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The Effects of Differential Gain and Loss on Sequential Two-Choice Behavior

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Introduction

In order to increase the range of reinforcement above that of merely having S's predictions confirmed or disconfirmed, monetary incentive has been introduced into the sequential two-choice situation (e.g., Goodnow, 1955; Siegal & Goldstein, 1959). The purpose of the present experiment was to study the effects on two-choice behavior of varying monetary gains and losses associated with a single response while holding the reinforcement of the other response constant.

In the two-choice situation, first used by Humphreys (1939), a stimulus is presented to which Ss respond by predicting which one of two mutually exclusive E-manipulated events will occur. The two events, occur with fixed, but usually unequal, frequencies in a random sequence for a series of trials and the occurrence of an event is not contingent on S's behavior. The two events, designated E_1 and E_2, occur with respective probabilities π and $1-\pi$. Predictions of E_1 and E_2 by S's are designated, respectively, as the responses A_1 and A_2. Generally, Ss predict E_1 more as π increases (e.g., Grant, Hake, and Hornseth, 1951). If π is greater than $1-\pi$, Ss predict E_1 more as the number of trials increases (Derks, 1962).

Siegal and Goldstein (1959) demonstrated the effect of equal monetary gains and losses. With π equal to .75, A_1

responding increased under conditions in which Ss gained 5¢ for each correct response as compared with conditions in which Ss neither gained nor lost money. The level of A_1 responding was highest under conditions in which Ss gained 5¢ for each correct response and lost 5¢ for each incorrect response. Thus, the introduction of monetary incentive tended to make Ss respond in a more nearly optimal manner, because, for π greater than .5 and equal gains and losses, always responding with A_1 is the optimal strategy. Suppes and Atkinson (1960) demonstrated that increasing the level of monetary incentive increases this effect. For π of .6, Suppes and Atkinson found that percentage of A_1 responses increased progressively for gains and losses of 0¢, 5¢, and 10¢.

Taub and Myers (1961) explored the effects of differential payoff by varying the gain associated with E_1 with constant gain associated with E_2 and constant loss associated with either event. As the difference in expected value (ΔEV) between the events increased, the event with the higher EV was predicted more frequently.[1] In an extension of this experiment by Myers, Reilly, and Taub (1962), three levels of each π, gain, and loss were varied factorially to produce several levels of EV. While choice of the event with greater

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[1] The EV of an E_1 choice, for example, is defined as the product π times the amount that can be gained minus the product $1-\pi$ times the amount that can be lost; that is, $EV(A_1) = \pi G(A_1) - (1-\pi) L(A_1)$: $\Delta EV = EV(A_1) - EV(A_2)$.

EV increased generally with increases in ΔEV, there were occasional discrepancies, particularly with regard to negative expected differences. Events with negative EV generally altered choice behavior more than events with equal but positive expectancies; i.e., a loss had a greater effect than a gain of equal size.

Expected value and ΔEV have not been found to be accurate predictors of choice in situations similar to the sequential two-choice situation; e.g., the choice between two gambles. Pruitt (1962), citing gambling data of Mosteller and Nogee (1951) and Coombs and Komorita (1951), suggests a breakdown in prediction of choice from small EV or small differences in EV.

The most specific objective of the present study, therefore, was a detailed assessment of effects of relatively small EV's on choice of E_1 and E_2. For π = .50, 1, 2, and 4 units of gain associated with A_1 were combined factorially with 1, 2, and 4 units of loss associated with A_1. Gain and loss associated with A_2 were each 1 unit for all experimental groups. Table 1 presents ΔEV for each combination of gain and loss. The two measures employed were percentage of choices of E_1 (i.e., A_1 responses) and first-order conditional probabilities of A_1. First-order conditional probabilities of A_1 are the probabilities of A_1 on trial n+1 given that, on trial n, A_1 was followed by E_1, $p(A_1|A_1E_1)$, A_1 was followed by E_2, $p(A_1|A_1E_2)$, A_2 was followed by E_1, $p(A_1|A_2E_1)$, and A_2

Table 1

Combinations of Gains and Losses
with Associated ΔEV's in Each Cell

	Gain		
Loss	1	2	4
1	0.0	+0.5	+1.5
2	-0.5	0.0	+1.0
4	-1.5	-1.0	0.0

was followed by E_2, $p(A_1 | A_2E_2)$.

