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COMPENSATORINESS OF PREFERENCES IN MATCHING AND CHOICE

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Abstract: This paper empirically studies the influence a questioning mode can have on elicited preferences. The preference structure of decision makers is elicited using two different questioning modes: choice and matching. The results show a strong failure of procedure invariance. The impact on preference modelling and on importance parameter elicitation techniques is discussed.

1. Introduction

Real world decision situations often involve several objectives, viewpoints or criteria. Several methodologies dealing with Multiple Criteria Decision Aid (MCDA) have been proposed over the past three decades (see [15], [21]). The numerous aggregation techniques reported in the literature are useful tools for managers facing decision tasks. Several fundamental principles concerning the consistency of preferences emerge from these works. Among these is *the procedure invariance principle* which states that normatively equivalent preference elicitation techniques should lead to the same elicited preferences. By analogy, when comparing the length of objects, all available tools should give the same lengths for each object and thus compare the objects in the same way; no interaction occurs between the tools and the objects measured.

This principle does not always correspond, however, to decision makers' (DMs) behavior in real-world decision situations. DMs express their preferences using task contingent strategies (see [20]). Psychological and behavioral science studies have shown that DMs do not respect the procedure invariance principle when expressing preferences. [16] and [17] first highlighted the preference reversal phenomenon in the context of risky decision making. These authors found that DMs' answers to direct comparisons and questions on minimum selling price induced different preferences, even though these two questioning modes are normatively equivalent. This preference reversal phenomenon clearly contradicts the procedure invariance principle.

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2. (Non-)Compensatoriness of preference structures

The notion of (non-)compensatoriness of preference structures is intuitively linked to the possibility of using to substitution rates in the construction of preferences that take all criteria into account. These subtitution rates allow us to compensate for a disadvantage on a particular criterion with a sufficient advantage on another criterion. When an aggregation procedure uses such ideas to solve conflicts between criteria, the induced preference structure is said to be compensatory; otherwise it is said to be non-compensatory. Similarly, preferences expressed by a DM denote a preference structure of a more or less compensatory nature.

2.1. Definitions

The first formal definition of this notion was proposed by [7]:

Let us define by

P and I the preference and indifference relations on a product set $X=X_1 \times X_2 \times \ldots \times X_n$

P_i a preference relation on X_i

$\succ(x,y) = \{i \text{ such that } x \, P_i \, y\}$; we denote $\Pi_P = \{P_1, P_2, \ldots, P_n\}$

Definition 1: a preference structure (X, P, Π_P) is totally non-compensatory iff:

$$\forall\, x,y,z,t \in X, \quad \left.\begin{array}{c} \succ(x,y) = \succ(z,t) \\ \succ(y,x) = \succ(t,z) \end{array}\right] \Rightarrow [\; xPy \Leftrightarrow zPt \;]$$

In other words, a preference structure is totally non-compensatory when all pairs of alternatives (x,y) and (z,t) with the same "preferential profile" (i.e. whose comparisons are similar on all criteria) are compared in the same way on the overall level (i.e. when all criteria are taken into account). A generalization of this notion may be found in [4]. [3] proposes a definition of a minimally compensatory preference structure.

Definition 2: a preference structure (X, P, Π_P) is minimally compensatory iff:

$$\exists\, x,y,z,t \in X \quad \text{such that} \quad \left.\begin{array}{c} \succ(x,y) = \succ(z,t) \\ \succ(y,x) = \succ(t,z) \\ x_i = y_i \text{ and } z_i = t_i \;\; \forall i \in I(x,y) \end{array}\right] \text{ with } [\; xPy \text{ and } zIt \;]$$

with $I(x,y) = \{\, i \,/\, i \notin \succ(x,y) \text{ and } i \notin \succ(y,x) \,\}$

More recently [24] proposed a definition allowing the analysis of compensation on each criterion individually (this definition is grounded on a new formalism for analysing the notion of relative importance of criteria). However, the (non-)compensatoriness of a preference structure is a notion that deserves to be studied in further detail. Firstly, no general consensus has emerged concerning its definition. Moreover, the available definitions characterize only extreme cases and do not enable us to specify to which level a preference structure is (non-)compensatory.

