New Directions in Research on Decision Making
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JUDGMENT AS A COMPONENT DECISION PROCESS FOR CHOOSING BETWEEN SEQUENTIALLY AVAILABLE ALTERNATIVES

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Choice alternatives are frequently presented as multidimensional descriptions. In some cases the alternatives can be looked at together, while in other cases the alternatives are located in different places and can only be inspected in sequence. For example, the products offered in a store are simultaneously available to the purchaser, whereas the information about products in different stores must be processed in sequence, possibly separated by some unrelated cognitive activity such as finding the way to the next store. This differential availability of the information about the alternatives could influence the cognitive processes which determine a choice. For simultaneously available alternatives, dimensional comparisons are usually applied to derive a choice (Russo & Dosher, 1983). However, dimensional processing could lead to a high cognitive load for sequentialy presented alternatives. Since people have limited capacity for processing information, they tend to apply decision procedures which reduce this cognitive load. To reduce the cognitive effort a strategy involving overall judgments of each alternative and a subsequent comparison of the overall judgments could be applied instead.

In the present paper, the criterion dependent choice models designed to explain the selectivity and adaptiveness of human choice processes (Schmalhofer, Albert, Aschenbrenner & Gertzen, 1986) are used to analyze the effort and quality of two different choice procedures. For sequentially and simultaneously available alternatives dimensional comparisons and overall judgments will be analyzed as component processes in binary choices. The results of this analysis will then be compared to the results of an

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experiment in which choice pairs were presented simultaneously, sequentially, or sequentially and separeted by some interpolated task.

Criterion and Dependent Choice Models

The basic assumption of criterion dependent choice models is that the processing of an alternative or choice pair continues until some evidence criterion is surpassed. This evidence criterion is specified by a number k, which is the only free parameter in a criterion dependent model. Thus, decision making is assumed to be a selective, sequential process. The criterion dependent choice models postulate that the availability (and importance) of the features of the choice alternatives determines both which features will be processed and the order in which they will be processed.

The processing of a feature yields an attractiveness value for that feature. For attractive and unattractive features, positive or negative attractiveness values are obtained, respectively. The attractiveness values are combined according to some rule. This rule may specify dimensional comparisons or the formation of overall judgments as component processes of choices.

Dimensional Comparisons as Component Processes. It is assumed that at the beginning of the choice process neither alternative is favoured. Therefore, at the beginning the evidence value is assumed to be zero. In the first processing step the features on the most important dimension are evaluated, and the difference of the two attractiveness values is calculated. This calculated value represents the evidence value after the processing of the first dimension. Then the second most important dimension is processed. After the processing of the second dimension the evidence value is updated by adding the attractiveness difference determined for the second dimension. This process continues until all dimensions have been processed or one or two criteria is surpassed, i.e. the evidence value is larger than k or the evidence value is smaller than -k. A positive evidence value determines the choice of an alternative, and a negative evidence value determines the choice of the other alternative. Previous experimental research has shown that such models can account for the information processing of dimensionally described and simultaneously presented choice alternatives (Aschenbrenner, Albert & Schmalhofer, 1984). Similar models have been used to explain decision making under uncertainty (Busemeyer, 1985).

A dimensional strategy may be difficult to apply for sequentially presented alternatives, because the feature of the first alternative would have to be stored in memory until the next alternative becomes available. To decrease the demands upon working memory, subjects could however use judgment as a component decision process in this case. Thus, subjects would make an overall judgment of the first alternative and store it in memory rather than its features. A second overall judgment is then made for the second alternative, and the decision would be based upon a comparison between the two overall judgments. For such a strategy, the criterion dependent processing occurs for the formation of the judgments of the two choice alternatives.

Judgment as Component Processes. The procedural character in the cognitive formation of judgments has already been emphasized by Lopes (1982). Contrary to Lopes' averaging assumption, the present conception assumes that the feature evaluations, which which may be positive or negative, are summed. In particular, it is assumed that at the beginning of the judgment process the evidence value is zero, i.e., there is no bias towards a positive or a negative judgment. In the first processing step, the feature of the most important dimension is evaluated and represents the evidence value after the processing of the first dimension. Then the second most important dimension is processed. After the processing of the second dimension the evidence value is uppdated by adding the new attractiveness value. This process continues until one of two criteria is surpassed or all features have been processed. If the boundary k is surpassed the alternative is considered to be attractive. If the boundary -k is surpassed the alternative is unattractive. A judgment about the choice alternative is obtained by dividing the evidence value (the sum of the attractiveness values) by the number of the features that have been processed.

