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The Differential Effects of Stimulus Presentation During Error- and Success-Feedback Intervals in Concept Identification

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To test an hypothesis that information is processed better after successes in concept identification than after errors because of failure to remember the stimulus, 40 Ss were run in 16 simultaneous-discrimination problems. Blank trials were included to show S's hypothesis after each error. In group ES the positive member of the stimulus pair was presented during the feedback interval on all feedback trials. This was done only after errors in group E, only after successes in group S, and on no trials in group C. Ss' responses between errors were almost always consistent with exactly one hypothesis. Ss in groups E and ES were more locally consistent, more globally consistent and more likely to choose the correct hypothesis after errors than Ss in groups S and C, consistent with the idea that failures to process efficiently after errors are due to memory loss. Ss in all groups showed more global consistency than expected on the basis of random or just locally consistent sampling by Ss. Modifications of several models of concept identification were developed in the light of these results.

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Abstract

The Differential Effects of Stimulus Presentation During Error- and Success-Feedback Intervals in Concept Identification

Most viable theories of concept identification hold that the efficiency with which information from previous trials is processed is greater on successes than on errors. Levine has proposed that subjects process the information on each trial prior to actually responding and on the basis that their chosen response will be correct. On error trials the subject must reprocess the information from that trial on the basis of a possibly degraded memory of prior events. Levine's proposal suggests that memory loss for the stimulus during feedback on errors should be more damaging than such memory loss on successes. The effects of this memory loss were evaluated by presenting the stimulus, and thus attenuating memory loss, during the feedback interval on success or on errors. Forty college students with extensive pretraining were run in 16 simultaneous-discrimination problems with one of eight binary dimensions relevant. Each problem consisted of six feedback trials, each of which was followed by five blank trials on which no feedback was given. The subjects were divided into four groups of 10 subjects each. In group ES the positive member of the stimulus pair was presented during the feedback interval on all feedback trials. This manipulation was introduced only on error trials in group E, only on success trials in group S, and on no trials in group C. Subjects' responses between errors were almost always consistent with exactly one hypothesis. The blank-trials responses were used to determine this hypothesis after each error. Subjects in groups E and ES were more locally consistent, more globally consistent and more likely to choose the correct hypothesis after errors than subjects in groups S and C. Subjects in all groups showed more global consistency than could be accounted for by models which assume random or locally consistent hypothesis sampling. Modifications of several models were developed in the light of these results.

This study is concerned with some specific determinants of the differential effects of errors and successes in concept identification (CI). In conventional CI paradigms the information given in a sequence of trials does not depend on the sequence of responses on those trials. However, most viable theories of CI hold that subjects lose more information on errors than on successes. At one extreme, Restle (1962) proposes that the subject forms a set of hypotheses, the focus sample, after each error according to a random process that is independent of the preceding sequence of events. Hence, no information given prior to a particular error will influence behavior following that error. Trabasso and Bower (1968) in a slightly different version of the same theory suggest that the subjects sample only those hypotheses which are locally consistent, that is, consistent with the information given on that error trial. Therefore, after an error subjects retain the information from exactly one trial, that error trial.

Levine (1966, 1969) has proposed a system which allows for less severe information loss on errors than do either Restle's or Trabasso and Bower's theories. Levine assumes that subjects entertain a set of hypotheses or focus sample on each trial. Each subject begins a trial by choosing a response consistent with one member of the focus sample. Before actually making the response, the subject eliminates all members of the focus sample which are inconsistent with the chosen response (i.e. all hypotheses which would have dictated the opposite response). If the response is correct, the subject retains the revised focus sample until the next trial. If the subject receives error feedback, he attempts to retrieve the old focus sample and retests each member against the correct response. The efficiency with which this retesting is carried out determines the extent of information loss after errors. In general it is not necessary to require, as does Restle, that retesting after errors fails to preserve any information from past trials. Nor is it necessary to assume, as do Trabasso and Bower, that the retesting procedure preserves all the information from the error trial.

The empirical evidence on the effects of task variables in CI yields ample evidence that information loss after errors depends on experimental conditions. For example, practice may be an influential variable. Numerous studies with naive subjects (Bower and Trabasso, 1964; Trabasso and Bower, 1968) have demonstrated that errors are recurrent events, a result which supports the view of total information loss on errors. Studies by Levine (1963, 1966, 1969), however, indicate that practiced subjects retain a considerable amount of information after errors.

More direct evidence for the influences of practice and task variables on the detrimental effects of errors was obtained by White (1968). White found that if subjects were appropriately pretrained to process information about a sequence of stimuli, the introduction of a suboptimal intertrial interval (ITI) after errors had a deleterious effect on performance, whereas a suboptimal ITI after successes had no significant effect on performance. Further, in a control group given a simple memory pretraining task, as opposed to pretraining in information processing, these effects were significantly attenuated. Hence, it would seem that for practiced subjects the amount of time available for processing after errors is a significant determinant of the efficiency of the cognitive processing after errors. This result is consistent with Levine's conjecture that subjects engage in a good deal of cognitive processing after errors but not after successes.

The purpose of this study is to investigate the effect of memory loss during the process of retesting after errors suggested by Levine. It is reasonable to assume that memory loss for the stimulus after errors interferes with this retesting process, whereas memory loss for the stimulus on success trials should have no effect on performance. White's study can be interpreted in terms of such a memory loss effect. That is, on trials with a suboptimal ITI the onset of the stimulus on trial n + 1 might interfere with the subject's visual memory of the stimulus on trial n. This interference would not occur on trials followed by a long ITI. This type of evidence is indirect and is open to other interpretations such as that suggested above with regard to processing time after errors.