2.2. Construction of a (non-)compensatoriness index

Total non-compensation is an extreme situation never reached in real world decision contexts. Let us define an index aiming at "measuring" the (non-)compensatory aspects of a preference structure $\Psi = (X,P,\Pi_P)$. Ψ is even more non-compensatory since two pairs of alternatives with the same preferential profile on criteria are linked to the same preference relation on the overall level. Compensation possibilities in a preference structure depend on the overall preference situation that links pairs (x,y) and (z,t)) $\in X^2$ verifying:

$$\begin{cases} \succ(x,y) = \succ(z,t) \\ \succ(y,x) = \succ(t,z) \\ x_i=y_i \text{ and } z_i=t_i \ \forall i \in I(x,y) \end{cases} \qquad [1]$$

When all pairs (x,y) and (z,t) verifying [1] are such that $xPy \Rightarrow zPt$, the considered preference structure is totally non-compensatory (see definition 1). Compensation possibilities appear in a preference structure if $\exists$ (x,y), (z,t) such that

not($xPy \Rightarrow zPt$) i.e. xPy and not(zPt)

i.e. (xPy and zIt) or (xPy and tPz)

The first case of compensation (quadruplet verifying [1] such that xPy and zIt) corresponds to definition 2. The second situation (quadruplet verifying [1] with xPy and tPz) corresponds to a stronger compensation (a preference reversal). However, our index will account for these two situations in the same way. This index will measure the proportion of quadruplets (x,y,z,t) verifying [1] such that $xHy \Leftrightarrow zHt$ (H being any preference relation).

Suppose that all X_i are discrete and let us define:

$T=\{(x,y,z,t)\in X^4 \text{ such that } \succ(x,y)=\succ(z,t) \text{ and } \succ(y,x)=\succ(t,z)\}$

with $\succ(x,y)=\{i \text{ such that } xP_iy\}$

$NC = \{(x,y,z,t)\in T \text{ such that } xHy\Leftrightarrow zHt\}$, H being any overall relation

Let us define the (non-)compensatoriness index of a preference structure Ψ by:

$$nc(\Psi) = \frac{|NC|}{|T|}$$

The range of variation of $nc(\Psi)$ is $[1/\lambda,1]$, where λ is the number of possible preferential situations on the overall level (when preferences are modeled using an (I,P) structure, three preferential situations are possible between two alternatives: aPb, aIb and bPa). This index is built so that $nc(\Psi)=1$ means that Ψ is totally non-compensatory (lexicographic order); a decreasing value for $nc(\Psi)$ means greater compensation possibilities in Ψ. Thus the nc index allows us to compare the (non-)compensatoriness of two preference structures; this index has an ordinal signification only (no cardinal use of this index will be made).

3. Empirical scheme

Our aim in this experiment is to highlight the violation of procedural invariance and to demonstrate a link between the use of a specific questioning mode (choice and matching in our case) and the (non-)compensatoriness of the elicited preference structures. We will deal with a bi-criteria context. The scale on both criteria will be discretized on a four-level scale {A,B,C,D} where $A\ P_i\ B\ P_i\ C\ P_i\ D$ $i=1,2$, P_i being the preference relation restricted to the i^{th} criterion.

3.1. The two questioning modes

The experiment consists of an exhaustive elicitation of the discretized preference structure using two different questioning modes:

Choice: this type of question consists of a holistic comparison of two alternatives defined by their evaluations on all criteria. Subjects are to choose between an indifference situation or a preference in favor of one of the alternatives. As we deal with a bi-criteria context, let us denote these questions by $(x_1,x_2)?(y_1,y_2)$.

Matching: this type of question consists of proposing two alternatives (x_1,x_2) and (y_1,y_2) leaving y_2 undetermined. The subjects' task is to determine y_2 in order to obtain indifference between the two alternatives. Let us denote these questions by $(x_1,x_2)I(y_1,?)$. In our experiment, answers are given on a continuous scale. It is thus necessary to analyse the answers in terms of the discretized four-level scale (A$\rightarrow$D). In order to do this, we use an indifference threshold q which represents the minimum discernable difference between two evaluations (see [25]). This threshold is elicited beforehand[1] and used to compare the value y_2 to the four levels of the discretized scale. The nine possible situations are represented in figure 1.