For percentage of A_1, the prediction was a direct relation between such choices and ΔEV. Thus, the smallest number of A_1 choices was predicted for the group in which $\Delta EV = -1.5$, and the largest number for the group in which $\Delta EV = +1.5$. Considering only ΔEV, no differences among the three 0 ΔEV groups could be predicted. However, a hypothesis based on the variance differences among the three games could be made. Coombs and Pruitt (1959) demonstrated that preferences for gambles existed which were based on variance differences between gambles. For the present study, it was predicted that choice of the response with the higher payoff variance (the A_1 or the gain-loss combinations [2,-2] and [4,-4]) would be monotonically related to the size of the variance. Thus, if the combination (1,-1), with the smallest variance, had the smallest number of A_1 choices, (4,-4) should have the largest and vice versa.

First-order conditional probabilities for equal gains and losses have been reported previously by Suppes and Atkinson (1960). With $\pi = .60$, the probability of A_1 following A_1E_2 was greater than the probability of A_1 following A_2E_1 during the first 150 trials. At the end of 240 trials, the two probabilities were equal, a result that is contrary to the notion that punishment in the form of a loss should decrease the frequency of an incorrect choice. Atkinson (1962) has presented a mathematical model of choice that includes

parameters for incentive and which predicts the observed inversion of $p(A_1|A_1E_2)$ and $p(A_1|A_2E_1)$. In this model, the size of the difference between the two porbabilities is an increasing function of the amount of monetary incentive. The present study, which included more trials than the Suppes and Atkinson experiment, provided sequential data which were more nearly asymptotic and, therefore, provided a basis for a clearer demonstration of the relationships among the first-order conditional probabilities.

Method

Apparatus. Each of four Ss sat in adjacent stalls before a 7 x 9 inch game board. On each board were two toggle switches; one of which was 2 inches to the left of the vertical centerline and the other 2 inches to the right of the vertical centerline. Green pilot lights, 1 inch in diameter, and 3 inches above each switch, were the event stimuli. A smaller amber neon glow lamp, 1 inch above each pilot light was lighted when the toggle switch for that pilot light was thrown. Finally, above each neon lamp was a rectangular white paper indicating the amount of gain for correct responses and the amount of loss for incorrect responses.

For two game boards, the E_1 pilot light and the A_1 switch and neon light were on the right side; for the other two, they were on the left. At the beginning of the experiment, Ss were given $1.00 worth of white, red, and blue poker chips worth 1, 2, and 4 units, respectively, redeemable at .25¢ per unit. Each of E's two assistants stood between and behind two of the four Ss and dispensed and reclaimed chips after each trial.

When S's switches were closed, corresponding lights came on in an adjacent room in which E recorded S's responses. There was a one-way vision glass between the rooms.

Procedure. The instructions were read to Ss at the beginning of the session informing them of the number of units and monetary equivalent of each chip and about the number of units they would gain with a correct and lose with an incorrect prediction. Also, they were informed that the $1.00 in chips given to them was "their money". Further, any additional money they won could be taken with them in addition to the $1.00 but whatever money was lost would be deducted from the $1.00. Finally, they were told to win as much as possible rather than to be correct as often as they could.

Each trial was initiated by a .5 sec. buzzer which was the signal to respond. Two sec. later one of the green event stimuli was lighted. Chips were then given or taken away from Ss by E's assistants. Three sec. later the event stimulus went out and Ss opened their switches. The inter-trial interval was 2 sec.

The sequence of equal numbers of E_1 and E_2 events through 400 trials was random with the restrictions of equal numbers of each event in each block of 50 trials and of occurrence of the expected number of runs of each length (Nicks, 1959). Then, the sequence was divided into four starting points, each separated from the adjacent starting points by 100 trials. For every five Ss in each experimental group, the session began at one of the four starting points and made a complete cycle of 400 trials. The sequence was programmed on a Western Union tape transmitter.

Subjects. The Ss were 186 undergraduate males and females at the University of Massachusetts. Six Ss were discarded, two because of failure to complete the experiment and four because of recording errors. The remaining 180 Ss were assigned in equal groups of 20 Ss to each of the nine experimental groups. The nine games were run successively with 10 Ss in each game (assigning every five Ss in each game to one of two starting points); then the experiment was replicated with an additional 10 Ss in each game (assigning every five Ss in each game to one of the two remaining starting points).