In order to investigate memory loss in a more direct way, memory for the stimulus can be allowed to decay naturally on some trials; on the remaining trials the stimulus could be presented during or after the feedback interval. Bourne, Guy, Dodd, and Juteson (1965) have shown that stimulus presentation during the ITI on all trials enhances performance. The theoretical framework proposed by Levine suggests that this enhancement should only be evident on error trials since access to the stimulus after feedback is only required on errors when retesting occurs.

This study is an empirical test of the hypothesis of differential effects of memory loss following errors and successes and involves four experimental conditions. The stimulus may be presented after errors in one condition (E), after successes in another condition (S), on all trials in a third condition (ES), and on no trials in the fourth condition (C). We would expect that conditions E and ES would be superior in performance to conditions S and C, but that conditions E and ES would perform equally well, as would conditions S and C. That is, stimulus presentation following error feedback should enhance performance, and stimulus presentation after success feedback should have no effect.

Method

The study was conducted within a paradigm developed by Levine (1966, 1969) for two category problems with one dimension relevant. There are three basic aspects of Levine's method. First, Levine uses a simultaneous discrimination task in which two complementary stimuli are presented and the subject is required to choose the one designated as correct or positive. This aspect of the paradigm is theoretically relevant since a positive instance is available to the subject on each trial. Levine proposes that the subject samples and tests hypotheses with reference to the positive member of the stimulus pair, a view which receives indirect support from several studies indicating the superiority of positive instances over negative instances (Freiberg and Tulving, 1961; Hovland and Weiss, 1953; Smoke, 1932).

A second aspect of Levine's method is his use of stimulus sequences which are controlled for information transmission. All stimuli are drawn from a set, called internally orthogonal (I-0), which is equal in size to the number of dimensions. In an I-0 set, each level of each dimension occurs exactly half the time with each level of every other dimension. Further exactly half of the dimensions change levels between any two stimuli in an I-0 set. If there are 2^k dimensions it is possible to find special subsets of an I-0 set which contain $k + 1$ members. These subsets, called I-0 subsets, have the property that each of the 2^{k+1} patterns of level changes are represented in the set. The stimuli on the first $k + 1$ trials of a CI problem consist of an I-0 subset. Hence it is possible to solve the problem in exactly $k + 1$ trials no matter what the relevant dimension is. Levine (1969) presents a more detailed description of the construction of stimulus sequences.

The third feature of Levine's method is the use of blank trials. A series of blank trials on which the subject is given no feedback is administered after each feedback trial. If the series of blank trials is properly constructed, and if the subject responds according to one hypothesis throughout the series, that hypothesis will be isomorphic to the sequence of responses on the series of blank trials. Specifically, if an I-O subset is included in the series of blank trials, the subject's response sequence will be a function of the pattern of level changes of the dimension on which his hypothesis is based. In practice each series of blank trials consisted of an I-O subset and one additional member of the parent I-O set. The purpose of the additional member was a check on the proposition that the subject uses only one hypothesis throughout the blank trial series.

A complete discussion of Levine's results with the blank-trials method may be found in Levine (1966, 1969). For our purposes it suffices to note three aspects of these results. First, Levine found that, for the most part, responses on blank trials seem to be dictated by one and only one hypothesis. In an eight-dimension problem about 91% of the obtained response sequences on blank trials were consistent with one hypothesis where only half of all possible response sequences were consistent with one hypothesis. Second, in about 95% of the cases the response on a feedback trial was the one dictated by the hypothesis evidenced on the preceding sequence of blank trials. Finally subjects appeared to retain the same hypothesis after informed successes about 94% of the time and to reject their hypotheses about 99% of the time after informed errors. From these three results we may infer that subjects select an hypothesis from the focus sample formed after an error, and that their responses are consistent with this hypothesis on all trials, blank and feedback, until another error occurs on some feedback trial.

<u>Subjects</u>

The subjects were 42 female students of the University of Michigan who had volunteered to serve in experiments for pay. The data from two subjects was discarded for failure to solve at least one of the first set of four practice problems.

Apparatus and Stimuli

The stimuli were presented on a CRT display console (Digital Equipment Corporation, Model 340). The diameter of the round screen was 33 cm. Responses were made by pressing one of two buttons below the screen and about 5 cm to the left and right of its center. The stimuli consisted of two complementary patterns which were formed by combining one of two values of each of four or eight dimensions. These dimensions and their values are given in Table 1, and a typical stimulus pair is shown in Figure 1.