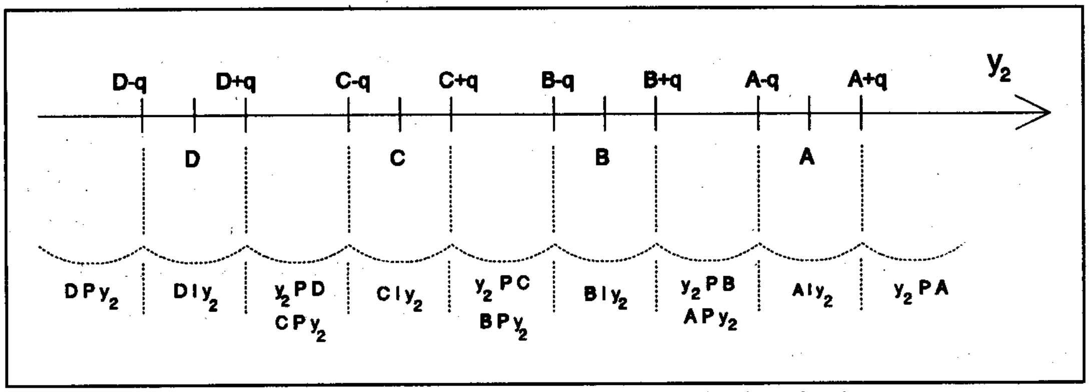

Figure 1 : Preferences restricted to a single criterion

3.2. Empirical hypotheses

We use a within-subject experimental design to test two connected hypotheses: the prominence hypothesis and the contingent compensation hypothesis.

The prominence hypothesis states that preferences elicited by choice questions should be closer to a lexicographic order than those elicited by matching questions. In other words, the "more important" criterion should be taken into account more often in the first case than in the second. In order to test this hypothesis, we will count, for both of the elicited preference structures, the number of "cases" in which an advantage on the preponderant criterion is taken into account first (if $(x_1,x_2)P(y_1,y_2)$ with x_1Py_1 and y_2Py_1 then criterion C_1 is taken into account first). Let us denote C^* the criterion most frequently taken into account. Let $p(\Psi_m)$ and $p(\Psi_c)$) be the proportion of cases in which an advantage on C^* is decisive on the overall level when preferences are elicited by matching questions and choice questions respectively. The prominence hypothesis states that: $p(\Psi_m) < p(\Psi_c)$

The contingent compensation hypothesis states that there are more compensation possibilities in preference structures elicited with matching questions than in those elicited using choice questions. In order to judge the (non-)compensatoriness of elicited preferences, we will use the nc(Ψ) index proposed in section 3.2. Let us recall that this index varies between ⅓ and 1 and that its value increases with the non-compensatoriness of Ψ. Let us denote by Ψ_m and Ψ_c the preference structure

[1] Using a standard dichotomy procedure (see [Mousseau 93]).

elicited using matching questions and choice questions respectively. The contingent compensation hypothesis states that: $nc(\Psi_m) < nc(\Psi_c)$.

3.3. Experimental framework

The real world context concerns the evaluation of firms by young computer science executives in order to apply for jobs in these firms. The firms proposed differ in both the annual salary and the job interest they afford. The scales on both criteria (salary and job interest) are discrete; they consist of four levels of evaluation.

Criterion 1: Job interest is evaluated on a qualitative scale built with subjects. Each level is defined by linguistic terms. Subjects were asked to build this scale so as to perceive the "distance" between consecutive levels as equivalent[2]. It was then verified that all levels were separated by a strict preference.
For example, one subject's scale was:

- A: Very interesting job, good training prospects, no repetitive aspect, prospects for increased responsibility and large degree of independence at work.
- B: Interesting job, slightly repetitive but good training prospects, some prospects for increased responsibility, fair degree independence at work.
- C: Job of little interest, quite repetitive but still some training prospect, some prospects for increased responsibility in the long term, fairly little independence.
- D: Boring job, poor training prospects, numerous repetitive aspects, annoying hierarchy.