Results

Expected value. The data were analyzed as function of $_\Delta$EV, Sign of $_\Delta$EV, and Trials. Figure 1 shows mean percentages of A_1 responses in successive 50-trial blocks for each of the nine experimental groups. Each curve is identified by the combination of gain and loss and by the $_\Delta$EV. The three 0_ΔEV did not separate systematically and each oscillated about 50 per cent occurrence of A_1. The mean percentage for the $+_\Delta$EV groups increased in the order +1.0, +.5, and +1.5 and the mean percentage for the $-_\Delta$EV groups decreased in the order -1.0, -.5, and -1.5.

In each $+_\Delta$EV game [$EV(A_1) > EV(A_2)$] and in each $-_\Delta$EV game [$EV(A_2) > EV(A_1)$], optimal responses were A_1 and A_2, respectively. Therefore, in order to study the effect of $_\Delta$EV on the frequency of optimal responding, it was necessary to contrast the frequency of A_1 for each $+_\Delta$EV group with the frequency of A_2 for each $-_\Delta$EV group. The mean percentage of A_1 for each $+_\Delta$EV game and the mean percentage of A_2 for each $-_\Delta$EV game for Blocks 7 and 8 combined (Trials 301-400) are plotted in Figure 2. In the analysis of variance performed on the frequency of optimal responses in $+_\Delta$EV and $-_\Delta$EV groups in each of Blocks 7 and 8 (Table 2), $_\Delta$EV (without respect to sign) is significant at $p < .01$. But whether $_\Delta$EV was positive or negative (Sign) and the $_\Delta$EV x Sign interaction were not

