Effects of cost and gain ratios, and probability of outcomes on ratings of alternative choices.

Mary Mace Suydam
University of Massachusetts Amherst

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Effects of Cost and Gain Ratios, and Probability of Outcomes on Ratings of Alternative Choices

by

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Thesis submitted to the Graduate Faculty in partial fulfillment of the requirements for the degree of Doctor of Philosophy

University of Massachusetts, Amherst

September 1963
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Introduction

The major purpose of the present study was to determine the effects of cost and gain ratios, and probability of outcomes on ratings of alternative choices. In most experiments on choice behavior the same options have been presented repeatedly. With the technique employed here, each combination of cost, gain, and probability was presented only once. Another departure from the conditions of most previous experiments was replacement of a binary decision with the more sensitive measure of rating of choices.

Several models of the manner in which different combinations of cost and gain ratios, and probability of outcomes effect choice behavior have been proposed. A further purpose of the present study was to evaluate several of the models in terms of extent to which each predicts ratings of choices.

Cost Ratios, Gain Ratios, and Probabilities

The variables of cost and gain ratios, and probability of outcomes in a two-choice situation can be represented in the following matrix:

<table>
<thead>
<tr>
<th>Response</th>
<th>Outcome</th>
</tr>
</thead>
<tbody>
<tr>
<td>A₁</td>
<td>E₁</td>
</tr>
<tr>
<td>A₂</td>
<td>E₂</td>
</tr>
<tr>
<td></td>
<td>G₁</td>
</tr>
<tr>
<td></td>
<td>G₂</td>
</tr>
<tr>
<td>Probability of Outcome</td>
<td>P</td>
</tr>
<tr>
<td></td>
<td>1-P</td>
</tr>
</tbody>
</table>
The outcomes, $E_1$ and $E_2$, occur with probability $P$ and $1-P$, respectively. When responses and outcomes coincide, the gain is $G_1$ or $G_2$; when responses and outcomes differ, the cost is $C_1$ or $C_2$. Probability of outcome can be varied in combination with relative or absolute values of gain, of cost, or of both. Gain and cost ratios are the value for the gain or cost associated with one choice relative to the gain or cost, respectively, associated with the other choice.

In an early experiment involving monetary gain in the two-choice situation, Edwards (1956) varied both probability and gain associated with correct prediction of each event. Asymptotic probabilities of choice of events exceeded their probabilities of occurrence which was contrary to the matching of event probabilities then thought to occur.

Taub and Myers (1961) investigated monetary gain, where the gain received by $S$ depended on which of two events was correctly predicted, and where all incorrect predictions were of equal cost. Although $S$s did not utilize mathematically optimal strategies, they eventually chose the more rewarding alternative more often than the outcome occurred.

The variable of cost ratio was introduced by Myers, Reilly, and Taub (1961). Number of choices of $E_1$ increased as its relative frequency increased, as its cost decreased, and as the gain associated with $E_2$ decreased. Again $S$s did not achieve mathematically optimal strategies.

In an experiment where the number of choices was increased to four (Miller & Lanzetta, 1962), absolute amounts
of cost and payoff were varied among three groups of Ss. Defining Expected Value (EV) as \( EV = G_1 x P - C_1(1 - P) \), EV and probability were constant among groups; they differed only among the four choices within each group. Choice behavior did not vary with absolute amounts of cost and payoff, nor did Ss approximate the optimal strategy of always choosing the alternative with the higher EV. For a fourth group, costs were altered to equalize the EVs of the four choices. Contrary to expectation, the distribution of choices was not rectangular.

**Single Presentation of Options**

In the preceding four experiments, each group of Ss experienced the same options repeatedly. Under repeated presentation, choice is a function not only of payoff parameters but also of sequential effects, feedback and set. Thus, choice on a given trial is influenced by the pattern of stimuli, responses, and payoffs on immediately preceding trials (Jarvik, 1951; Anderson, 1959; Anderson & Whalen, 1960; Myers & Fort, 1962). Also, as reported in a pilot study (Coombs & Komorita, 1958), choice behavior of Ss offered a few options repeatedly differed from that of Ss offered each of several options just once.

Sequential effects and set can be eliminated effectively by a technique of single presentation of options (Suydam & Myers, 1962). On each trial, Ss are required to choose between a gamble and a known alternative to gambling, and to rate the strength of their choice. Until all bets are com-
pleted, Ss are given no information regarding outcomes. The single presentation technique permits the use of more levels of the independent variables with a larger number of Ss than is usually feasible with the repeated-presentation technique. Despite the several differences in conditions under the two techniques, Suydam and Myers' (1962) findings with the single-presentation technique paralleled those of other experiments with similar independent variables but the technique of repeated-presentation of options (Myers & Sadler, 1960; Katz, 1962).

In the present study, the single-presentation technique was employed to investigate choice behavior as a function of gain ratio, cost ratio, and probability of outcomes. These variables are the same as those of the Myers, Reilly and Taub (1961) experiment, but more combinations of cost and gain ratios, and levels of probability were employed.