Note, that according to this model, the number of processed features depends upon the particular choice alternative. For very attractive and very unattractive alternatives, fewer features will be processed than for less extreme alternatives.

A judgment of the alternative presented second is derived in the same way. The alternative which receives the better judgment will then be chosen. For the two processing strategies, the effort and quality of a choice can now analyzed under the conditions of simultaneous or sequential presentation of the choice alternatives.

Effort-Quality Analyses

To demonstrate that the judgment based strategy really leads to less cognitive load under conditions of sequential presentation, effort-quality (Schmalhofer & Saffrich, 1984) or performance-resourcse functions (Norman & Bobrow, 1975) were computed. Johnson & Payne (1985) have pointed out that such analyses depend upon the particular choice alternatives under examination. Therefore, the effort-quality analyses were performed for alternatives which would indeed be considered by the individual subjects in a choice task.

Method

Subjects. Eighteen University of Heidelberg students participated in the experiment.

Procedure. Every subject was randomly assigned to one of four choice domains (choosing a news magazine, vacation area, rental car, or university to study at). For the selected domain subjects were asked to name nine alternatives which they would consider in a choice situation. Further, they specified the 11 dimensions which they considered to be most relevant for the choice and ordered these dimensions by their importance. The subjects then generated the respective features of the 9 alternatives on the 11 dimensions. Finally, the attractiveness of every feature was rated on a 7-point scale.

Results

Three indicators of cognitive effort were calculated. The number of accumulation operations as well as the number of comparison operations required to derive a choice by the two strategies were calculated as two separate indicators of computational effort. It can be assumed that feature comparisons within a dimension are easier to perform than accumulations across dimensions (Tversky, 1969). Since memory load is crucial for the difference between simultaneous and sequential availability of choice alternatives, the average number of items held in working memory for each processing step was computed as a third indicator of cognitive effort.

The three indicators were calculated as follows: Whenever a strategy required the addition of either an attractiveness value or an attractiveness difference to the running evidence value, this was calculated as an accumulation operation. Each determination of an attractiveness difference, i.e., the comparison of feature evaluations within a dimension or the judgment of overall judgments, was counted as a comparison operation. Average memory load was calculated as follows: For every processing step, it was determined how many items had to kept in memory to enable the application of each strategy. Due to the particular strategy, the stored items could consist of single features, the running evidence valua and/or the overall judgment of an alternative. The items thus determined for each step are summed up over all processing steps for a choice pair and then divided by the number of processing steps for that choice pair. This yields the average memory load per processing step. The percentage of choices coinciding with the choice predictions of tha additive model serced as an indicator of choise quality.

The effort and quality measures were computed for every possible value of the criterion k. For every subject, the calculations were performed for a complete paired comparison of the 9 alternatives. For a given parameter value k, the model calculations yield a measure for accumulation operations and comparison operations (computational effort) and memory effort, as well as the percentage of choices coinciding with the choices of the additive model (quality measure). For two quality levels, the respective results of the two processing strategies under simultaneous and sequential presentation of the alternatives are shown in Table 1.

Since there is no difference between sequentially and simultaneously presented alternatives for the judgment based procedure, the indicators of the judgment based procedure are presented only once. As would be expected, however, Table 1 shows that the memory effort required for the dimensional strategy is much grater for sequentially available alternatives than for the simultaneously presented alternatives. More important, the memory efforts of this procedure clearly exceeds the respective measure of judgment based processing for sequentially availble alternatives. Though the average number of items held in memory per processing step slightly decreases with increasing values of k (and consequently with an increasing number of steps), the memory load at the beginning of the choice process is quite high and may well exceed the capasity of working memory. Judgment based processing on the other hand requires more accumulations across dimensions which are probably more difficult to perform than comparisons within

Table 1: Effort indicators for two processing strategies under two task demands for two selected quality levels (i.e., level 1 = 83 % and level 2 = 97 % of choices coinciding with the addictive rule)