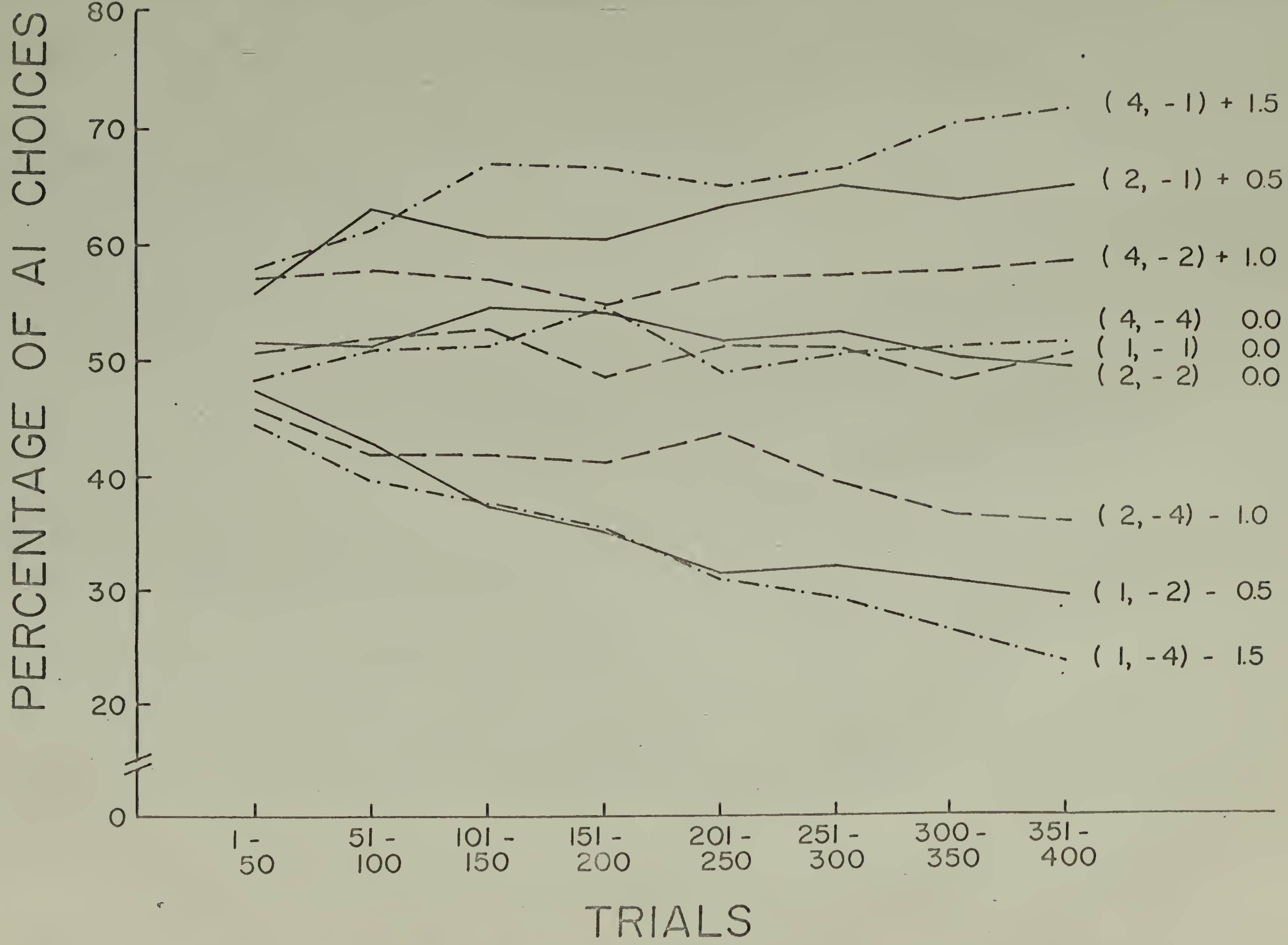

Figure 1. Percentage of AI choices through successive blocks of 50 trials for each combination of gain and loss (within parentheses) or ΔEV.