Models

The characteristic of choices of greatest interest has been asymptotic percentages of occurrence of each choice, or, more often, asymptotic percentage of occurrence of the choice involving the greater or greatest gain, and the lesser or least cost. Instead of equations in which percentage of choices is related directly to cost, gain, and probability, most experimenters have preferred to develop equations in which these variables have been combined in different ways to define new dimensions which are then related to asymptotic
percentages. Described here are several of such equations, models, or rules, primarily for the two-choice situation, but also for situations involving more than two choices. Subjective-decision models involving such so-called subjective parameters as utility of money or utility of gambling were excluded because these parameters do not always have even equal predictive power. Moreover, difficult measurement problems arise. Also excluded were stochastic models which describe mean percentages of choices as functions of knowledge of outcomes, accumulation of reward, and other factors operating through repeated trials. With the single-presentation technique of the present study, these factors are absent. Stochastic models, therefore, are not applicable.

The starting point of all of the models to be described is the payoff matrix considered earlier. Some models also require a loss matrix.

Expected Gain Models. Taub and Myers (1961) developed the original Expected Gain (EG) model to predict mean percentage of choices under differential monetary gain. The proposed equation is

\[ P_1(\infty) = \frac{EG_1}{EG_1 + EG_2} \]

where \( P_1(\infty) \) is the asymptotic probability and

\( EG = P \times G \).

The \( EG \) estimates of asymptotic probability were accurate for the four .60-.40 probability groups but consistently too low for the four .80-.20 probability groups to suggest a shift
from matching toward an optimal solution in the interval between .60-.40 and .80-.20.

The two-alternative EG model was later modified to fit the four-alternative case (Miller & Lanzetta, 1962). In the resultant Relative Expected Gain (REG) model, the REG for any particular alternative was the EG of that alternative divided by the sum of the four EGs. The rank ordering of relative frequency of choice was predicted perfectly, but the relation between observed proportions and REG values was non-linear, thus indicating that EG matching did not occur.

Neither the EG model nor the REG model explicitly considers cost. Unless modified, therefore, these models, at best, are only partially applicable to the conditions of the present experiment.

**Expected Payoff Matching Generalization.** Called the Expected Value Matching Generalization by Edwards (1956), this model was renamed the Expected Payoff (EP) Matching Generalization (Taub & Myers, 1961) to indicate its derivation from EPs rather than from EVs. The EP equation is,

\[ P_1 (\infty) = \frac{EP_1}{EP_1 + EP_2} , \]

where \( EP_1 \) is the expected payoff resulting from choice of \( E_1 \), and \( EP_2 \) is the expected payoff resulting from choice of \( E_2 \). In turn, \( EP \) is defined as equal to \( (G + A)P \) where \( A \) is the ante required to bet, or potential cost. Values obtained from the EP equation were more nearly correct than those based on the hypothesis of probability matching but they did not
accurately predict the asymptotic probabilities of choice for Edwards' (1956) data.

The EP model can be applied to the present variables of cost, gain, and probability by substituting cost for ante, since ante is essentially the potential cost of an incorrect choice. Although the EP model includes cost, whenever the absolute value of cost is equal to the absolute value of gain for each event, its predictive power breaks down. EP values are then a function only of differences in probability.

**Expected Value Matching Model.** Miller and Lanzetta (1962) developed the Expected Value (EV) Matching Model from relative EV (REV) in order to account for behavior in situations involving more than two choices. For the four-choice situation the model is,

$$\text{REV} = \frac{\sum \text{EV}}{4}$$  

This property can be shown in general for \(G_1 = |C_2|\) and \(G_2 = |C_1|\). In this case,

$$\text{EP}_1 = (G_1 + |C_1|)P,$$

$$\text{EP}_2 = (G_2 + |C_2|)(1-P)$$

$$\text{REP} = \frac{(G_1 + |C_1|)P}{(G_1 + |C_1|)P + (G_2 + |C_2|)(1-P)}$$

$$= \frac{(C_2 + C_1)P}{(C_2 + C_1)P + (C_1 + C_2)(1-P)}$$

$$= \frac{(C_2 + C_1)P}{(C_2 + C_1)P + C_1 + C_2 - (C_1 + C_2)P}$$

$$= P$$
where $EV_1 = G_1 \times P - (1 - P)C_1$.

The distribution of choices obtained in three of the four cost-payoff conditions of Miller and Lanzetta's (1962) four-choice situation was predicted accurately by this model.

The EV matching model is readily adaptable to the two-choice situation for which probability of choice of a particular outcome should be approximately equal to the ratio of the EV of that outcome to the sum of the EVs of the two outcomes. However, when $C$ and $G$ are equal in absolute value, and the probabilities of the two alternatives sum to one, the denominator of the ratio is equal to zero. Since quantities divided by zero are indeterminate, no prediction can be made. Accordingly, the EV matching model is not applicable to many of the combinations of conditions of the present and of other experiments with the two-choice situation.