TABLE 1

Dimensions and possible values

Dimension	Values 1.	2.
1. Letter	X	T
2. Size	large	small
3. Horizontal position	left	right
4. Vertical position	upper	lower
5. Central square	present	absent
Surrounding lines:		
6. Number	1	2
7. Orientation	horizontal	vertical
8. Shape	dashed	solid

Design

The subjects were randomly assigned to one of four groups with 10 subjects in a group. Subjects in group ES were shown the positive number of the stimulus pair during the feedback interval on all trials. Subjects in Group E and Group S saw the positive stimulus with feedback only after errors or after successes, respectively. The subjects in Group C never saw the positive

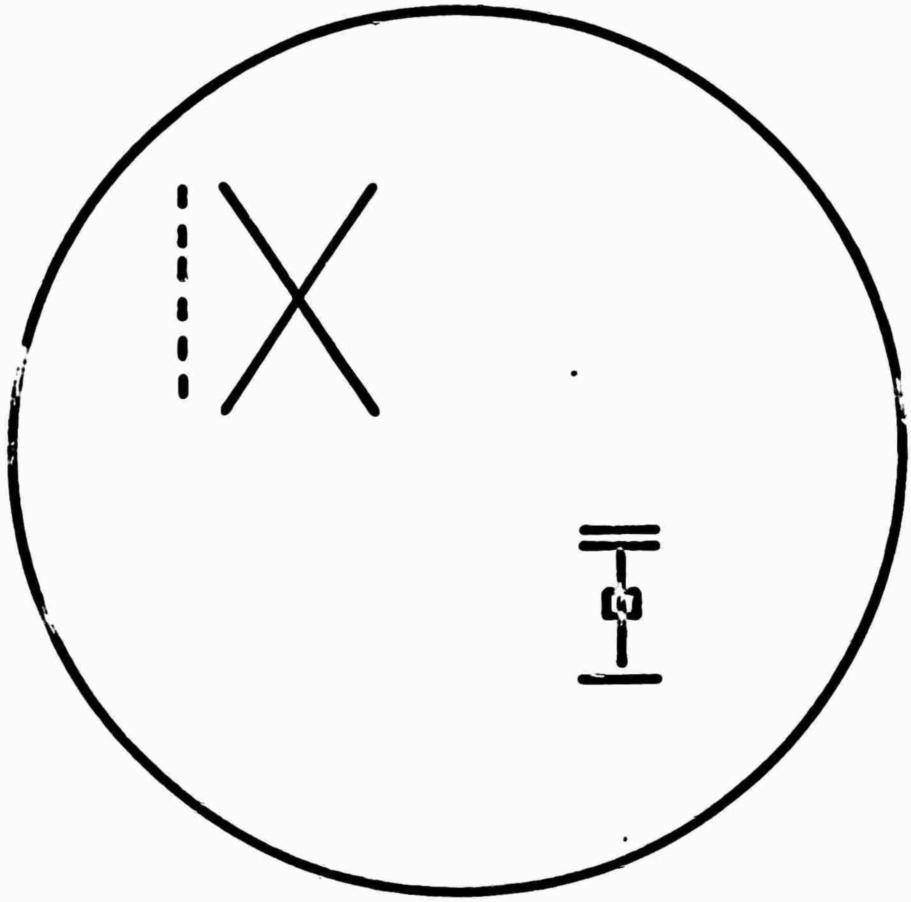

Figure 1. Typical stimulus display for eight-dimension problems.

stimulus during feedback. Hence, the design is a 2 X 2 factorial design. One factor, SPE, represents the effect of stimulus presentation with errors feedback and the other factor, SPS, respresents the effect of stimulus presentation with success feedback.

Procedure

Each subject received 12 practice problems followed by 16 training problems. All problems were identical for each subject and were given in a uniform order. The first four practice problems used four dimensions, and each problem consisted of eight feedback trials with no blank trials. The second set of four practice problems again used four dimensions, but each problem consisted of three feedback trials, each of which was followed by four blank trials. The final set of four practice problems used eight dimensions and each problem consisted of six feedback trials each followed by five blank trials. The subjects then proceeded without interruption to the 16 training problems.

The training problems each used eight dimensions and had six feedback trials each followed by a series of five blank trials. The stimuli for the feedback trials were drawn from one of four mutually exclusive I-0 sets and the blank-trials stimuli were drawn from a second of the four sets. Each consecutive four feedback stimuli formed an I-0 subset as did four of the five stimuli in each series of blank trials. Each of the 16 possible response assignments were used in one of the training problems.

Instructions to the subjects included an explanation of all dimensions and their possible values. The subjects were required to recite the possible values of all dimensions before the beginning of the first eight-dimension problem. The subjects were told that one member of each pair was classified as positive and that the other was negative and that only one dimension was relevant. They were instructed to press the button under the positive stimulus on each trial.

The subjects were paid one cent for each feedback trial which was answered correctly and eight cents for each errorless series of blank trials. These payoff contingencies were explained to the subject before the fifth practice problem along with the following instruction. "Each series of blank trials was especially constructed to tell whether or not you have solved the problem. The only way to get all four of a series of blank trials right is to use the correct solution on all four. Using any incorrect solution or using any mixture of solutions will cause at least one error in the set of four."

Each trial began with the presentation of a stimulus pair on the screen. On blank trials the word "BLANK" appeared on the screen directly below the stimulus pair. As soon as the subject responded, the display was removed from the screen for one second to allow for decay of the intensified points. Feedback was then displayed for a duration of two seconds. The feedback display consisted of the word "BLANK" displayed at the bottom of the screen on blank trials and either "RIGHT" or "WRONG" displayed in the same position on feedback trials. The positive member of the stimulus pair was displayed during the entire interval on appropriate trials and was accompanied by a small plus sign centered directly below it. The ITI lasted for one second.