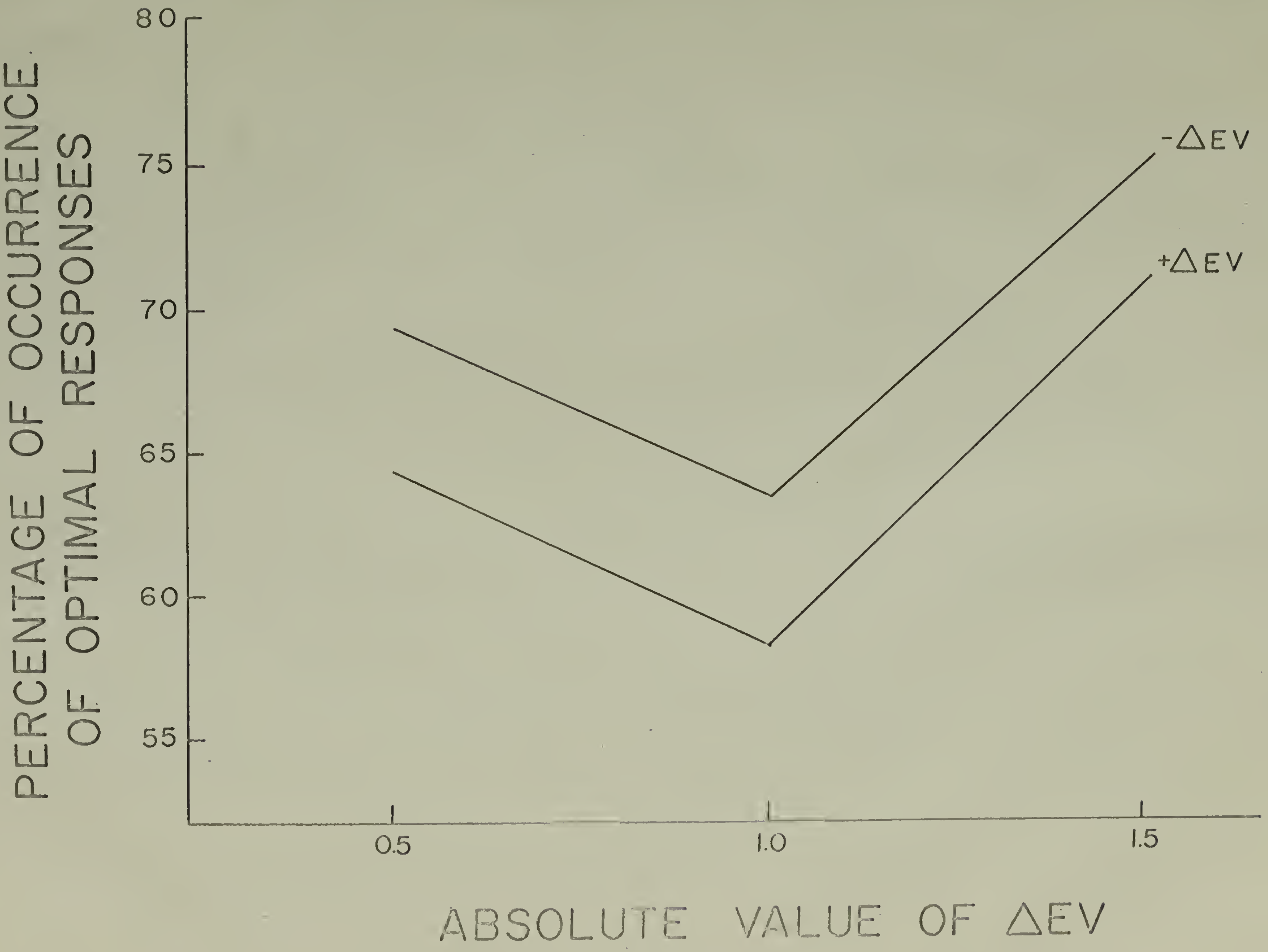

Figure 2 . Percentage of occurrences of optimal responses during trials 301-400 as functions of absolute value and sign of ΔEV.

Table 2

Analysis of Variance of Frequency of Optimal Response as a Function of $_{\Delta}EV$ and Sign of $_{\Delta}EV$ during Trial-Blocks 7 and 8

Source	df	MS	F
Between Ss	119		
$_{\Delta}EV$	2	747.5	5.26*
Sign (S)	1	333.5	2.31
$_{\Delta}EV$ x S	2	3.1	--
Ss/$_{\Delta}EV$ x S	114	142.3	--
Within Ss	120		
Blocks (B)	1	30.0	2.20
B x $_{\Delta}EV$	2	2.5	--
B x S	1	2.0	--
B x S x $_{\Delta}EV$	2	0.0	--
Ss x B/$_{\Delta}EV$ x S	114	13.6	

*$p < .01$

significant. Nor were any of the sources involving the last two blocks significant.

Gain and loss. Percentages of A_1 during Trials 301-400 were also analyzed as functions of gain and loss associated with A_1, without regard to ΔEV. Figure 3 presents the percentage of A_1 for each experimental group for Trials 301-400. Each point on the graph represents a different group. For example, the point represented by the abscissa value, 4, and the parameter value, -2, identifies the group (4,-2). As gain increased, percentages of occurrence of A_1 increased and as loss increased, percentages of occurrence of A_1 decreased.

Orthogonal polynomials for the spacing 1, 2, 4 were constructed according to the procedure of Robson (1959) and a trend analysis was performed on the frequencies of A_1 during Trials 301-400 (Table 3). Both gain and loss had significant linear ($p < .001$) and quatratic ($p < .01$) components. In addition, an increase in either gain or loss from one unit to two units had a greater effect on the percentage of A_1 than an increase from two to four units. This suggestion was supported by Duncan range tests (Edwards, 1960) performed on the mean A_1 frequencies of adjacent units of reinforcement ($p < .005$). The gain x loss interaction was not significant. Thus, the percentage of A_1 was a linear function of the gain and loss functions and both the gain and loss functions were negatively accelerated with large initial slopes.