**Differences in Expected Value.** The $EV$ for one outcome can be subtracted from that for the other outcome. This rule can be expressed as,

$$\Delta EV = EV_1 - EV_2$$

where $EV_1 = P_1 \times G_1 - (1 - P)C_1$, and $EV_2 = (1 - P)G_2 - P_1 \times C_2$.

Myers, Reilly, and Taub (1961) used the $\Delta EV$ rule to describe the data from an investigation which utilized the independent variables of the present study. For the last 50 of 150 trials, an approximately linear relationship existed
between $\Delta EV$ and percentage choice of $E_1$ for the various combinations of cost, gain, and probability, with the exception of combinations involving .50-.50 probability.

**Expected Loss Models.** In Edwards (1956) Relative Expected Loss Minimization (RELM) rule, the loss involved in risk-taking is defined as the amount which would have been obtained had $S$ predicted the event which occurred minus the amount of payoff for $S$'s actual choice. The following matrices illustrate the transformation of a Payoff Matrix to a Loss Matrix:

<table>
<thead>
<tr>
<th>Payoff Matrix</th>
<th>Loss Matrix</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Response</strong></td>
<td><strong>Outcome</strong></td>
</tr>
<tr>
<td></td>
<td>$E_1$</td>
</tr>
<tr>
<td>$A_1$</td>
<td>1φ</td>
</tr>
<tr>
<td>$A_2$</td>
<td>-1φ</td>
</tr>
<tr>
<td><strong>Probability of Outcome</strong></td>
<td>.7</td>
</tr>
</tbody>
</table>

An $A_1$ response followed by occurrence of $E_1$ results in no loss since $S$ has done as well as is possible on this trial. An $A_1$ response followed by occurrence of $E_2$ results in a loss of 15φ, the possible 10φ gain minus the actual 5φ cost. The losses associated with an $A_2$ response are computed similarly.

The probabilities of occurrence of $E_1$ and $E_2$ of .7 and .3, respectively, yield the following expected losses:

For $A_1$, $\text{EL}_1 = .7(0) + .3(15) = 4.5$
For $A_2$, $EL_2 = .7(2) + .3(0) = 1.4$

By the RELM rule, probability of choice of the alternative with the smaller $EL$ becomes greater as the quantity $rac{EL_2 - EL_1}{(EL_1 + EL_2)/2}$ increases. For the two-choice case, the greater the positive value of $\frac{\Delta EL}{EL}$, the more probable an S's choice of $E_1$. With negative values, $E_2$ should be chosen more often than $E_1$.

For 24 combinations of conditions, Edwards (1956) reported a linear relationship between RELM values and probability of choice, with a Pearson product-moment correlation ($r$) of .96. For the eight combinations of conditions employed by Taub and Myers (1961), the relationship between RELM values and probability of choice was again linear with an $r$ of .98.

In order to further assess the validity of the RELM rule, RELM values have been computed for two additional experiments. In the first (Suydam & Myers, 1962), Ss chose between a gamble with .50-.50 probability, and a known alternative to gambling. The monetary level (range) of the gamble and the value of the known alternative were the variables; the response measure was S's rating of choices. The RELM rule correctly predicted the tendency of the value curves to converge as the range of the gamble increased. In the second experiment (Myers, Reilly, & Taub, 1961), the RELM values accurately predicted the rank ordering of groups with respect to the dependent variable, choice probability;
the only notable inversions were under conditions of .50-.50 probability.

In an attempt to fit the data from all four payoff conditions, Miller and Lanzetta (1962) extended Edwards' (1956) RELM rule to the four alternative case. The Relative Expected Loss (REL) for a given alternative was defined as the ratio of the difference between the EL of that alternative and the mean EL of the three other alternatives to the mean EL of all four alternatives. For four choices, the equation for alternative A is,

\[
\text{REL}_A = \frac{\text{BL}_A - \frac{1}{N-1} \left[ \sum_{i=1}^{N} \text{EL}_i - \text{EL}_A \right]}{\frac{1}{N} \sum_{i=1}^{N} \text{EL}_i}
\]  

(5)

One prediction is the greater the REL value between conditions, the lower the relative frequency of choice of that alternative within payoff conditions. Another prediction is the same ordering of alternatives within each of the four payoff conditions. But the order in the equal EV condition differed from that in the other three EV conditions.

Perhaps the RELM rule cannot be extended to situations of more than two choices. Alternatively, Miller and Lanzetta's data may not have constituted an adequate test, since, contrary to the results of previous experiments (Edwards, 1956; Myers, Reilly & Taub, 1961; Taub & Myers, 1961), they found no sig-
significant differences in choice behavior attributable to cost and payoff which are basic parameters in the RELM model.