Criterion 2: The salary is measured in thousands of francs per year. This numerical scale is discretized on a four-level scale ; all consecutive levels are separated by a strict preference and are built so as to reflect various salaries (from very attractive to quite unattractive). The values corresponding to the four levels are determined according to the subject's salary expectations.

3.4. Simplifying postulates

Eliciting the subject's overall preference structure constist of determining the Cartesian product of X (the number of couples $((x_1,x_2),(y_1,y_2)) \in (X_1 x X_2)^2$ is $4^4=256$). In order to minimize the number of questions submitted to subjects, we have formulated three postulates that impose relatively weak conditions on preference structures and do not interfere with the questioning modes. Let us consider the P-dominance relation defined by:

$$\forall\ x,y \in X \quad x\ \Delta_P\ y \iff \begin{bmatrix} \forall i\ \ \text{not}[y_i P_i x_i] \\ \exists j\ \ x_j P_j y_j \end{bmatrix}$$

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[2] This particular instruction does not, however, influence the interpretation of the experiment's results.

Postulate 1 (preference contains P-dominance): $\forall\ x,y \in X\ x\Delta_P y \Rightarrow xPy$.

This first postulate results in reducing the number of pairs of alternatives for which the preferential situation is initially not determined. The number of undetermined comparisons is reduced to 36.

Postulate 2 (monotonicity): $\forall\ x,y,z,t \in X \left[\begin{array}{l} xPy \text{ and } t\Delta_P x \Rightarrow tPy \\ xPy \text{ and } y\Delta_P z \Rightarrow xPz \end{array} \right.$

The interpretation of this postulate is the following :"when an assertion aPb is established, increasing the evaluations of x or decreasing the evaluations of y leaves the overall preference relation between x and y unchanged.

Postulate 3 (a partial preference is valid on the overall level):

$$\left[\begin{array}{l} xIy \text{ and } y\Delta_P z \Rightarrow xPz \\ xIy \text{ and } t\Delta_P x \Rightarrow tPy \end{array} \right. \text{ i.e. } \left[\begin{array}{l} I\,\Delta_P \subset P \\ \Delta_P\, I \subset P \end{array} \right.$$

As in the preceding postulate, this postulate enables us to induce assertions from previously determined assertions. In concrete terms, if $(x_1,x_2)I(y_1,y_2)$ then we have:

$$\forall\ (z_1,z_2)\in X\ \ (z_1,z_2)\Delta_P(x_1,x_2) \Rightarrow (z_1,z_2)P(y_1,y_2)$$
$$\forall\ (t_1,t_2)\in X\ \ (y_1,y_2)\Delta_P(t_1,t_2) \Rightarrow (x_1,x_2)P(t_1,t_2)$$

3.5. Data acquisition software

According to the preceding postulates, we can build an algorithm whose aim is to reduce the number of questions submitted to the DM in order to elicit his/her overall preference structure. Let us ground our algorithm on the oriented graph G=(C,U) where C is composed of every pair (x,y) with $x \neq y$ whose comparison is not determined by postulate 1 and U represents possible deductions (according to postulates 2 and 3). Thus, U is defined by: $\forall\ ((x,y),(z,t)) \in C^2,\ \ ((x,y),(z,t)) \in U \Leftrightarrow z\Delta x$ or $y\Delta t$

```
Begin
|     While a comparison remains unmarked
|     do
|     |  Determine an unmarked comparison by a question.
|     |  If the first alternative is preferred to the second one,
|     |    then mark the current comparison and all its successors P
|     |  If the second alternative is preferred to the first one,
|     |    then mark the current comparison and all its predecessors -P
|     |  If the two alternatives are indifferent,
|     |   then mark the current comparison I, all its successors P and all its predecessors -P
|     End
End
```

During the experiment, the two questioning modes described in 3.2 were used simultaneously and randomly mixed. To implement this experiment, we have built data acquisition support software that allows us to make the deductions (corresponding to the postulates) instantaneously during the questioning procedure. In the software, the two questioning modes were phrased as shown on the screens below (see figures 2 and 3). More details concerning the software supporting this experiment may be found in [19].

