4 Information Processing in Children's Choices Among Bets

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ABSTRACT

Children's information processing of risky choice alternatives was investigated in two studies without using verbal reports. In Study 1, the ability to integrate the probabilities and the payoffs of simple bets was examined using the rating scale methodology. Children's choices among three of those simple bets were recorded also. By cross-classifying the children's choice and rating behavior it was shown that a three-stage developmental hypothesis of decision making is not sufficient. A four-stage hypothesis is proposed.

In Study 2, the influence of enlarging the presented number of alternatives from two to three and the influence of the similarity of the alternatives on children's choice probabilities was examined with those bets. Children's choice behavior was probabilistic and was influenced only by enlarging the presented number of alternatives. These results suggest that a Bayesian approach, based on two probabilistic choice models, should not be applied in order to analyze children's choice behavior. The functional measurement approach is, as was demonstrated in Study 1, a powerful implement to further the understanding of the development of decision making.

INTRODUCTION

This paper is concerned with children's information processing when they make decisions among conflicting alternatives. Developmental studies may contribute generally to the understanding of decision making in human beings. This developmental approach to decision making is a research strategy that avoids various difficulties with the common strategy of comparing human behavior with normative or statistically optimal decision theories.

Schmidt (1966) adopted this point of view in a study of children's information processing when they made risky decisions among five alternatives. Each alternative consisted of a box into which 10 marbles of two colors (blue and yellow) were placed. The subjects were told that they would receive a specified amount of money or candy if they got a blue marble in a blind draw. The number of the blue marbles and the magnitude of the prize inversely varied across the alternatives. Thus, no alternative "dominated" another (see, e.g., Table 4.3 later).

Schmidt found three stages of choice behavior with this task. The youngest children, 4 and 6 years in age, chose most often the alternative with the highest payoff; 8-year-old children chose the alternative with the highest probability of winning, while the 11-year-olds chose the alternatives with medium payoffs and probabilities. To investigate the information processing of these three stages of choice behavior more closely, Schmidt asked the children for retrospective explanations of their choices. He concluded that the youngest children paid attention only to the payoff, that children at the second level considered only the probability, and that children at the third level took both attributes into account.

The main argument against these conclusions is that Schmidt relied too much on the validity of the children's explanations of their choices. These explanations have questionable value because they depend on verbal skills that may portray only part of the process. Also, only the older children may have the conceptional and verbal abilities for more detailed answers. In addition, some authors (Kleber, 1970; Hommers & Gloth, 1978) have found a high percentage of verbal explanations that cannot be attributed to any of the three levels. In order to analyze children's information processing of risky choices, other approaches using nonverbal techniques may be necessary.

Nonverbal techniques were used by the present author (Hommers, 1975, 1976) to analyze the information processing of the third level children more carefully. Among other results, it was found that third level children chose the largest expected value of the alternatives more likely than could be expected. Because the expected value of these alternatives is defined as the product of probability and payoff, this result supports the hypothesis of a multiplying rule applied by the third level children. However, similar studies have not been done for the first two stages.

STUDY 1

Problem

The hypothesis of Schmidt (1966), that subjects in the first or second stage base their decisions on either the payoff or on the probability and do not combine these two attributes, is questioned here. The functional measurement approach of information integration theory may be able to determine whether younger children can integrate these two attributes. Anderson and Shanteau (1970) found additive and multiplicative combination rules for single and duplex bets with adult subjects. However, a similar study with children has not been made. One advantage of the functional measurement approach is that it allows statistical analysis for the individual child. Such individual analysis is a necessity to avoid artifacts that can arise from pooling data over children who have different strategies.

Method

A 3 × 3, probability × payoff stimuli design was employed. The probability levels .10, .50, and .90 and the payoff levels 5, 25, and 45 Deutsche Pfennigs were used. Two replications of the nine stimuli from the design were given. In each replication the nine stimuli followed in a different order. Forty-two children (24 male; age 5-10 to 13-10) were tested in single sessions at their homes.