The RELM model has yielded accurate predictions of choice behavior in a variety of two-choice situations. However, the ELs upon which it is based can be combined into a simpler equation which yields identical predictions. The new equation, which will be called the Expected Loss Ratio (ELR), is defined as,

$$\text{ELR} = \frac{EL_2}{EL_1 + EL_2}.$$  \hspace{1cm} (6)

RELM and ELR are related linearly, the proof for which is as follows:

$$\text{ELR} = \frac{2EL_2}{2(EL_1 + EL_2)} = \frac{EL_2 - EL_1}{2(EL_1 + EL_2)} + \frac{EL_1 + EL_2}{2(EL_1 + EL_2)} = 1/4 \left[ \frac{EL_2 - EL_1}{(EL_1 + EL_2)/2} \right] + 1/2 \left[ \frac{EL_1 + EL_2}{EL_1 + EL_2} \right] = 1/4 \left[ \frac{EL_2 - EL_1}{(EL_1 + EL_2)/2} \right] + 1/2.$$  

The quantity in brackets is RELM, thus,

$$\text{ELR} = 1/4 \text{ (RELM)} + 1/2. \hspace{1cm} (7)$$

ELR is simpler to compute than RELM and simpler conceptually. All further discussion, therefore, centers about the ELR model.

The success of loss models in predicting choice behavior under both sequential-choice and single presentation techniques suggests that ELR must be sensitive to factors which are similar under both conditions and be unaffected by those
that are dissimilar. The model takes into account tendencies to prefer high probability of gain to low, larger gain to smaller gain, and accounts also for the cost associated with an incorrect choice. The predictive power of the ELR model depends not only upon the parameters included but also upon the manner in which they are included. Contained in the ELR model are three desirable features of models for predicting choice behavior. First, since the definition of EL requires a loss matrix containing no negative quantities, except for the trivial case where all entries in the matrix are identical, a zero denominator is impossible.

Second, ELR has limits of 1 and 0. The proof for these limits is, \( \frac{EL_2}{EL_1 + EL_2} \rightarrow 1 \) when \( EL_2 \) takes on any positive value and \( EL_1 \rightarrow 0 \), and

\[ \frac{EL_2}{EL_1 + EL_2} \rightarrow 0 \], when \( EL_1 \) takes on any positive value and \( EL_2 \rightarrow 0 \).

The limits of 0 and 1 occur in the two-choice situation only when probability is equal to 0 or 1, or when one choice dominates in the sense that it is preferred regardless of outcome.

Third, as gain on the alternative event \( (E_2) \) increases by equal amounts at constant probability and cost, the denominator of ELR increases by equal amounts, and the ratio decreases in negatively accelerated fashion. For constant probability and gain, equal increases in cost for an incorrect
prediction of $E_1$ also increase the denominator of ELR by equal amounts to produce a negatively-accelerated decrease in the ratio. Therefore, ELR is a decreasing, negatively-accelerated function of both amount of gain associated with a correct prediction of $E_2$, and amount of cost associated with an incorrect prediction of $E_1$. For generality, a model must involve negative acceleration since performance in decision making and other learning areas is generally a negatively-accelerated function of amount of reward (Pubols, 1960).

Of particular concern in the present experiment was the applicability of ELR and $\Delta EV$ rules. Interactions among gain, cost, and probability were also of concern as were comparisons of these interactions for the single-presentation technique with those obtained under the repeated-presentation technique.
Method

Experimental Design and Materials. Forty-five matrices representing 45 pairs of options were constructed by using all combinations of the probabilities, cost ratios, and gain ratios shown in Table 1. The complete set of matrices is in Appendix A.

Each matrix appeared at the top of a separate page with the rating scale below in the format shown in Figure 1. The matrices were arranged in random order and then assembled in 45-page booklets. The order of the matrices in each booklet represented a different sequence of the original random order.

The S played either Red (R) or Black (B) which occurred with probabilities $P$ and $1 - P$, respectively. Choice of R followed by occurrence of R always resulted in a gain of 1. Choice of B followed by occurrence of R always resulted in a cost of 1. Choice of B followed by occurrence of B resulted in gains of 1, 5, or 10, and choice of R followed by occurrence of B resulted in costs of 1, 5, or 10.