Results

In this section we will consider the data from the 16 training problems. These data can be coded as a sequence of responses, R_n, on the six feedback trials and a sequence of response patterns, H_n, on the six series of blank trials. We will denote errors and successes on feedback trials by $R_n = E_n$ and $R_n = S_n$ respectively. Note that there are 32 possible response sequences on each series of blank trials. Sixteen of these sequences are consistent with one and only one admissable hypothesis; the remaining 16 sequences are not consistent with any admissable hypothesis. The occurrence of one of these inconsistent patterns will be denoted $H_n = I$. The occurrence of the correct sequence, that sequence with no errors, will be denoted $H_n = T$.

Before considering the effects of the experimental manipulations it is necessary to establish a replication of Levine's critical results with respect to the blank trials procedure. Recall that the proportion of times that $H_n \neq I$ is an indication of the extent to which the subjects use one and only one hypothesis on the n^{th} series of blank trials. Table 2 presents this proportion for each group across all trials.

TABLE 2

Consistency and Learning Rate Statistics

Statistics	Group C	Group S	Group E	Group ES
$P(H_n = I)$ (Inconsistent Response patterns)	.064	.041	.038	.055
$P(H_n \rightarrow R_{n+1} \mid H_n \neq I)$	.941	.945	.966	.968
$P(H_n = H_{n-1} \mid S_n, H_n \neq I, H_{n-1} \neq I)$	.895	.914	.949	.925
$P(H_n = H_{n-1} \mid E_n, H_n \neq I, H_{n-1} \neq I)$	.049	.051	.026	.012
$P(H_n = T \mid E_n, n \leq L)$ (learning rate)	.216	.210	.283	.313
$P(H_n \rightarrow s_n \mid n \leq L)$ (local consistency)	.893	.868	.975	.977

In view of the high rate of consistent responding on blank trials it seems safe to assume that all subjects are using one hypothesis throughout a series of blank trials, and that inconsistent patterns are due to random unintentional mistakes in responding.

We turn now to the stronger assumption that all responses between errors are determined by exactly one hypothesis. Apart from the inconsistency analysis presented above, there are two statistics which are relevant to to this conjecture. First R_{n+1} should be dictated by the same hypothesis which dictated H_{n+1} Table 2 gives the proportion of times that this event, denoted $H_n \rightarrow R_n$ occurred for each group. As in Levine's studies this proportion is quite high. Second, following successes H_n should be the same as H_{n-1}. That is, hypotheses should not change after successes. Table 2 shows that this proportion, $P(H_n = H_{n-1} | S_n)$, is also quite high, and that the proportion of times that subjects maintain hypotheses across errors, $P(H_n = H_{n-1} | E_n)$, is quite low. Naturally, inconsistent response patterns were excluded from these last three analyses.

Finally, in order to investigate the possibility of differences between groups on the four statistics discussed above, each subject was assigned four scores representing the first four statistics listed in Table 2. Four 2 X 2 (SPE X SPS) analyses of variance yielded no significant sources of variance for any of the four statistics.

In view of the above results, it is reasonable to establish a learning criterion of one errorless set of blank trials. We will let L denote the position of this series in the sequence of blank trial series. That is, H_L is the first errorless series of blank trials on a particular problem. We will say that $L > 6$ if no such series occurred. In establishing this criterion we are assuming that the small number of errors following trial L is due to unintentional response mistakes. Since the proportion of such mistakes appears to be uniform across groups, their exclusion from further analyses should have no effects on further analyses.

The major concern of this investigation is the difference in learning rate between groups. Recall that theoretical considerations suggest that the effect of SPE, presentation of the positive stimulus during error feedback, should have an effect on learning rate whereas SPS, presentation of the positive stimulus during success feedback, should have no effect on learning rate. The most obvious measure of learning rate is the probability of reaching criterion after an informed error, that is, $P(H_n = T \mid E_n, n \leq L)$. This proportion from each group is given in Table 2. In order to make a statistical decision about the differences between groups, each subject was assigned a score representing his individual learning rate, the proportion of precriterion errors followed by H_L. An analysis of variance on these scores indicated that the SPE effect was significant ($F(1,36) = 7.94, p < .01$); neither the SPS effect or the SPE X SPS interaction was significant ($F(1,36) < 1$ in both cases). These results support the conclusion that presentation of the positive stimulus with error feedback enhanced performance whereas presentation of the positive stimulus with success feedback does not affect the learning rate.

One possible source of the SPE effect is that of differences in local consistency between groups. Recall that local consistency is an hypothesis being consistent with the stimulus on the error trial on which it was sampled. This variable is important as there are two possible effects of memory loss for the stimulus after errors. First, the subject could choose a focus sample which is consistent with the dimensions which he remembers. In this case the effect of memory loss would be to limit the size of the focus sample without introducing significant decreases in the local consistency. Second, the subject could form a focus sample from dimensions that were forgotten or incorrectly remembered. In this case we would expect memory loss to produce significant decreases in the local consistency.

Local consistency is easily investigated in blank trials data. Each H_n can be classified as being locally consistent ($H_n \rightarrow s_n$) or locally inconsistent ($H_n \rightarrow e_n$) depending on whether the hypothesis corresponding to H_n would have dictated a success or an error respectively on feedback trial n. The proportion of locally consistent H_n's following errors is given in Table 2 for each group. An analysis of variance on the individual local consistency rates showed the effect of SPE to be significant ($F(1,36) = 42.46$, $p < .001$) and the effects of SPS and the SPE X SPS interaction to be not significant ($F(1,36) < 1$ in both cases). Hence we may assume that at least some of the detrimental effect of not presenting the positive stimulus after errors is due to an increased rate of locally inconsistent sampling.