On each trial, a colored picture of a bag was shown that contained 10 marbles, some red, some green. The number of red marbles (1, 5, 9) indicated the probability of winning. Below the bag, yellow coins were seen that represented the prize (5, 25, or 45 Pfennigs). The children were told that picking a red marble in a blind draw would win the prize. Before drawing, however, the experimenter wanted to learn how much they liked each bet.

To indicate their liking of each bet, the children used a graphic rating scale of 20 small circles, each 1 cm in diameter. At the left end of the scale a frowning face was shown. At the right end a smiling face was shown. Anchors were placed at each end of the scale. The upper anchor consisted of a bag with 10 red marbles and a prize of 50 Deutsche Pfennigs. The lower anchor showed a bag with 10 green marbles and no coins.

After the instructions, six practice stimuli were presented to train the children in the use of the scale. Following this, the two replications of the main design were given.

Finally, the children chose one alternative from each of 10 three-alternative decision tasks. Before they chose, they had been introduced to all 10 tasks in order to avoid artificial risk tendencies. All 10 tasks had the inverse arrangement of probabilities and amounts of win, but varied in the specific values of these attributes. The first of the decision tasks had the alternatives with the highest, lowest, and medium payoff of Schmidt's (1966) study and will be considered later. Payoffs were given immediately so that choices in later tasks that might be influenced by the gains or no-gains were not considered.

Results

The main purpose of the data analysis was to relate the rating data to the choice data in order to obtain behavioral evidence on the three stages considered previously. The first step was to calculate an analysis of variance separately for each individual subject. The main effects in this analysis provide a sensitive index of the child's utilization of the two stimulus cues in the factorial design.

Raw data for three illustrative children are shown in Table 4.1, and the corresponding analyses of variance are summarized in Table 4.2.

The child in the first row of Table 4.1 employed a payoff-only response strategy. His responses vary markedly as a fuction of the amount to be won, but are independent of the probabilities. This one-dimensional, payoff-only strategy reappears in the analysis of variance of Table 4.2: The mean square for payoff is very large compared to the error mean square, showing a highly significant payoff effect, while the probability effect does not approach significance.

The second row of Table 4.1 shows a probability-only response strategy. The responses of this child vary markedly as a function of the probabilities, but are independent of the amounts of win. This one-dimensional, probability-only strategy reappears in the analysis of variance of Table 4.2: The mean square for probability is very large compared to the error mean square, showing a highly significant probability effect, while the payoff effect does not approach significance.

TABLE 4.1
Rating Data for Three Subjects Selected to Illustrate Three Response Strategies, Study 1

	Probability × Payoff Levels								
	.1			.5			.9		
Strategy	5	25	45	5	25	45	5	25	45
Payoff only	3,1	11,11	20,20	2,1	11,11	20,20	3,1	11,11	20,20
Probability only	1,5	2,4	5,4	15,17	15,17	17,17	17,20	20,20	20,20
Payoff + Probability	3,5	7,6	8,9	10,9	12,16	17,16	13,11	18,19	20,20

TABLE 4.2
Summary of Analysis of Variance for Three Selected Subjects, Study 1

		Mean Square		
Source	*df*	*Payoff Only*	*Probability Only*	*Payoff + Probability*
Replications	1	1.4	8.0	.5
Probability	2	.1	430.7	171.5
Payoff	2	495.1	2.7	66.5
Interaction	4	.1	.5	2.5
Error	8	.4	1.4	1.8

The child in the last row of Table 4.1 utilized both stimulus factors in a probability + payoff strategy. This two-dimensional, probability + payoff strategy reappears in the analysis of variance of Table 4.2: The mean squares for both factorial effects are considerably large compared to the error mean square. This means that this child took account of both factors in making his judgment. By virtue of the logic of functional measurement, the nonsignificant interaction implies that these two stimulus dimensions were integrated by an adding-type rule.