Strength of choice of R to win could vary downward from "definitely prefer this choice" to the neutral point of "impossible to make a choice", with strength of choice of B then increasing to "definitely prefer this choice". In parentheses to the right of each verbal statement in Figure 1 are the numerical values later assigned to them.
<table>
<thead>
<tr>
<th>Cost Ratio</th>
<th>Gain Ratio</th>
<th>Probability of Red</th>
<th>( EV_r )</th>
<th>( \Delta EV )</th>
<th>ELR Value</th>
<th>Mean</th>
<th>SD</th>
</tr>
</thead>
<tbody>
<tr>
<td>1:1</td>
<td>1:1</td>
<td>0.1</td>
<td>0.8</td>
<td>1.6</td>
<td>0.90</td>
<td>8.44</td>
<td>1.15</td>
</tr>
<tr>
<td></td>
<td></td>
<td>0.7</td>
<td>0.4</td>
<td>0.8</td>
<td>0.70</td>
<td>8.09</td>
<td>1.41</td>
</tr>
<tr>
<td></td>
<td></td>
<td>0.5</td>
<td>0.0</td>
<td>0.0</td>
<td>0.50</td>
<td>5.19</td>
<td>1.03</td>
</tr>
<tr>
<td></td>
<td></td>
<td>0.3</td>
<td>-0.4</td>
<td>-0.8</td>
<td>0.30</td>
<td>1.86</td>
<td>1.47</td>
</tr>
<tr>
<td></td>
<td></td>
<td>0.1</td>
<td>-0.8</td>
<td>-1.6</td>
<td>0.10</td>
<td>1.67</td>
<td>1.41</td>
</tr>
<tr>
<td>1:5</td>
<td></td>
<td>0.9</td>
<td>0.8</td>
<td>1.2</td>
<td>0.75</td>
<td>7.54</td>
<td>1.78</td>
</tr>
<tr>
<td></td>
<td></td>
<td>0.7</td>
<td>0.4</td>
<td>-0.4</td>
<td>0.44</td>
<td>3.79</td>
<td>2.47</td>
</tr>
<tr>
<td></td>
<td></td>
<td>0.5</td>
<td>0.0</td>
<td>-2.0</td>
<td>0.25</td>
<td>1.69</td>
<td>1.44</td>
</tr>
<tr>
<td></td>
<td></td>
<td>0.3</td>
<td>-0.4</td>
<td>-3.6</td>
<td>0.13</td>
<td>1.61</td>
<td>1.07</td>
</tr>
<tr>
<td></td>
<td></td>
<td>0.1</td>
<td>-0.8</td>
<td>-5.2</td>
<td>0.04</td>
<td>1.17</td>
<td>0.49</td>
</tr>
<tr>
<td>1:10</td>
<td></td>
<td>0.9</td>
<td>0.8</td>
<td>0.7</td>
<td>0.63</td>
<td>6.26</td>
<td>2.75</td>
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<td>0.30</td>
<td>2.91</td>
<td>2.26</td>
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<tr>
<td></td>
<td></td>
<td>0.5</td>
<td>0.0</td>
<td>-4.5</td>
<td>0.16</td>
<td>1.64</td>
<td>1.36</td>
</tr>
<tr>
<td></td>
<td></td>
<td>0.3</td>
<td>-0.4</td>
<td>-7.1</td>
<td>0.07</td>
<td>1.22</td>
<td>0.73</td>
</tr>
<tr>
<td>1:5</td>
<td>1:1</td>
<td>0.9</td>
<td>0.4</td>
<td>1.2</td>
<td>0.75</td>
<td>7.31</td>
<td>2.15</td>
</tr>
<tr>
<td></td>
<td></td>
<td>0.7</td>
<td>-0.8</td>
<td>-0.4</td>
<td>0.44</td>
<td>4.52</td>
<td>2.45</td>
</tr>
<tr>
<td></td>
<td></td>
<td>0.5</td>
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<td>1.61</td>
<td>1.11</td>
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<tr>
<td></td>
<td></td>
<td>0.1</td>
<td>-8.9</td>
<td>-17.8</td>
<td>0.01</td>
<td>1.19</td>
<td>0.42</td>
</tr>
<tr>
<td>You play Red</td>
<td>Red</td>
<td>Black</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>-------------</td>
<td>-----</td>
<td>-------</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>You play Black</td>
<td>win 1%</td>
<td>lose 5%</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>lose 1%</td>
<td>win 10%</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Odds</td>
<td>7/10</td>
<td>3/10</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

- Definitely prefer this choice (9)
- This choice seems much better (8)
- This choice seems slightly better (7)
- Very difficult to decide (6)
- Impossible to make a choice (5)
- Very difficult to decide (4)
- This choice seems slightly better (3)
- This choice seems much better (2)
- Definitely prefer this choice (1)

Figure 1. Sample Page Showing the Format for the Matrices and the Rating Scale.
Procedure. Subjects were run in groups. Instructions were read to them which described the task and what they were to do. More specifically, Ss were shown a sample matrix and told they were to decide each time whether they preferred to bet on R or B to win. The several possible gains, losses, and odds were explained. They were also told that the strength of each decision was to be indicated on the rating scale. That each new decision was to be made independently from previous decisions was emphasized. The Ss were also told that the object of the experiment was to win as large an amount as possible, but that no actual exchange of money would take place.

The time allotted for completion of the booklets was 20 minutes. All Ss were able to finish within this limit which was predetermined on the basis of time records from pilot Ss.

In order to show Ss the results of their decisions, at the end of the session several bets were run off on a specially constructed roulette wheel which could be adjusted to show appropriate proportions of red and black. The wheel consisted of a circular wooden base, 10" in diameter, on which was mounted a sheet metal disk of the same diameter. The disk was painted half red and half black. In addition, two semicircular disks of 10" diameter sheet metal with spindle holes were constructed. One of the disks was painted red, the other black. The disks could be interchanged on a simple metal spindle which protruded from the center of the
wheel to give any desired proportions of red and black. A brass pointer which could also be placed on the spindle completed the apparatus.