	Number of: Accumulation operations		Comparison operations		Items in memory per processing step	
	level 1/1	level 1/2	level 1/1	level 1/2	level 1/1	level 1/2
Judgment based processing	6.8	17.5	1.0	1.0	1.5	1.5
Dimensional processing for:						
-sequential presentation	2.0	5.8	3.0	6.8	11.0	9.1
-simultaneous presentation	2.0	5.8	3.0	6.8	1.0	1.0

Note. Because of the limited capacity of working memory a high memory load in one processing step can hardly be compensated for a low memory load in a second processing step. The reported average memory load is a global and therefore a possibly somewhat misleading characterization of memory demands.

dimensions. Thus the advantages of judgment based processing of sequentially presented alternatives may not be as clear cut as we had originally assumed.

In order to examine which strategies subjects actually apply an experiment was performed. Since choise predictions by themselves may not suffice to indicate which strategy was used (Dawes & Corrigan, 1974), aditional indicators were collected. If an overall judgment of an alternative is indeed formed, it should become incidentally learned and stored in memory. Consequently, memory judgments of the overall evaluations of alternatives should predict subjects' choices if they used the judgment strategy to derive a choice. Thus, we expect that memory judgments yield better choice predictions under sequential presentation than under simultaneous presentation of the alternatives.

Another variable of interest is processing time. Since accumulations across dimensions are more difficult and therefore more time consuming than dimensional comparisons (Gamb, 1985), we would expect longer choice latencies for sequentially presented alternatives than for simultaneously presented alternatives.

Experiment

Several pairs of multidimensional descriptions of word processors were used as choice alternatives in order to investigate human decision strategies. There were three between-subjects conditions in the experiment: the two alternatives of a choice pair could be presented (1) simultaneously, (2) sequentially, i.e., one after the other, or (3) one after the other with an interfering task in between.

Method

Subjects. Thirty-six students of the University of Heidelberg, who were paid DEM 10 per hour for their participation in the experiment, served as subjects.

Apparatus. The experiment was run under control of Apple II computers. Learning materials and choice alternatives were presented on the video screen of the Apple computer. A button box with two response buttons and a lever which could be moved in two dimensions was used for collecting the subjects' responses.

Materials. Eight fictious word processors, which were described by their features on eight dimensions, served as choice alternatives. For every description of an alternative, a meaningless name (cvc-trigram) was introduced. A sample choice pair with the respective meaningless names is shown in Table 2.

In order to familiarize the subjects with the relevant dimensions, a text was constructed, which explained the eight relevant dimensions and the range of possible features of the word processors. In this text, the features on a dimension (e.g., printing speed 80 characters per second) were specified together with their respective evaluation (e.g., "optimal"). Furthermore the text described an importance ranking of the eight dimensions, which was obtained in a prior study, in which 32 subject ranked the eight dimensions by their importance.

Table 2. English translation of a sample pair of word processors

Dimensions	Alternatives	
	TAF	BID
correction facilities	optimal	quite poor
graphics facilities	moderate	optimal
accessibility	poor	medium
reliability	quite poor	very good
user friendliness	good	quite good
learnability	optimal	moderate
maintenance costs	good	very good
printing speed	quite good	medium

Procedure. The experiment consisted of four major segments: a study task, decision task, memory tasks and rating tasks. Each of these segments began with instructions, which were displayed on the video screen. Every subject first acquired knowledge by studying the explanatory text about word processors, supposedly making all subjects equally knowledgable about word processors. A subject was then randomly assigned to one of the three experimental conditions. The three conditions differed in how the multidimensional descriptions of the alternatives were presented: simultaneously, seqentially, or sequentially with an interpolated task to be performed between the presentations of the two alternatives. The interpolated task involved remembering a 5-digit number for 30 seconds. In the simultaneous and sequential condition, the interopolated task was presented after a choice pair. In the third condition the interpolated task was presented between the alternatives of a choice pair. In order to reduce the number of times an alternative had to be presented in a complete paired comparison, the eight alternatives were divided into two sets of four alternativer each. For both sets, a complete set of paired comparisons was performed. Since every alternative was presented in the first as well as in the second position, every choice had to be presented twice, yielding a total of 24 choices.