The next step in the analysis is to relate the response strategies in the rating task to the behavior in the choice task. Table 4.3 correlates these rating strategies with the choice behavior of the children in the first three-alternative decision task. Table 4.3 shows that nearly one-half of those children who chose the alternative with the highest or the lowest payoff used a one-

TABLE 4.3
Attributes of Alternatives in Choice Task and Subjects Cross-Classified by Behavior in Rating Task and Choice Task

	Alternative		
Dimension	*A*	*B*	*C*
Probability	.1	.5	.9
Payoff value	25	15	5
Expected value	2.5	7.5	4.5
Rating Task Classification	*Number of Subjects*[a]		
Two-dimensional subjects	5	14	7
One-dimensional subjects	7	0	9

[a]Entries indicate number of subjects who chose the given alternative in the first choice trial.

dimensional response strategy. Contrarily, all subjects who chose the alternative with the medium payoff in that choice task employed a probability + payoff response strategy in the rating tasks, $\chi^2(2) = 12.92$, $p < .001$.

All the one-dimensional subjects who chose the alternative with the highest payoff had just the factor "payoff" significant. Similarly, all the one-dimensional subjects who chose the alternative with the highest probability had just the factor "probability" significant.

In summary, Study 1 showed that the children who chose the alternative with the intermediate attribute levels differ in their rating behavior from the children who chose other alternatives. In accord with Schmidt's conclusions, they were able to combine the two attributes of single, simple bets in their judgments. Also, if a child significantly responded in the rating task to only the probability (payoff) factor, then he or she chose the alternative with the highest probability (payoff). However, some children who chose the alternative with the highest payoff or with the highest probability were actually able to combine probabilities and payoffs. This result does not fit into the framework of three developmental stages of decision making as given by Schmidt (1966).

STUDY 2

Problem

One might regard the integration of information present in a single alternative as a complete elucidation of children's information processing in decision making. This view is adequate only if choices among two or more alternatives depend on the rank order of subjective values obtained from the rating of single bets alone. But as Tversky (1972) showed with adolescents, the number and the similarity of the presented alternatives can have important influences on choices. Thus, the set of alternatives presented to the children may affect their decision making in two ways. First, there may be an influence of the presented number of alternatives on their choices. Second, there may be an effect of the similarity[1] of the alternatives on their choices. Study 2 examines whether these aspects of a specified set of alternatives have an effect on children's choice probabilities of the alternatives.

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[1]Let (p/v) denote the attributes of an alternative, then a similarity pattern of three alternatives may consist within the set (.1/45), (.2/40), (.9/5), where the first two alternatives are apparently similar. But that apparent similarity would vanish in the set (.1/45), (.2/10), and (.9/5). So, a similarity pattern exists in a set of three alternatives when a difference in the distances of one attribute across adjacent alternatives is not compensated by a contrary pattern in the distances of the other attribute.

Method

A 2 × 2 design was used with two sets of alternatives and two response modes as factors. By employing two sets of alternatives, the effects of the presented number of alternatives and of the similarity within each set on the choice probabilities were studied. The two response modes were used to assess the choice probabilities because each of them seemed desirable to answer certain questions.

The influence of the presented number of alternatives was examined by comparing the choice behavior in two-alternative decision tasks with that in a three-alternative decision task, all of them derived from the same total set of three alternatives. The elements of each set were combined to obtain three two-alternative and one three-alternative task. Thus, eight decision tasks were derived from the two sets of alternatives that are listed in Table 4.4. Each task was presented as a colored picture of two or three bags in the same manner as in Study 1. Each bag represented an alternative option for the child.

The influence of the similarity of the alternatives was investigated by comparing behavior of two sets of choice tasks that differ in their apparent similarity of the three alternatives. Probabilities and payoffs for Set I define the similarity pattern so that the pair of alternatives B and C (see Table 4.4) is more similar than the pair A and B or the pair A and C. Set II was constructed so that no apparent similarity of alternatives appears.

Assessment of the choice probabilities was done in two ways, both of which have possible objections. One could obtain repeated choices, either within one session or distributed over several sessions. Repetition over several sessions would allow possible developmental changes during and between sessions. Therefore, repeated choices during one session were obtained to assess the choice probabilities. But repeated choices during one session could produce boredom, especially with children. As boredom could presumably be prevented thereby, payoffs were given after each decision depending on the outcome.