**Subjects.** Eighty-five male students enrolled in the elementary psychology course at the University of Massachusetts were selected randomly. Twenty-three were run in the first group, 15 in the second, 25 in the third, and 22 in the fourth. Scores of Ss from all four groups were pooled.
Results

Means and standard deviations of ratings are presented in Table 1; the means are plotted in Figure 2. Described first are effects on ratings of cost ratios, gain ratios, and probabilities. Then examined are the relationships between ratings and values obtained by $\Delta EV$ and $ELA$ models.

Cost Ratios, Gain Ratios, and Probabilities. As shown in Figure 2, means of ratings decreased as probabilities of $R$ decreased, and as cost ratios and gain ratios increased. In the analysis of variance on ratings (Table 2), all three variables were significant ($p < .001$). At each combination of cost and gain, the mean rating of $R$ decreased as the probability of $R$ decreased. Mean ratings decreased rapidly as probability of $R$ decreased to .5, then more slowly as probability approached .1. Mean ratings of $R$ also decreased as the cost of an incorrect choice of $R$ increased, and as the gain on a correct choice of $B$ increased.

The interactions of probabilities and cost ratios, of probabilities and gain ratios, of cost ratios and gain ratios, and of all three variables were also significant ($p < .001$). When the probability of $R$ equaled .9, mean ratings were highest for the 1:1 cost ratio, with the 1:5 and 1:10 cost ratios following in order, but as probability of $R$ decreased differences in mean ratings as a function of cost
Figure 2. Mean Rating of Red for Each Combination of Cost Ratio, Gain Ratio, and Probability of Occurrence of Red.
Table 2

Analysis of Variance of Rating Scale Data

<table>
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<th>Source of Variance</th>
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<th>MS</th>
<th>F</th>
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<tbody>
<tr>
<td>Subjects (S)</td>
<td>84</td>
<td>17.86</td>
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<td>Probability of Red (P)</td>
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<td>3579.15</td>
<td>542.33 *</td>
</tr>
<tr>
<td>S x P</td>
<td>336</td>
<td>6.60</td>
<td></td>
</tr>
<tr>
<td>Cost (C)</td>
<td>2</td>
<td>160.71</td>
<td>42.68 *</td>
</tr>
<tr>
<td>S x C</td>
<td>168</td>
<td>3.77</td>
<td></td>
</tr>
<tr>
<td>Gain (G)</td>
<td>2</td>
<td>623.43</td>
<td>191.46 *</td>
</tr>
<tr>
<td>S x G</td>
<td>168</td>
<td>3.26</td>
<td></td>
</tr>
<tr>
<td>P x C</td>
<td>3</td>
<td>61.37</td>
<td>24.43 *</td>
</tr>
<tr>
<td>S x P x C</td>
<td>672</td>
<td>2.51</td>
<td></td>
</tr>
<tr>
<td>P x G</td>
<td>8</td>
<td>58.13</td>
<td>23.60 *</td>
</tr>
<tr>
<td>S x P x G</td>
<td>672</td>
<td>2.45</td>
<td></td>
</tr>
<tr>
<td>C x G</td>
<td>4</td>
<td>111.90</td>
<td>53.14 *</td>
</tr>
<tr>
<td>S x C x G</td>
<td>336</td>
<td>2.11</td>
<td></td>
</tr>
<tr>
<td>P x C x G</td>
<td>16</td>
<td>32.54</td>
<td>17.56 *</td>
</tr>
<tr>
<td>S x P x C x G</td>
<td>1344</td>
<td>1.85</td>
<td></td>
</tr>
</tbody>
</table>

* p < .001
also decreased. Variability among the mean ratings at the three levels of gain also decreased as probability of $R$ decreased from .9 to .1. As cost increased from 1:1 to 1:10, the effects of gain decreased. The greatest decrease in variability due to gain was between the 1:1 and 1:5 cost ratios; there was only a slight difference in the spread of gain curves at the 1:5 and 1:10 cost ratios. When the cost ratio was 1:1, the spread among gain curves decreased as probability of $R$ decreased but at the higher cost ratios differences among gain curves varied only slightly as probability decreased.

**Ratings and Models.** Also presented in Table 1 are $EV_R$, $\Delta EV$, and $ELR$ values for each of the combinations of cost ratios, gain ratios, and probabilities. $EV_R$ is the gain associated with $R$ multiplied by its probability plus the cost associated with $B$ multiplied by its probability; $EV_B$ is computed similarly. $\Delta EV$ is $EV_R - EV_B$ (Equation 4).

$ELR$ is the ratio of $EL_B$ to $EL_R$ plus $EL_B$ (Equation 7). $EL_B$ is the gain associated with a correct prediction of $R$ minus the loss associated with an incorrect prediction of $B$ multiplied by the probability of $R$. $EL_R$ is computed in the same way. The $ELR$ values are plotted in Figure 3.