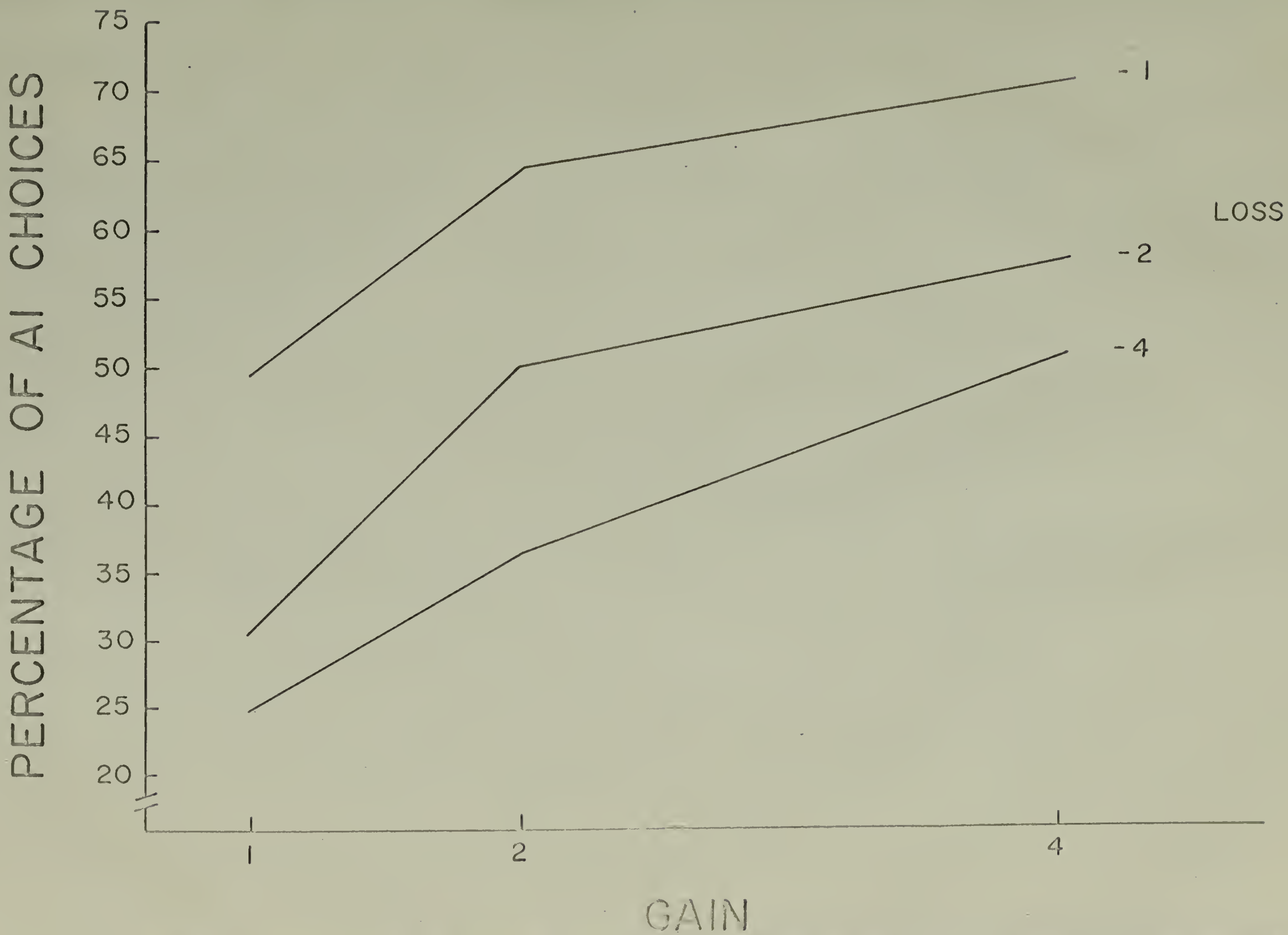

Figure 3. Percentage of Al choices during trials 301-400 as functions of amount of gain an d loss.

Table 3

Analysis of Variance of Frequency of A_1 Responses
as Functions of Gain and Loss
during Trials 301-400

Source	*df*	*MS*	*F*
Gain (G)	2	9783	39.93**
Linear	1	17606	71.86**
Quadratic	1	1960	8.00*
Loss (L)	2	8895	36.30**
Linear	1	15775	64.38**
Quadratic	1	2014	8.22**
G x L	4	157	.64
*S*s/G x L	171	245	

*$p < .01$
**$p < .001$

Sequential statistics. Figure 4 shows the means for each of the first-order conditional probabilities of an A_1 response through successive blocks of 50 trials. The means for all blocks for which data were available only on less than 19 Ss were omitted. All the omitted means are those for probabilities contingent on the non-optimal response. In some of the last five blocks, some Ss never made the non-optimal response and, thus, provided no data. To use the data of the remaining Ss in each group would bias a mean in favor of those who failed to use the optimal response.

The order of conditional probabilities in each experimental combination in Block 8 was $p(A_1|A_1E_1) > p(A_1|A_2E_1) > p(A_1|A_1E_2) > p(A_1|A_2E_2)$. When comparisons among the experimental combinations were made in Block 8, it was observed that each conditional probability increased as gain increased and decreased as loss increased.