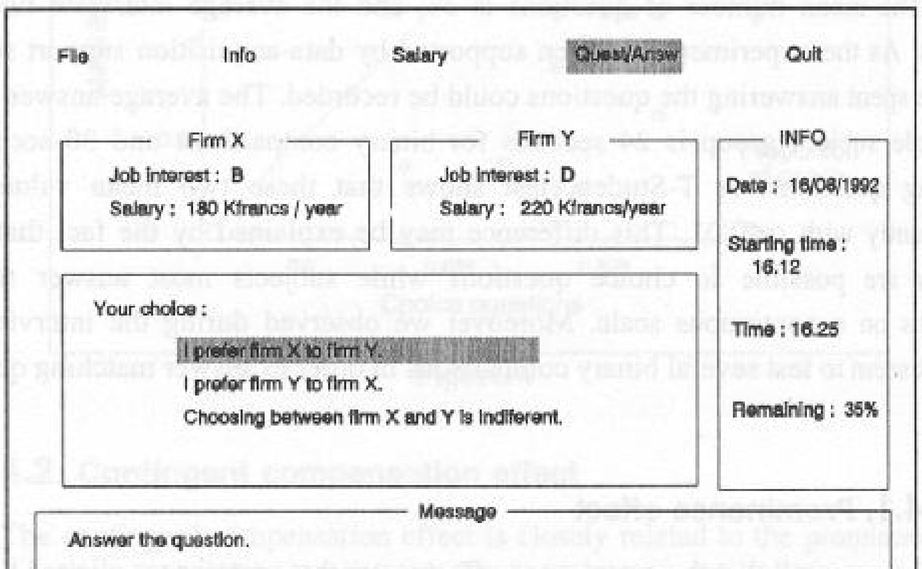

Figure 2

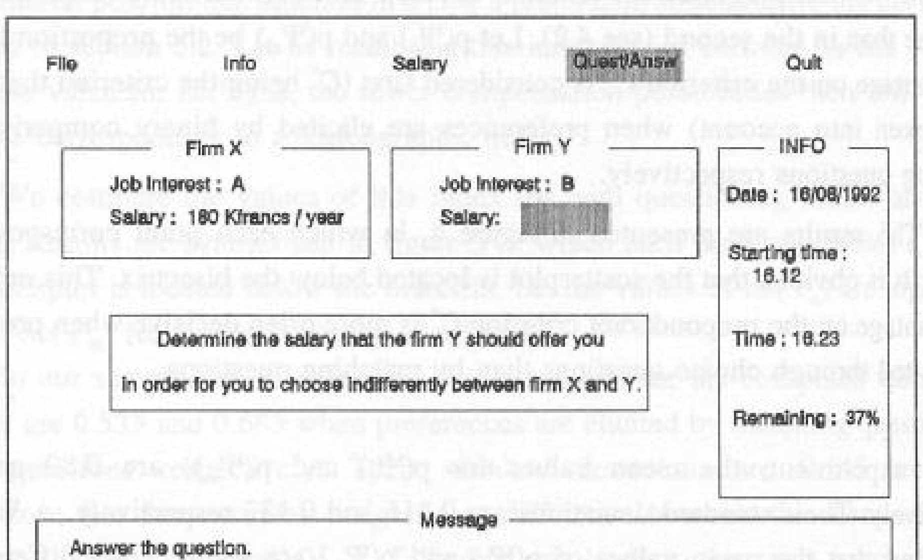

Figure 3

4. Results

The 33 subjects are young executives with a high level of education, most of them working in the computer science sector. The mean age is 28 (σ_{age}=3.2) and their professional situation is such that they can consider several job types with different salaries. In this sense, comparing jobs offered by companies is for them a pertinent and real-life decision problem.