But, giving payoffs could change prior probabilities of choice. Thus, a second mode, "distributing choices in advance," was applied. With this

TABLE 4.4
Sets of Alternatives from Which Eight Decision Tasks Were Derived

	Set I Alternatives			*Set II Alternatives*		
Win	*A*	*B*	*C*	*A*	*B*	*C*
Probability	.1	.4	.6	.1	.5	.9
Payoff (Pfennigs)	35	12	8	45	25	5

procedure, one had to assume that, if several choices were to be made in advance for each task, they would picture actual choice probabilities of children's single decisions. Unfortunately, no empirical support for this assumption was available. Thus, both response modes were used as no one other approach was found to be more suitable.

Thirty-seven children (18 male) aged 8 to 15 years (mean age 11-8) were tested in a summer camp. As a pretest, the children were presented with a three-alternative task that had equal expected-value alternatives. The probabilities of this task were .10, .50, and .90. The payoffs were in the same order as the probabilities, 45, 9, and 5 Deutsche Pfennigs.

After the pretest, subjects made hypothetical advance choices for each of the eight tasks. They were asked to indicate in advance how often they would choose each alternative when they had 10 choices in each task during the session. Following this, they were given a sequence of 10 choices on each of the eight tasks. Each such choice was implemented by the child's placing a hand into a bag filled with marbles in the same proportion as the chosen alternative and making a blind draw of one marble. Win received immediate payoff. The same order of tasks was used for all the children and all 10 replications per subject.

Results

Level of Decision Making. In the pretest, 24 subjects chose the alternative with medium payoff. Also, in the 10 single choices, 29 subjects chose this alternative most frequently. Therefore, a majority of the children are considered to be decision makers who were able to consider the expected value of an alternative or at least both pieces of information presented in each alternative.

Probabilistic Decision Making. For each child, two sets of choice probability estimates were available from advance hypothetical and actual single choices. If the decision making of the children was not probabilistic, one would expect choice frequencies of 0 or 10 within each set of estimates. Table 4.5 shows the frequencies of modal choice probabilities in the three-alternatives tasks for each set and each response mode. Probabilistic decision making implies high frequencies in the upper rows of Table 4.5 corresponding to near-chance probabilities. Table 4.5 indicates that the majority of subjects made decisions probabilistically with both response modes in both sets. This might suggest that one of the response modes assessed the actual choice probabilities of single decisions. This conclusion can be justified as follows. In Set II, the optimal strategy with 10 choices would be to choose always the medium alternative that has the largest expected value. This can be true only of subjects who consider the expected value in their choices. But although the

TABLE 4.5
Frequencies of Modal Choice Probabilities, Three-Alternative Task, Study 2

Choice Probabilities	*Hypothetical Choices in Advance* Set I	Set II	*Single Choices with Immediate Payoff* Set I	Set II
.4	16	12	3	1
.5	15	11	4	2
.6	4	6	10	6
.7	0	4	9	8
.8	0	0	5	3
.9	0	0	5	10
1.0	2	4	1	7

pretest results indicate that most of the subjects seem to be able to do that, the majority of them behaved probabilistically when several choices among the same alternatives were available.

Influence of Number of Alternatives. Two mathematical conditions were examined to test the influence of the presented number of alternatives. Let T denote a set of three alternatives. Let $P(x;y)$ be the binary choice probability of x when presented together with y, and $P(x,T)$ be the trinary choice probability when x is presented together with y and a third alternative. If the addition of a third alternative does not change the order of choice probabilities (order independence), condition (1) holds (see Tversky, 1972, p. 282).

$$\text{For each pair } x,y, \in T,\ P(x;y) \geq .5 \text{ if and only } P(x,T) \geq P(y,T)\ [P(y,T) \neq 0]. \quad (1)$$

If the addition of a third alternative did not change the ratio of choice probabilities (ratio independence), condition (2) holds (see Tversky, 1972, p. 292).

$$\text{For each pair } x,y, \in T,\ P(x;y)/P(y;x) = P(x,T)/P(y,T)\ [P(y;x) \neq 0 \neq P(y,T)]. \quad (2)$$

Table 4.6 shows how many subjects matched the ratio or order independence conditions. Order independence was found in a majority of subjects, especially in the real single choices. However, ratio independence was almost completely absent. Furthermore, the hypothetical advance choices showed less order independence than the real choices.