As $\Delta EV$ increased from $-17.8$ to $-3.1$, mean ratings increased irregularly from 1.19 to 3.30. For $\Delta EV$ of $-3.1$, mean ratings varied from 1.61 to 3.30. As $\Delta EV$ increased from $-3.1$ to $+1.6$, the largest value, mean ratings climbed
Figure 3. EER Value for Each Combination of Cost Ratio, Gain Ratio, and Probability of Occurrence of Red.
rapidly to their maximum of 3.44. The relationship between \( \Delta EV \) and the ratings is best described as positively-accelerated with considerable variation about the estimated curve of best fit.

The relationship between ELR values and means of ratings was linear. Comparison of the curves for ELR values plotted in Figure 3 with the curves for means of ratings for each combination of cost, gain, and probability in Figure 2 reveals that the ELR values predict not only the rank ordering of the means but also closely approximate the shape of the rating curves. The only notable difference between prediction and mean rating is to be found under the 1:10 C, .9 P condition where 1:5 G has a higher mean rating than 1:1 G. The \( r \) between ELR values and mean ratings was .97 for which the regression line had a slope of .94 and an intercept of 8.56.
Discussion

Cost Ratios, Gain Ratios, and Probabilities. The results of the present experiment parallel those reported by Myers, Reilly, and Taub (1961) in several respects. In both experiments, probability of outcomes had the greatest effect upon choice behavior with cost and gain ratios contributing to a lesser degree. However, in the present experiment, gain ratios had a greater effect than cost ratios while the reverse was true for the Myers, Reilly, and Taub experiment. This difference may reflect the effect of money upon choices: in the present experiment, gambling was imagined; in the earlier experiment, Ss gambled for chips which could later be exchanged for money. The possibility of winning money may cause Ss to consider more carefully the potential loss associated with each choice.

Ratings and Models. The $\Delta EV$ values obtained from the present study failed to predict the means of ratings. On the whole, ratings were a positively-accelerated function of $\Delta EV$ values with marked variability about the estimated regression line. In contrast, with a repeated presentation technique, Myers, Reilly, and Taub (1961) found a nearly linear relationship between $\Delta EV$ values and asymptotic probability of choice. The difference in results between the two experiments is very likely due to differences between the single-presentation and repeated-presentation techniques. Consequently, detailed
comparison of their differences and their possible effects is desirable.

The repeated-choice technique used by Myers, Reilly, and Taub (1961) requires that \( S \) estimate the probability of outcomes by observing the sequence of events, but with the single-presentation technique each probability is explicitly stated. Furthermore, in the sequential-choice situation, \( S \) is informed immediately of the outcome of each trial, and is reminded constantly of the effects of gain and cost by his growing or diminishing pile of chips. In contrast, the present procedure eliminates feedback and monetary incentive: \( S \) made each choice in the same state of ignorance and was aware that no real money was involved. Thus, in the present experiment, \( S \) was not "forced" to change his pattern of behavior in response to a shrinking pile of chips nor was he required to learn probabilities over trials. Although the relative effects of these procedural differences cannot be evaluated, such differences would be expected to affect choice behavior and could account for the lack of fit of the \( \Delta EV \) values.

Edwards (1956) RELM rule was originally developed to predict sequential two-alternative decisions, but it can also be applied to data obtained under the single-presentation technique. The RELM values or their linear transforms, the DLR values, predicted not only the rank ordering of the mean ratings, but also the shape of all main and interaction effects.
The BLR model is, so far, the only model which has yielded accurate predictions in both single-presentation (Suydam & Myers, 1962), and sequential-choice situations (Edwards, 1956; Taub & Myers, 1951).

The sensitivity of loss models to the parameters underlying choice behavior suggests that they may be extended into new areas of research. However, that research should be important in terms of adding more parametric data to the existing body of literature rather than being merely a vehicle for testing models. The proposed research could be carried out using either the sequential choice or single-presentation technique or both. At least three areas warrant consideration. The first one is multi-choice decision making. The lack of significant results in the Miller and Lanzetta (1962) study points to the need for additional investigation to test the reliability of their results. Since this is the only study which has provided data on monetary payoffs with more than two choices, data is also needed for three-choice situations before attempting the more complicated problems posed by four or more choices.

The second is further manipulations on payoffs. Extension of the present study to include multiplies of G and C would provide a further test of the applicability of the BLR model and yield additional information on the effect of increasing monetary levels. For example, the two payoff matrices below are equal in ratio and yield identical BLR predictions, but differ in amount of cost and gain.
### Payoff Matrix No. 1

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<thead>
<tr>
<th></th>
<th>Red</th>
<th>Black</th>
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</thead>
<tbody>
<tr>
<td><strong>Wheel Comes Up</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>You play Red</td>
<td>1%</td>
<td>-5%</td>
</tr>
<tr>
<td>You play Black</td>
<td>-1%</td>
<td>10%</td>
</tr>
<tr>
<td>Odds</td>
<td>7/10</td>
<td>3/10</td>
</tr>
</tbody>
</table>

\[
\text{BL}_p = .7(2) = 1.4
\]

\[
\text{BL}_r = .3(15) = 4.5
\]

\[
\text{ELR} = \frac{1.4}{1.4 + 4.5} = .24
\]

