3	Memory stick	AA dry batteries	L
16	3MP	×8	Memory stick	Lithium rechargeable batteries	W

Multivariate tests were conducted in order to determine whether the difference in card numbers produced any difference in the part-worths estimated for each survey. The most powerful of these, Wilks' lambda, showed that there was no statistically significant difference [$F(9) = 1.607$, $P=0.108$]. Given this, we can say that there is no difference in the part-worths estimated from the results of the two surveys using differing numbers of cards.

These results show that a conjoint analysis conducted using cards the number of which had been minimized by means of the proposed method was able to produce results identical to those produced by a survey using cards generated by means of the orthogonal design of experiment. This indicates that it will be possible to survey greater numbers of attributes and levels using the same amount of cards as generated by the orthogonal design of experiment without increasing the burden on respondents.

Table 3. Profile cards formulated using minimization algorithm

Card number	Pixel count	Zoom	Memory card	Battery	Design
1	3MP	×3	Memory stick	AA dry batteries	J
2	3MP	×3	SD card	Lithium rechargeable batteries	G
3	5MP	×8	SD card	Lithium rechargeable batteries	L
4	5MP	×8	SD card	AA dry batteries	W
5	3MP	×8	Memory stick	Lithium rechargeable batteries	J
6	5MP	×3	Memory stick	Lithium rechargeable batteries	L
7	5MP	×3	CompactFlash	AA dry batteries	G
8	3MP	×8	CompactFlash	AA dry batteries	L
9	5MP	×8	xD-Picture Card	AA dry batteries	G
10	3MP	×3	xD-Picture Card	Lithium rechargeable batteries	W

4 Conclusion

This paper has shown that when conjoint analysis is used to decide on a product concept, the use of the minimum number of profile cards and a good balance of profile cards make it possible to survey a greater number of attributes and levels, reduce the burden on respondents, and increase the accuracy of responses and the reliability of the survey.

Unlike analyses in which holdout cards (which are not used for estimation but exclusively for verification) are introduced, because the proposed method generates only the minimum number of profile cards necessary for the estimation of part-worths, it has the problem that it is not possible to obtain indicators of the reliability of the estimation results. In the case of the first conjoint analysis conducted during product research, a standard analysis using holdout cards should be conducted prior to using the proposed method, in order to check the reliability of the survey.

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