The above analysis of local consistency suggests a way of looking at the data which is more relevant to the theoretical concerns of this study. Recall that the main area of interest is the extent to which behavior following an error reflects information presented prior to that error. The issue may be examined in the data by determining the extent to which H_n is consistent with information presented on trials 1, 2, ..., n. Each H_n following an error may be assigned a global consistency score, C_n, corresponding to the proportion of previous feedback trials on which the corresponding hypothesis would dictate a correct response. That is, $C_n = P(H_n \rightarrow s_k \mid E_n,\ k \leq n \leq L)$. Figure 2 presents the global consistency rates, C_n, across precriterion errors for each trial and group. The relative contributions of SPE and SPS to these global consistency scores is evident in this figure and is consistent with the results presented above.

The consistency analysis is also relevant to the two all-or-none models discussed in the introduction. Recall that Trabasso and Bower (1968) require random sampling with local consistency. The "local consistency" curve in Figure 2 is the expected value of C_n under this sampling scheme. If, as Restle (1962) proposes, the H_n were randomly sampled from the set of all possible hypotheses, global consistency should remain at chance level on all trials as is indicated by the "chance consistency" curve in Figure 2. The mean C_n for all groups is considerably higher than both theoretical curves, indicating that neither Restle nor Trabasso and Bower can account for the extent

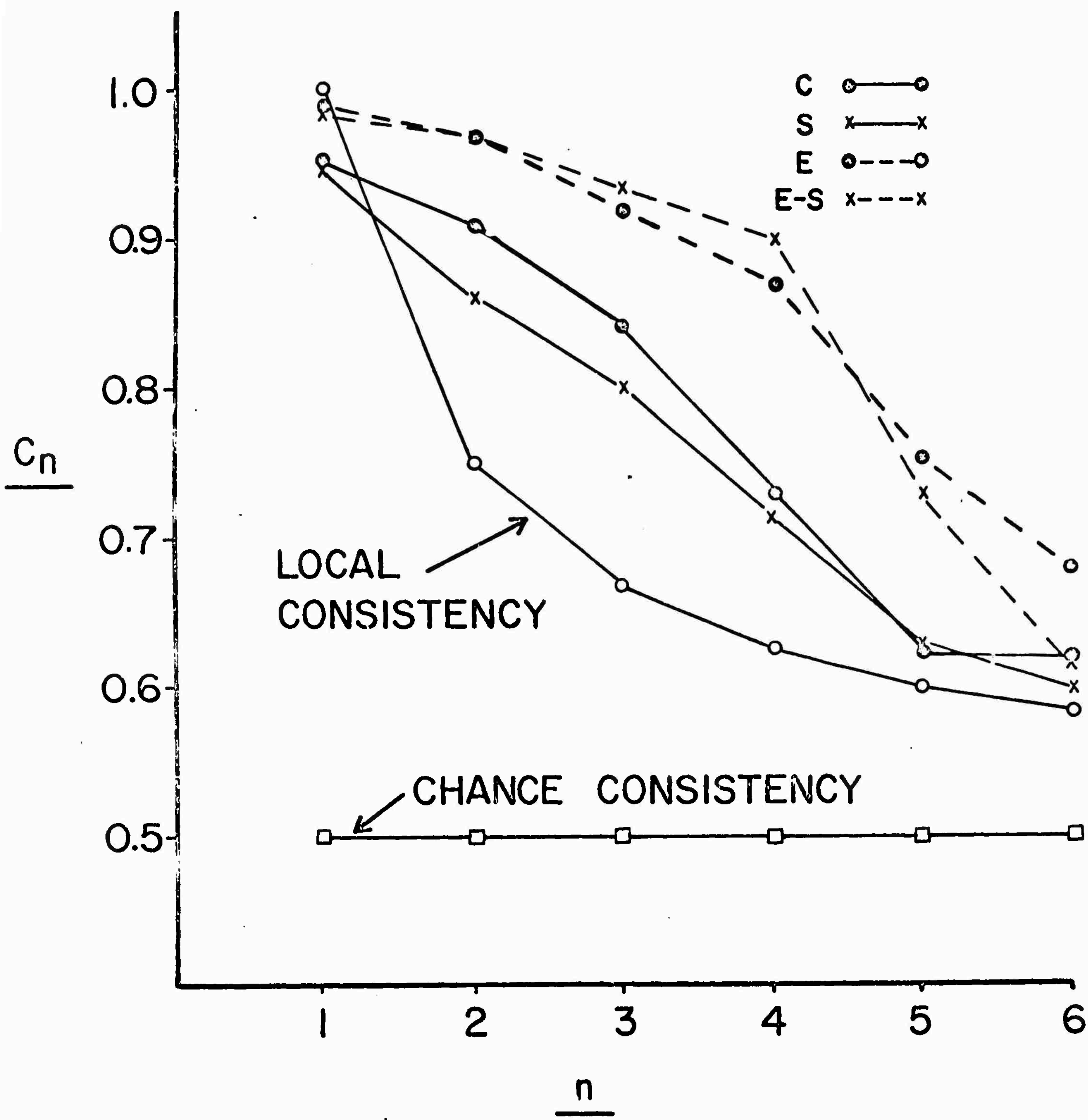

Figure 2. Global consistency. (C_n is the proportion of stimuli on Trials 1, 2, ..., n with which H_n is consistent, given an error on Trial n.)

to which pre-error information is reflected in post-error behavior. Figure 3 presents an even more conclusive contrast between the data and the local consistency model. In this figure C'_n represents the consistency of H_n's following precriterion errors with information given on trials prior to but not including feedback trial n. That is, $C'_n = P(H_n \rightarrow s_k \mid E_n, k < n \leq L)$. Since information given on trial n is not included in this score, C'_n does not reflect local consistency and the Trabasso-Bower model predicts that C'_n should not differ from the chance level of 0.5. This prediction is clearly disconfirmed in the data.