Under simultaneous presentation both alternatives remained on the screen for 40 seconds. After 20 seconds a signal appeared at the bottom of the screen, indicating that a choice could be made at any time from then on by pressing the right or left button, respectively. In the other two conditions (i.e., sequential presentation with or without the interpolated task between the alternatives of a pair) each alternative remained visible for 20 seconds. In these two conditions a choice could be made as soon as the second alternative was presented. Thus, in all three conditions the alternatives could be inspected for 40 seconds and a choice could be made after 20 seconds of inspection. Choices and choice latencies were collected. The latency timer was started 20 seconds after the onset of the two alternatives (simultaneous presentation) or concurrently with the onset of the second alternative (sequential presentation). It was stopped by the subject's button press.

After the 24 decision tasks, subjects judged the attractiveness of the alternatives from memory as well as from multidimensional descriptions. In the memory judgment task, subjects were only presented with the name of the alternative. In the (regular) judgment task, the respective multidimensional descriptions were shown to the subjects without the alternative's name (cvc-trigram). The latter judgments were collected for the sake of comparison. The memory judgment task, which was separated from the (regular) judgment task by an interfering activity of about 30 minutes, thus indicates the judgments about the alternatives which are stored in the decision maker's memory after several choices.

At the end of the experiment subjects judged the importance of the eight dimensions and the attractiveness of the 64 features on a 9-point rating scale. These ratings were entered as external parameters into the model predictions. The judgments were obtained by having the subjects move a lever so that the cursor was moved to a respective judgment category. As soon as the desired category was reached, the subject pressed the button. In all judgment tasks the nine categories ranged from unattractive (-4) to very attractive (+4). For the importance ratings the categories ranged from unimportant (-4) to very important (+4).

Results and Discussion

A complete report of the experimental data is given in Gertzen (1985). In this paper, only the data which may indicate whether dimensional comparison or judgment based strategies have been applied will be reported. Both models correctly predicted approximately 80 percent of the choices for the three experimental conditions. Because no systematic differences existed in the percentage of correctly predicted choices, the subjects' processing strategy cannot be inferred from these choice predictions. However, if people based their decision upon the overall judgment of the alternatives rather than upon dimensional comparisons, these overall judgments should have been stored in memory. The memory judgments should therefore have been suitable for predicting a decision maker's choice. For deriving the choice predictions it was assumed that the alternative with a higher memory judgment would be chosen. Table 3 shows the results.

Table 3: Relative frequency of correct choice predictions by judgments from memory, and correlations between judgments from memory and regular judgments.

	Presentation of alternatives		
	simultaneous	sequential	with interpolated task
predictions	.54	.65	.73
correlations	.22	.27	.35

The results show that for sequentially available alternatives, memory judgments were a better predictor of the choices than for simultaneously available alternatives (X^2 (2,553) = 7.98, $p < .005$). In that case, there was also a higher correlation between the memory judgments and the (regular) judgments. All correlations significantly differed from zero; however, there were no significant differences between the conditions of the experiment. The results indicate that for sequentially presented alternatives, decision makers are more likely to base their choices upon overall judgments of the alternatives than for simultaneously presented alternatives.

As can be seen from Table 4, choices between sequentially available alternatives required more time than choices between simultaneously available alternatives, $F(2,33) = 14.3$, $p < .0001$. Since alternative based processing usually requires more time than dimensional processing (Russo & Dosher, 1983; Klayman, 1982), this result is further evidence for the assumed alternative based processing of sequentially available alternatives.

According to the reported effort-quality analysis, the longer latencies result from execution of a larger number of operations which in addition are more difficult and more time consuming to perform.

Table 4: Average choice latencies and standard deviations (in parentheses) for the three experimental conditions

Presentation of alternatives		
simultaneous	sequential	with interpolated task
5.56 (3.30)	12.05 (5.31)	13.21 (2.97)

Summary and Conclusion

The present study indicates that for sequentially presented choice alternatives, decision makers are more likely to apply alternative based processing, but not necessarily to the complete exclusion of any dimension based processing. This empirical result is consistent with the effort-quality analyses for criterion dependant choice models which were reported at the beginning of this paper. These analyses showed that for sequentially available alternatives, judgment based processing is more economical, but does not completely dominate dimension based processing with respect to effort-quality measures. Nevertheless, the experimental results show that the differences in the effort-quality relations are significant and that more judgment based processing is included by sequentially presented alternatives than by simultaneously presented alternatives.

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