The mean number of questions is 31, and the average interview time is 40 minutes. As the experiment has been supported by data-acquisition support software, the time spent answering the questions could be recorded. The average answer time for the whole subject group is 24 seconds for binary comparisons and 30 seconds for matching questions. A T-Student test shows that these two mean values differ significantly with $\alpha \leq 0.01$. This difference may be explained by the fact that only 3 answers are possible in choice questions while subjects must answer matching questions on a continuous scale. Moreover we observed during the interviews that subjects seem to test several binary comparisons in order to answer matching questions.

4.1. Prominence effect

Let us recall that the prominence effect states that preferences elicited by binary comparisons are closer to a lexicographic structure than those elicited by matching questions, i.e. the preponderant criterion is taken into account more frequently in the first case than in the second (see 4.2). Let $p(\Psi_c)$ and $p(\Psi_m)$ be the proportion in which an advantage on the criterion C^* is considered first (C^* being the criterion that is most often taken into account) when preferences are elicited by binary comparisons and matching questions respectively.

The results are presented in figure 4, in which each point corresponds to a subject. It is obvious that the scatterplot is located below the bisectrix. This means that an advantage on the preponderant criterion C^* is more often decisive when preferences are elicited through choice questions than by matching questions.

In this experiment, the mean values for $p(\Psi_c)$ and $p(\Psi_m)$) are 0.80 and 0.663 respectively. Their standard deviations are 0.116 and 0.133 respectively. A Wilcoxon test shows that the mean values of $p(\Psi_c)$ and $p(\Psi_m)$ are significantly different with $\alpha \leq 0.01$. A T-Student test leads to the same conclusion with $\alpha \leq 0.01$. We can thus conclude that our experiment confirms the prominence effect.

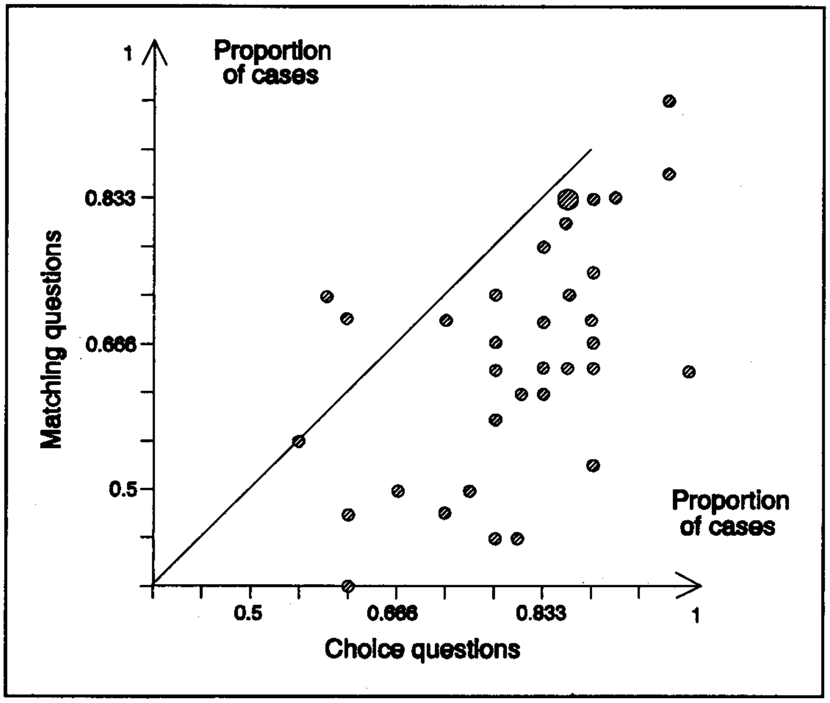

Figure 4

4.2. Contingent compensation effect

The contingent compensation effect is closely related to the prominence effect and states that elicited preferences reveal more compensation possibilities if the questioning mode is matching rather than binary comparison. In order to measure the compensation possibilities inherent in a DM's preference structure, we use the nc index proposed in section 3.2. Let us recall that this index varies between ⅓ and 1 and the higher the value for nc(Ψ) is, the fewer compensation possibilities there will be in Ψ (nc(Ψ)=1 corresponding to a lexicographic order).