Finally, we turn to the analysis of consistency of an hypothesis with information given on previous error and success trials. Figure 4 presents the mean values of two conditional consistency scores. $C'_{E,n}$ is the proportion of previous error trials with which H_n is consistent, given a precriterion error on trial n. $C'_{s,n}$ is the proportion of previous success trials with which H_n is consistent, given a precriterion error in trial n. That is, $C'_{E,n} = P(H_n \rightarrow s_k \mid E_n, E_k, k < n \leq L)$ and $C'_{s,n} = P(H_n \rightarrow s_k \mid E_n, S_k, k < n \leq L)$. This figure indicates that the SPE effect acts mainly on the subject's ability to retain information from previous errors as would be expected.

Discussion

The results of this study may be summarized within the general theoretical framework proposed by Levine (1966, 1969). Levine proposes that CI consists of the trial-by-trial manipulation of a set of hypotheses, the focus sample. Each trial begins with a response choice dictated by one member of the focus sample. All hypotheses which are inconsistent with that choice are eliminated from the focus sample. If the response is correct, the subject retains the revised focus sample. If the chosen response is in error, the subject performs another revision, which is in general less efficient than the prefeedback

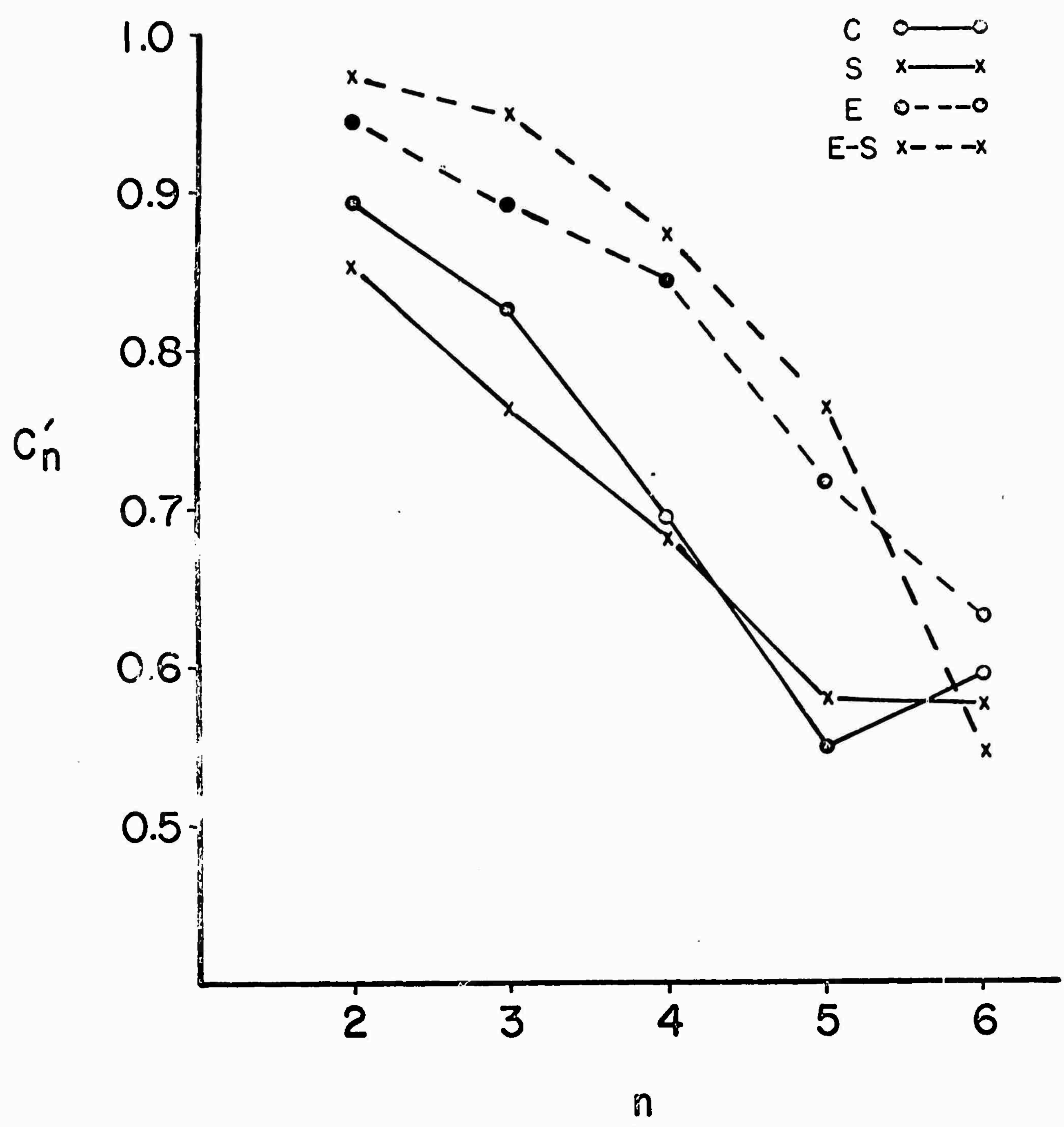

Figure 3. Global consistency excluding local consistency. (C'_n is the proportion of stimuli on Trials 1, 2, ..., n-1 with which H_n is consistent, given an error on Trial n.)