Overall, therefore, these data indicate, on an individual level of analysis, that the response modes of hypothetical choices in advance and of repeated real single choices with immediate payoffs did not yield choice probability

TABLE 4.6
Frequencies of Children (n = 37) Who Fit Order or Ratio Independence

	Set I		*Set II*	
Mode	*Order*	*Ratio*	*Order*	*Ratio*
Hypothetical choices	21	1	19	2
Single choices	31	0	29	5

estimates that are independent of adding a third alternative. Although the majority of children showed order independence, some subjects showed order dependence. This suggests that children's choice behavior in two-alternative tasks might differ from that in three-alternative tasks, as the enlargement of the presented number of alternatives can change even the order of choice probabilities.

Group Analysis of Ratio Independence. The individual analyses of ratio independence in Table 4.6 might not have adequate sensitivity. Accordingly, it seems justified to examine ratio independence on a group level. For each subject, therefore, the individual deviation $d = P(x;y) - P(x,T)/[P(x,T) + P(y,T)]$ was calculated for each pair x,y. The observed mean $\bar{d}$ was tested against the expectation $E(d_i) = 0$, which should hold if ratio independence holds because condition (3) then becomes an equality.

The analysis of variance showed no significant effects. The overall mean was $\bar{d} = .015$. The estimated standard deviation was .011, yielding $z = 1.38$. Although $\bar{d}$ is not significantly different from 0, this z-value indicates that even the group data reflect the influence of the third alternative on the choice probabilities. To understand that conclusion, one should imagine first that, although the d of two pairs of one individual subject were positive, the third d need not be, and second, that the individual analysis showed that individuals might differ in which of their d pairs are positive. Both circumstances reduce the z-value of $\bar{d}$. Thus, the influence of adding a third alternative was almost strong enough to be revealed as a trend in the group data analysis.

Influence of Similarity Perception. Similarity of alternatives with medium and highest probability (see Table 4.4) was systematically high in Set I. If children take into consideration this similarity, then condition (3) should hold (see Tversky, 1972, p. 292).

$$P(B;A) > P(B,T)/[P(B,T) + P(A,T)] \text{ and}$$
$$P(C;A) > P(C,T)/[P(C,T) + P(A,T)]. \qquad (3)$$

This condition can be justified intuitively by the argument that, if an alternative is added that is similar to only one of two already existing alternatives, then it will subtract more from the choice probability for the similar alternative than for the dissimilar alternative.

Perceived similarity need not be bound to the objective similarity that has been arranged in Set I. Children may perceive alternatives A and B or alternatives A and C to be equally similar. These three similarity pairs must be considered separately. This argument can be applied to Set II as well.

The children's choice probabilities were analyzed with regard to how often condition (3) was supported in each possible similarity pair. Table 4.7 shows the frequencies of children to whom one of the three similarity perceptions could be attributed. If the similarity manipulation influenced the individual children, one would expect that the entry in row BC of Set I would be higher than the other entries of the same set and higher than the entry BC in Set II. As can be seen, this expectation was not supported. The real single choices show a strong disagreement with expectation.

It is difficult to estimate the chance probability of an entry in Table 4.7. However, it seems reasonable to assume that a verification of one part of condition (3) is as probable as a falsification, if similarity plays no role in the decision process. This assumption implies a probability of .25 in each of the four rows. Testing the observed frequencies against this expectation yielded only one significant chi-square (see Table 4.7). Because this one significant chi-square partly results from an overly high frequency of "no similarity" judgments, it clearly does not support the similarity hypothesis.

Two further tests for similarity effects were also performed. The first sought for a more sensitive index by comparing attributed similarities across Sets I and II. The second extended the first by allowing for some within-subject variability within each of Sets I and II. Neither test provided any sign

TABLE 4.7
Frequencies of Children Satisfying the Perceived Similarity Assumptions, Study 2

Similarity Assumed Between	*Hypothetical Choices*		*Single Choices*	
	Set I	*Set II*	*Set I*	*Set II*
A B	5	8	8	3
B C	12	8	9	15
A C	10	5	9	4
No similarity	10	16	11	15
χ^2 ($df = 3$)	2.89	7.22	.51	14.35[a]

[a] $p < .05$.

of similarity effect. Overall, therefore, these data provide no support for the hypothesis that similarity affected the children's choices.