We compute the values of this index for both questioning modes and for all subjects. Results are synthesized in figure 5 in which each point represents a subject. The scatterplot is located below the bisectrix, i.e. the values of nc(Ψ_c) are higher than those of nc(Ψ_m) for a large majority of subjects.

In our sample, the mean values across subjects for the computed value of the nc index are 0.535 and 0.685 when preferences are elicited by matching questions and choice questions respectively. Their standard deviations are 0.145 are 0.144. A Wilcoxon test demonstrates a significant difference between the mean values for nc(Ψ_c) and nc(Ψ_m) with $\alpha \leq 0.01$. A T-Student test leads to the same conclusion with $\alpha \leq 0.01$. We can thus conclude that our experiment confirms the contingent compensation effect.

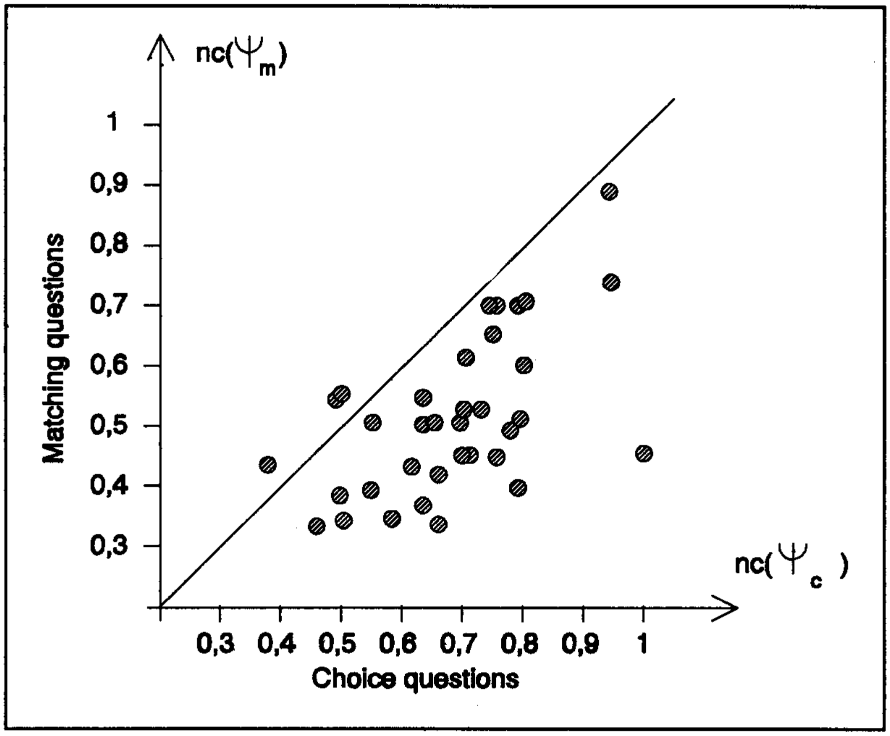

Figure 5

5. Discussion

The experimental results show a strong failure of the procedure invariance principle: in our sample we observed a significant divergence among preferences elicited through the two different questioning modes used (choice and matching questions). More precisely, subjects answered in such a way that matching questions elicited preference structures in which there were more compensation possibilities and in which the preponderant criterion looms larger than in the preference structures elicited with binary comparisons. Such labilities in preferences have already been reported in the literature (see [11], [12], [5] and [28]) and would seem to constitute a problem that is inherent in preference elicitation.

Descriptivist vs constructivist analysis preference lability

Many researchers in the field of behavioral research have reported a great lability in elicited preferences and values (see [9]), such as the framing effect (see [14], [26], [13]), splitting effect (see [8], [1], [29]), question order effect (see [18]), procedure invariance violation (see [27], [6]).

There are two ways to account for such lability and to explain observed phenomena. These two approaches diverge on the nature of what is being modelled: are preferences to be considered as pre-existing and thus to be discovered or are they a result of interaction between the DM and the elicitation tool (see [23]) ? This distinction is essential, as the two approaches use experimental works in very different ways.