### Payoff Matrix No. 2

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<td><strong>Wheel Comes Up</strong></td>
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<td></td>
</tr>
<tr>
<td>You play Red</td>
<td>2%</td>
<td>-10%</td>
</tr>
<tr>
<td>You play Black</td>
<td>-2%</td>
<td>20%</td>
</tr>
<tr>
<td>Odds</td>
<td>7/10</td>
<td>3/10</td>
</tr>
</tbody>
</table>

\[
\text{BL}_p = .7(4) = 2.8
\]

\[
\text{BL}_r = .3(30) = 9.0
\]

\[
\text{ELR} = \frac{2.8}{2.8 + 9.0} = \frac{1.4}{1.4 + 4.5} = .24
\]

In addition, the effect on choice behavior of multiplying one payoff ratio while holding the second payoff ratio constant should be determined. For example, multiplying G by 2 and holding C constant results in a new ELR prediction. Compare Payoff Matrix No. 1 with Payoff Matrix No. 3 below which has a doubled G but identical C.
The two matrices should yield different choice behavior according to ELR predictions although the difference is small in the example cited. Perhaps in such cases, amount of cost and gain will operate to produce greater differences in choice behavior than is predicted by the ELR model.

The third area is gamble vs. known alternative. The ELR model also accounted for the data from a very different two-choice situation, that of choice between a gamble with .5 probability of winning, and a known alternative to gambling (Suydam & Myers, 1962). Additional research is needed to investigate the effect on behavior of varying the probability of payoffs, not only as a further test of the ELR model but also to complement the existing data.
Summary

Three parameters of risk-taking, gain ratio (G), cost ratio (C), and probability of occurrence of Red (P), were varied in an experimental design which provided for the control of effects due to repeated presentations. On each of 45 trials, 85 Ss were required to choose between two outcomes and to rate the strength of their choice along a 9-point scale. No exchange of chips or money took place.

Means of ratings decreased as C increased, as G on the alternative event increased, and as P decreased. As P decreased, differences in mean ratings as functions of C and G decreased. As C increased, differences in mean ratings as a function of G decreased, this decrease being more marked at the higher levels of P. An analysis of variance of the rating scale data showed all effects to be significant (p < .001).

Several objective decision models were discussed in relation to their predictive power for the present data. One model, the Relative Expected Loss Minimization (RELM) rule, accurately predicted not only the rank ordering of the mean ratings but also the pattern of all main and interaction effects. The RELM rule is a linear transform of a computationally and conceptually simpler equation, the Expected Loss Ratio (ELR). Suggested, therefore, was substitution of the ELR model for the RELM rule.

-31-
References


Katz, L. Monetary incentive and range of payoffs as determiners of risk-taking. J. exp. Psychol., 1962, 64, 541-544.


-32-
### Appendix A

The 45 Matrices Obtained from All Possible Combinations of 3 Cost Ratios, 3 Gain Ratios, and 5 Levels of Probability

<table>
<thead>
<tr>
<th>Wheel comes up</th>
<th>Wheel comes up</th>
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<td>Black</td>
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<td>Red</td>
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</table>

<table>
<thead>
<tr>
<th></th>
<th>You play Red</th>
<th>You play Black</th>
<th>Odds 9/10</th>
<th>1/10</th>
<th>7/10</th>
<th>3/10</th>
<th>5/10</th>
<th>5/10</th>
</tr>
</thead>
<tbody>
<tr>
<td>You play Red</td>
<td>1¢</td>
<td>-1¢</td>
<td>1¢</td>
<td>-1¢</td>
<td>7¢</td>
<td>-1¢</td>
<td>1¢</td>
<td>-1¢</td>
</tr>
<tr>
<td>You play Black</td>
<td>-1¢</td>
<td>1¢</td>
<td>-1¢</td>
<td>1¢</td>
<td>-1¢</td>
<td>1¢</td>
<td>-1¢</td>
<td>1¢</td>
</tr>
<tr>
<td></td>
<td>Odds 9/10</td>
<td>1/10</td>
<td>7/10</td>
<td>3/10</td>
<td>5/10</td>
<td>5/10</td>
<td>3/10</td>
<td>7/10</td>
</tr>
<tr>
<td>You play Red</td>
<td>1¢</td>
<td>-1¢</td>
<td>1¢</td>
<td>-1¢</td>
<td>1¢</td>
<td>-1¢</td>
<td>1¢</td>
<td>-1¢</td>
</tr>
<tr>
<td>You play Black</td>
<td>-1¢</td>
<td>5¢</td>
<td>-1¢</td>
<td>5¢</td>
<td>-1¢</td>
<td>5¢</td>
<td>-1¢</td>
<td>5¢</td>
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Acknowledgments

The author is deeply grateful to Dr. Jerome L. Myers, Chairman, and to Drs. Albert E. Goss, and Albert S. Anthony who served as members of the Thesis Committee. Their guidance and cooperation were invaluable in the preparation of this thesis.

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APPROVED:

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DATE: September 6, 1963

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