Variance preferences. The preferences for risk were small and unsystematic for experimental combinations (1,-1), (2,-2), and (4,-4). In each group, A_1 and A_2 were chosen nearly equally as often. With regard to individuals, nine Ss in (2,-2) and six Ss in (4,-4) made less than 50 per cent A_1's in the last 100 trials.

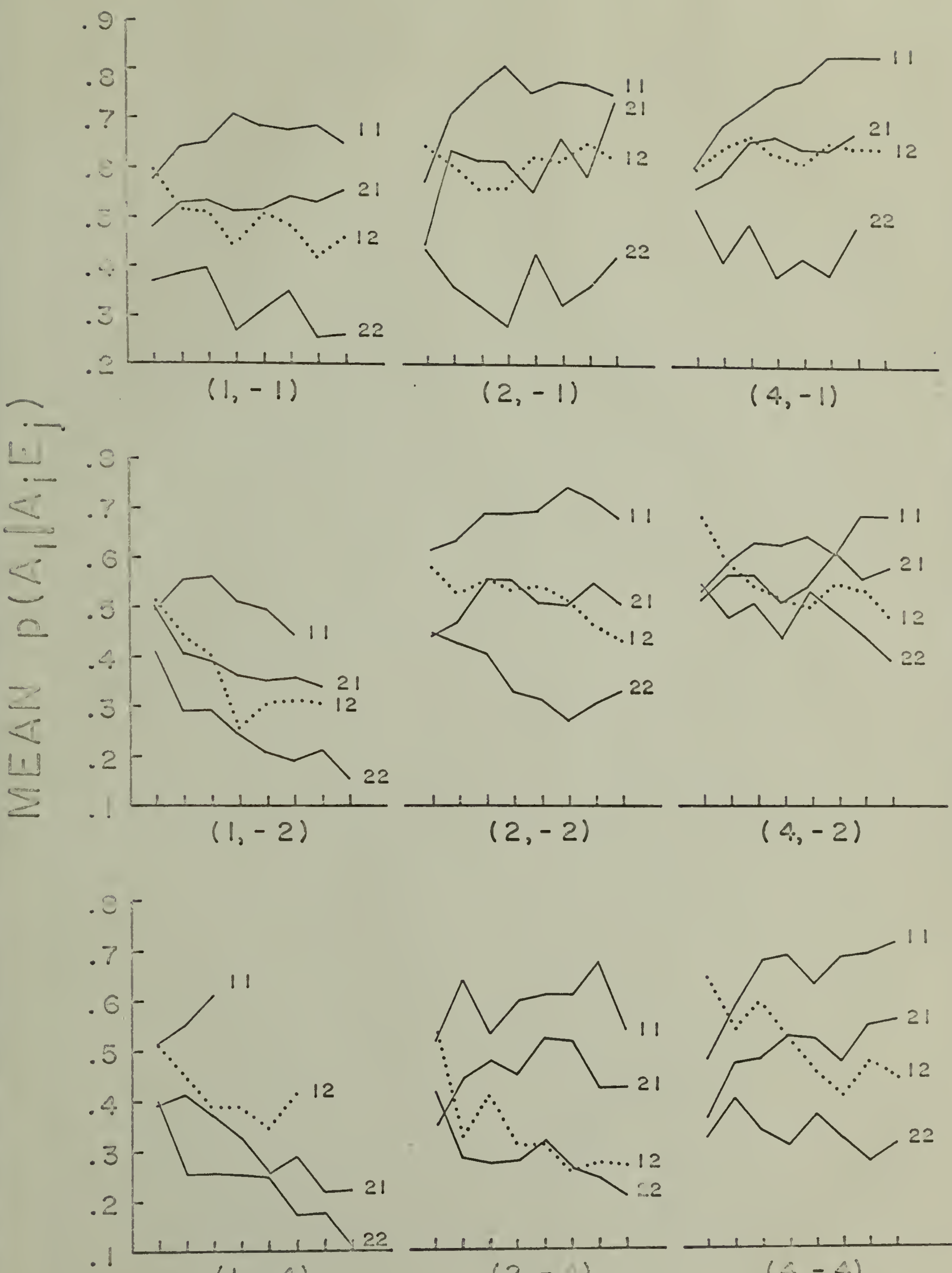

Figure 4. Means of first-order conditional probabilities of A1, $p(A_1|A_iE_j)$, i,j = 12, for each combination of gain and loss through successive blocks of 50 trials.