The first stream, the *descriptivist approach* (also called discoverist or realist approach) refers to stable pre-existing preferences. Within this framework, there are values to be discovered reflecting the DM's true preferences. By analogy with physical measurement in which each object is assumed to have a well-defined value for a specific attribute, true preferences exist and can be measured. Discrepancies between elicitation tools reflect the fact that these tools provide only estimates of the true preferences, the elicited preferences being biased. True preferences are thought to remain constant but to be distorded during the elicitation process. Elicitation techniques orient preferences in certain directions, introduce noises, etc. However, it is assumed that when the analyst and the DM are sufficiently careful, when they have enough time and use different elicitation methods, preferences obtained will converge toward true preferences.

Preference lability may also be analysed following a *constructivist approach.* In this case, preferences are not assumed to exist before the modelling process begins. [2] emphasize that "it is a platonic myth that latent probabilities and utilities really exist deep down and that the analyst merely has to cut away the fat in order to display the pre-existing structure". Observed preferences are considered to be a construct of the elicitation process and analysed as a result of interactions between the DM and the elicitation tool. This does not mean that DMs do not have any opinions but that the constructs refer to basic attitudes, values and opinions which cannot be observed directly and to which we have acces only through the filter of an elicitation procedure. Preference lability results, therefore, from differences in the interaction between DMs and elicitation tools.

In a descriptivist interpretation, the violation of the procedure invariance principle is then analysed as resulting from biases in the elicitation procedures (see [10]). In our study, choice questions are supposed to be biased in such a way that DMs tend to "overweight the more important criterion", while matching questions "push" DMs in the opposite direction. The "true pre-existing preferences" are supposed to be in between the two and the use of different questioning modes should lead to approaching these true preferences.

In the constructivist approach, DMs' preferences are not viewed as totally pre-formed; they are built up (at least partially) during the modelling process. Within this framework, elicited preferences are the result of interaction between the DM and the elicitation tools ; in this sense, this tool cannot be considered neutral. Following this approach, the experimental results described in this paper may be used in two distinct ways according to the objective pursued. [27] obtained similar results and proposed a model (the contingent tradeoff model) that accounts for the observed divergences among preferences elicited by different questioning modes, in which "the tradeoffs among input depend on the nature of the output". In this case, the pursued objective is to account for the observed phenomenon through an explicative model.

We propose an alternative use of the same observed phenomenon. Our goal is to use the general tendency of the empirical observations in order to induce a rule concerning the questioning mode to be used in importance parameter elicitation techniques. We observe that binary comparisons induce a preference structure of a more non-compensatory nature than a preference structure elicited with matching questions for the same DM. It seems to us that the choice of a questioning mode for elicitation techniques should be made with regard to the aggregation procedure used to model preferences. It is crutial for the information obtained from the DM to be consistent with the use of this information in the aggregation procedure. Consequently, if the chosen aggregation procedure is of a non-compensatory nature (lexicography, majority rule), then binary comparisons would seem to be more suitable than matching questions: choice questions will induce information that is likely to be more consistent with a non-compensatory aggregation rule. Conversely, matching questions will be better adapted to eliciting preferences when a compensatory aggregation procedure is used.

6. Conclusion

The experimental study reported in this paper shows that DMs strongly violate the procedure invariance principle. Our results confirm and enlarge those of [27]: prominence effect has been observed on the entire preference structure of DMs; moreover we have built a (non-)compensatoriness index and computed it for all subjects and both questioning modes (choice and matching): matching questions induce preferences in which there are more compensation possibilities and in which the preponderant criterion looms larger than in the preference structure elicited with binary comparisons. The analysis of these results differs according to basic assumptions concerning the origins of preference lability (descriptivist versus constructivist approach). Following a constructivist approach, we propose a new interpretation of these empirical results.

Further investigations should be undertaken in order to test similar hypotheses with other questioning modes. Such work should provide an interesting example of how behavioral science studies may be useful in multiple criteria decision aid.

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