DISCUSSION

Developmental Stages

The results of Study 1, obtained by the combined use of choice and rating responses, helped illustrate the information processing hypotheses of the three developmental stages found by Schmidt (1966). The children who chose the alternative with the highest payoff and also employed a payoff-only strategy in their rating responses represent information processing of the first developmental stage. These children seem to be unaware or to lack understanding of the "probability" attribute of the alternatives.

The second developmental stage was described by Schmidt (1966) as transitional, in which subjects consider only the probability of the alternatives. In the present study, those subjects who chose the alternative with the largest probability and also employed a probability-only rating strategy would seem to correspond to Schmidt's transition stage subjects.

In Schmidt's third developmental stage, subjects are considered to combine the payoff and probability attributes when choosing the medium alternative. Subjects at this stage were found in the present study too. Indeed, all those subjects who chose the alternative with medium attribute values appeared to use a probability + payoff strategy in their ratings. These three groups, defined in terms of choice and rating behavior, seem to accord with Schmidt's three-stage hypothesis.

However, there were two other groups of children who did not fit into Schmidt's three stages. This can be seen in the cross-classification of choice and rating strategies given in the lower part of Table 4.3. The 14 children who chose the medium alternative were not the only ones who employed the two-dimensional probability + payoff rating strategy. Five children who chose on the basis of payoff and seven who chose on the basis of probability also used the two-dimensional probability + payoff strategy in their ratings. The information processing of these children differs from that in Schmidt's stage descriptions. The present results suggest, therefore, that Schmidt's three-stage classification is not sufficient and that other stages exist.

In addition, it is necessary to consider a fourth, more advanced stage not considered by Schmidt. This stage could be characterized by the ability to combine attributes according to a multiplying rule when making decisions and judgments. This fourth stage would be consistent with previous studies of the present author (Hommers 1975, 1976), in which children who chose the medium alternative appeared to be sensitive to the expected value of an alternative, that is, to the product of payoff and probability.

In this hypothesis of four developmental stages, the first two would appear as described by Schmidt. These are one-dimensional subjects; they take account of just one attribute of the bets. The other two stages are two-dimensional, but differ in their integration rule. The third stage might be characterized mainly by its probability + payoff rating strategy, in which the choice behavior depends on the weights of the attributes. At the fourth stage the subjects might employ a multiplying rule in their ratings. This would reveal itself in the choice task as following a maximization of expected value rule.

Individual Bayesian Analysis of Choices

Wendt (1973, 1975) suggested a Bayesian technique to compare competing probabilistic models of the information processing of nondominated alternative bets. Two formal models were proposed: The constant-ratio model, and the sum-difference model.

The constant-ratio model assumes that the alternatives can be scaled so that choice probability ratios are independent of the number of presented alternatives. However, the results of the present Study II showed that ratio independence did not hold. This result indicates that the constant-ratio model is not valid for children's choices.

The sum-difference model requires that the highest choice probability among three alternatives is not greater than one-half. Table 4.5 shows that this condition failed for nearly all subjects with real choices and for at least some subjects with hypothetical choices. Additionally, the sum-difference model requires order independence. But, in both response modes, some subjects failed this condition. Thus, the validity of the sum-difference model for children's choices is also doubtful.

Power of the Functional Measurement Approach

The power of the functional measurement approach for the understanding of the development of decision making is demonstrated by the results of Study 1 in several respects. These data confirmed earlier results, but allowed a more penetrating analysis. Subjects who chose the medium alternative, in fact, combine the probability and payoff cues. Also, children who did not integrate probability and payoff in the rating task did not chose the alternative with medium attributes in the choice task. But most importantly, the power of the combined use of factorial design and rating response was shown by the result that the choice behavior of some children was observed together with a two-dimensional rating strategy. Previously, children who chose the alternative with either the highest payoff or the highest probability were not regarded as capable to consider both attributes of the bets simultaneously. This view was based on the choices. But, by the use of the functional measurement approach, it could be shown that they are, in fact, capable of integrating these attributes.

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