Discussion

With respect to percentage of A_1, the increase and decrease expected, respectively, for successively larger positive and negative ΔEV's did not occur. Instead, percentage A_1 increased in the order +1.0, +0.5, and +1.5, and decreased in the order -1.0, -0.5, and -1.5. The non-significant interaction of size of ΔEV and direction indicated parallel trends for positive and negative ΔEV's. The failure to obtain a monotonic relationship between choice of the optimal response and size of ΔEV suggests that ΔEV is of limited value as a single index for different combinations of π, gain, and loss.

The differences between $+\Delta EV$ and $-\Delta EV$ combinations of the same absolute value were small and nonsignificant. However, the slightly greater percentages of optimal responses for negative ΔEV games were in the same direction as Myers, Reilly and Taub's (1962) finding of a slightly greater effect on choice of loss than of equal-sized gain.

Percentages of choices of A_1 increased with amount of gain and decreased with amount of loss. Both functions were negatively accelerated and, as suggested by the nonsignificant interaction of gain and loss, the gain and loss functions combined linearly to affect percentages of A_1.

During all trials, percentages of A_1 were nearly the same for the three combinations of equal gain and loss. Variance of gain and loss for equal ΔEV's, therefore, did not have differential effects.

In each experimental combination A_1 was less likely to occur on n+1 when it was punished on n than when A_2 was punished on n. In addition, the greater the punishment, the smaller the probability of A_1 on n+1. The results do not agree with the finding of Suppes & Atkinson (1960) of initially greater $p(A_1 | A_1 E_2)$ than $p(A_1 | A_2 E_1)$ and equality at the end of 240 trials. The present data suggest that the data of Suppes and Atkinson which were puzzling when viewed as asymptotic results, were, in fact, not truly asymptotic. This indicates that it is necessary to run large numbers of trials (in excess of 400) in the two-choice situation in order to obtain stable data.

The results of the present study suggest that further study of EV concepts is not likely to be fruitful. However, two-choice behavior did exhibit orderly relationships with gain and loss and these variables appear to be worthy of additional exploration. Several aspects of the present study require further clarification. For example, the relationship between the effects of the arbitrarily chosen units of incentive and the effects of the conventional units of money should be investigated. It has been assumed that the effects of the two kinds of units are equal through

multiplication of a positive constant but this may not be true. Related to this problem is the problem of the effects of amounts of monetary incentive larger than those used in the present study. For example, choice behavior may change when a unit of reinforcement is worth 10¢ instead of 25¢. In addition, the effect on choice of varying Ss' initial stake should be studied. The variables of greatest interest are the frequencies of occurrence of E_1 and E_2. Unequal frequencies have been demonstrated to have large effects on choice (e.g., Myers, Reilly, and Taub, 1962). Detailed studies of unequal event frequency and differential reinforcement should be made.

Summary

The effects on two-choice behavior of varying the monetary gain and loss associated with a single response (A_1) while holding the reinforcement of the other (A_2) constant were investigated. Three levels each of gain and loss were varied factorially among nine experimental groups of 20 Ss each. The events, E_1 and E_2, predicted by the responses A_1 and A_2, respectively, occurred randomly and equally often in each 50-trial block of a 400 trial sequence.

Contrary to expectation, frequency of choice of A_1 did not increase with increases in the expected value of A_1, $[EV(A_1)]$, for all $EV(A_1)$. However, frequency of A_1 choice was an increasing negatively accelerated function of the amount of gain and a decreasing negatively accelerated function of the amount of loss associated with A_1. The absence of a significant gain x loss interaction suggested that frequency of A_1 choice was a linear function of the gain and loss functions. The results suggest that while EV notions are of limited predictive value, the parameters of gain and loss are worthy of further study.

The effects of reinforcement on the first-order conditional probabilities $p(A_{1,n+1} | A_{i,n}E_{j,n})$, where n is trial number and i, j=1, 2, were also investigated. In general, these probabilities were affected by reinforcement in a manner

similar to over-all frequency of A_1 choice. The peculiar superiority of the frequency of a response which follows punishment of that response over the frequency of a response which follows punishment of the alternate response, a result reported by other investigators, was not found asymptotically, in the present study. However, this superiority did occur initially.

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