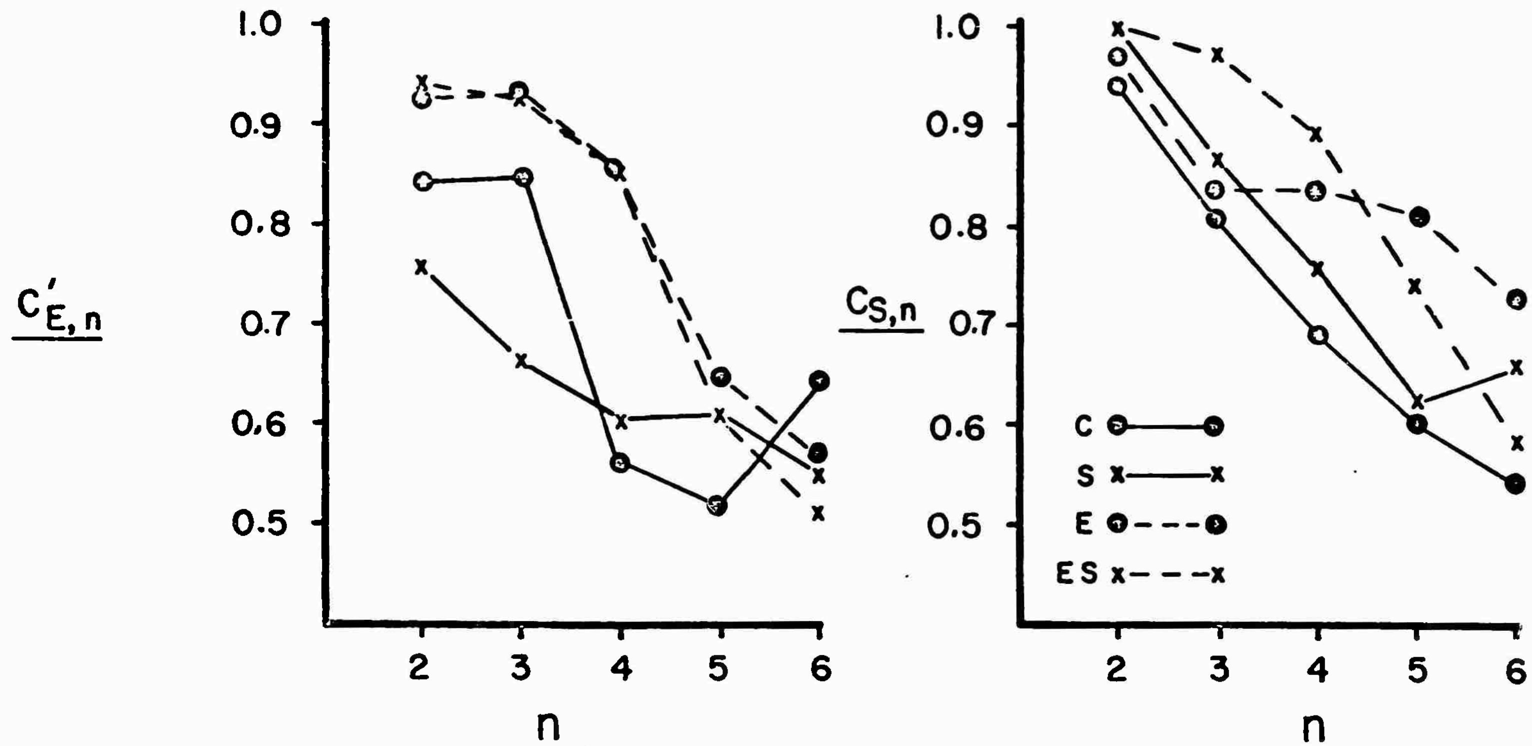

Figure 4. Consistency with previous error and success trials. ($C'_{E,n}$ is the proportion of stimuli on all Error Trials, 1, 2, ..., n-1 with which H_n is consistent, given an error on Trial n. $C'_{S,n}$ is the proportion of stimuli on all Success Trials 1, 2, ..., n-1 with which H_n is consistent, given an error on Trial n.)

revision. The deleterious effect of errors can therefore be attributed to factors which influence the revision of the focus sample after errors. The results of this study have two important implications for Levine's theory. First, the study indicates that presentation of the stimulus after error feedback will result in more efficient processing. Second, the study indicates that this type of manipulation is effective only after errors. These two results lend support to the idea that memory for the stimulus is an important determinant of the efficiency of the post-error revision process.

It is appropriate at this point then to consider possible theories of the processes occurring after errors in CI. Trabasso and Bower (1969) assume that the focus sample following an error constitutes a random sample of the hypotheses which are locally consistent. A modification of their theory to account for the effects of memory loss for the stimulus might require that subjects are locally consistent only to the extent to which they remember the stimulus, this extent being influenced by stimulus presentation after errors. This theory, however, must be rejected as global consistency rates, the consistency of present hypothesis with all previous trials, were much higher than would be expected from the Trabasso-Bower model.

Trabasso and Bower (1966) suggest another model which is somewhat more promising for these data. The authors again assume that the subjects randomly sample from a hypothesis set. However, they allow for the influence of past events in the constitution of this set. Specifically, they assume that the subject will not sample from those hypotheses which (a) are inconsistent with that error trial in conjunction with the trial previous to that error and (b) have been eliminated on this same basis as (a) for some constant number, k, of previous errors. In other words they assume that the subject is able to process the information from an error trial and the immediately preceeding trial, and that he retains the results of this processing for k errors afterward.

This theory could be easily modified to include imperfect memory for the stimulus on error trial. That is, the subject would remember the stimulus on error trial n with probability r and the stimulus of trial n-1 with probability 1 if S_{n-1} and with probability r' if E_{n-1}. Both r and r' would be affected by stimulus presentation after error feedback. The same retention rules as suggested above could apply for the revised model except that only those stimuli remembered on an error trial could be retained for k more errors.

This theory makes the strong prediction that the probability of solving following an initial error on trial n should be constant for all n = 2, 3,.... In the data from this study the probabilities of solving after an initial error on Trials 2, 3, and 4 are .158, .200 and .518 respectively for Groups C and S combined and .171, .366 and .583 respectively for Groups E and ES combined. This increasing monotonic relationship is also found by Levine (1969) and Richter (1965). As Chumbley (1969) has pointed out, the theory also predicts a monotonic increasing relationship between the probability of learning after an error and the number of previous errors. This prediction is again contrary to the results of Levine (1966, 1969) and Richter (1966).

Chumbley (1969) has developed a model of processing after errors which does not have some of the disadvantages of Trabasso and Bower's (1966, 1968) approach. The focus sample on trial n, F_n can be partitioned into two subsets, A_n, the set of hypotheses consistent with the chosen response and B_n, the set of hypotheses inconsistent with the chosen response. Chumbly assumes that the subject forms A_n prior to feedback. Then, if an error occurs, he attempts to recover B_n directly or F_n to form $B_n = F_n - A_n$. This recovery operation is successful with probability t. With probability 1-t, the subject starts over with a focus sample consisting of all possible hypotheses.

In order to relate Chumbley's theory to the results of this study we may again examine events following the first error. According to Chumbly's theory the global consistency rate of H_n should be constant across all n for the initial error on trial n. With probability t, H_n will be perfectly consistent with all previous trials and with probability 1-t, H_n will be consistent with a previous trial at only chance level. Hence global consistency following the first error will be given by the constant expression $t(1) + (1-t)(1/2)$ no matter what the trial number of the first error. Global consistency rates following initial errors in Trials 1, 2, 3 and 4 respectively were .950, .961, .873 and .798 for Groups C and S combined and were .984, .978, .931 and .886 for Groups E and ES combined. Global consistency after an initial error on trial n apparently decreases as n increases.

Analogous results can be seen in other published data. The probability of solving after an initial error on trial n is given by

$$I_n = t(1/c_n) + (1-t)(1/h)$$

where h is the total number of possible hypotheses and c_n is the number of hypotheses which are consistent with trials 1, 2, ..., n. The above equation may be solved for t;

$$t = c_n(hI_n - 1)/(h - c_n) = \hat{t}_n.$$

Hence $\hat{t}_n$ should be constant across trials. For Levine's (1969) study using eight dimensions, $c_1 = 8$, $c_2 = 4$, $c_3 = 2$, $c_4 = 1$ and $h = 16$. The values of $\hat{t}_1$, $\hat{t}_2$, $\hat{t}_3$ and $\hat{t}_4$ were .72, .55, .37 and .19 respectively. For Levine (1966), where a four-dimension problem was used, $c_1 = 4$, $c_3 = 1$ and $h = 8$. Here $\hat{t}_1$ was .78 and $\hat{t}_3$ was .37. Both cases are consistent with the results of the present study in that global consistency or amount of information retained appears to decrease across the initial success run.

This result can be accounted for in at least one of three ways. First, t, the probability of retaining the focus sample after an error could decrease with trials. This assumption seems a priori highly unlikely as the number of hypotheses in the focus sample decreases with trials resulting in a lighter burden on the subject's memory as the experiment proceeds. Second, it could be the case that subjects are not completely efficient on successes. That is, subjects may forget the focus sample after a success as well as after an error.

A third explanation for the apparent loss of efficiency over the initial success run is suggested by the results of the present study. When a subject loses his focus sample after an error he need not necessarily start over with the entire set of possible hypotheses. If he happens to remember the stimulus on that trial he may form a focus sample consisting only of the locally consistent hypotheses. In this case his global consistency rate would be a linear function of the global consistency rate of a randomly chosen locally consistent hypothesis. As the local-consistency curve in Figure 2 shows this consistency rate is a decreasing function of trials. Allowing for local consistency would therefore account for the decrease in consistency rate across the initial success run. It would also suggest a way of dealing with the main results of the present study. That is, the presentation of the stimulus with error feedback would enhance the probability that the subject would sample a locally consistent hypothesis on error trials where the focus sample is lost.

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