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Evidence for serial learning of multiple cues in concept identification.

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EVIDENCE FOR SERIAL LEARNING OF MULTIPLE CUES IN CONCEPT IDENTIFICATION

A Thesis Presented

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Abstract

The fact that some subjects learn both relevant dimensions in a relevant redundant cue concept identification problem has been offered in support of the use of a multiple look strategy by subjects. The present study shows that subjects are not necessarily using a multiple look strategy but rather may be using a one-look strategy to solve the problem. This was shown by asking one group of subjects to stop responding and state their solution to the problem when they felt that they had solved the problem. They then continued responding until they had completed a fairly large number of consecutive correct responses. At this point they were again quizzed on their solution. A total of 46 subjects were run in this group and of this number, 19 were identified as two cue learners at the end of the criterion run. Of these 19 two cue learners only 5 had learned about the two relevant cues at the solution trial. These results were compared with a group of subjects who solved the problem without being stopped. Of the 46 subjects run in this group 18 were classified as two cue learners at the end of the criterion run. The results are discussed in terms of supporting a one-look interpretation of concept identification learning.

Latencies showed that two cue learners took longer to respond than did one cue learners. Two possibilities explaining this result are considered.

Introduction

Psychologists have long been interested in how individuals learn to make a choice between objects in their environment and how they learn to use features of the objects as cues for adaptive behavior. Theorists such as Levine (1966, 1969, and 1970) and Trabasso & Bower (1968) have used multidimension concept identification problems in an attempt to answer these questions. In their experiments binary dimensions are normally used, examples of which are: color - red or blue, size - large or small. These dimensions are ordinarily incorporated into stimuli which are printed on cards or rear projected onto a screen, and the subject's task is to classify these stimuli according to two or more arbitrarily designated categories. As a measure of learning, the subjects are run to a criterion performance (such as 10 consecutive correct responses), after which they are quizzed on their rule of classification.

One line of research during the past 10 years has been an attempt to determine how a subject in a multidimensional concept identification problem with more than one potential solution solves the problem. Does the subject test just one dimension (or attribute of a dimension) on each trial or does he test a subset (greater than one) of all the possible dimensions on each trial? Two models have been given serious consideration in attempting to explain a subject's performance: a one-hypothesis-at-a-time model and a random-sample-of-hypotheses model.

It is from Restle's (1962) classic theoretical paper on concept identification that most of the assumptions for these models are derived. Restle presented and discussed three models in the selection of strategies of cue learning. The two extreme models, one strategy at a time and all strategies at once, were dismissed as not being intuitively feasible. The third model, a random-sample-of-strategies model, supposes that on the first trial and after each error the subject draws a random sample of all strategies. If the subject is correct, he takes a new independent sample from the strategies available.

Levine, a proponent of the random-sample-of-strategies model, defended his position in a paper (1970) in which he attempted to evaluate the single-hypothesis assumption, present an alternative, and marshall the evidence favoring this alternative. Levine devised a system of blank trial probes; that is, after feedback on trial one there were four trials without reinforcement, then a feedback trial and four more blank trials and so on. By use of very specific instructions, the universe of hypotheses from which the subject is sampling is finite and known to the experimenter, thus the use of blank trial probes in determining the average size of the hypothesis set from which the subject is sampling is possible. Using this procedure, Levine found that the size of the hypothesis set decreased from eight hypotheses at the start of the problem to approximately three hypotheses after the third feedback trial.

Latency data was also used as further evidence for this random-sample-of-strategies model. According to the single hypothesis assumptions the subject is in two states; he has an incorrect hypothesis and he makes correct responses by chance, or he has the correct hypothesis and he is consistently correct. The trial of last error (TLE) marks this transition point between the two states. Latencies should reflect this demarcation point. The one-trial-learning single hypothesis assumptions (Bower & Trabasso 1964) would predict that after the trial of last error latencies should be constant. Yet as Erikson, Zajkowski & Ehman (1966) pointed out, this prediction is not confirmed. Latencies continue to decrease for a few trials after the trial of last error before reaching their lower asymtote. Following this finding, Levine (1969), in a concept identification problem, had his subjects ring a bell when they felt that they had solved the problem. This identified what Levine called the 'solution trial' (ST). He predicted and confirmed that latencies from the trial of last error to the solution trial should decrease and that beyond the solution trial the latencies should be constant. This follows from the random-sample-of-strategies model which assumes that the trial of last error is that trial at which the subject first takes the correct hypothesis as his working hypothesis. During the next few trials (from the trial of last error to the solution trial), he is reducing his subset until none but the working hypothesis remains. Levine postulated that the subject samples a subset of hypotheses, taking one, the working hypothesis, and uses this as the basis for his response. The subject then uses the outcome as the basis for evaluating his subset. If the reasonable assumption is made that latency is a function of the number of hypotheses in the subset to be evaluated, there should be a decrease in latencies between the trial of last error and the solution trial. This is what Levine (1969) feels that he has confirmed.

Trabasso & Bower (1968), after acknowledging their debt to Restle, took this random-sample-of-strategies model and used it as their model of stimulus selection in learning. The aspects of their model that will be discussed in detail are the sampling schemes.

According to Trabasso & Bower, the subject in a concept identification problem alternately operates in a search and test mode. In the search mode the subject makes decisions about which dimensions (or which attribute of these dimensions) to select from the total and what classification to give to this subset. For instance, if the subject sees a large blue triangle (the opposite - a small red circle) and he responds A (versus B) and is wrong, he takes a fresh sample with replacement from the total. If correct, by using a system of rational consistency the subject would classify: Large - A, Blue - A, and Triangle - A. Conversely, Small would be classified B, Red - B, and Circle - B. The subject would have what Trabasso & Bower call a sample focus. The subject then switches to the test mode for the next presentation. If he responds correctly the hypotheses that dictated the response are retained whereas those that are not consistent with the response are eliminated. This alternation of search, sample, then test continues until the subject has errorless performance. Using Trabasso & Bower's terminology, the subject in a relevant redundant cue problem (RRC), takes a sample of size s, with replacement, selected from the total N according to the constant probability a_i. The a_i is the probability that the subject samples attribute i from the population of N attributes that he considers potential solutions. The probability of selecting the first relevant cue (in a two relevant redundant cue RRC problem) is a_1, the probability of selecting the second relevant cue is a_2 and the probability for all irrelevant cues is a_3, so that $a_1 + a_2 + a_3 = 1$. Thus at the end of a relevant redundant cue problem, we classify our subjects as having learned cue 1, cue 2 or both relevant cues and these solution types are labeled respectively P_1, P_2 and P_{12}. Therefore if the subject's solution focus contains both relevant cues the subject will learn both

(P_{12}), but if the solution focus contains only one of the relevant cues then the subject will learn just one (P_1 or P_2). They derived the expected proportion of solution types:

$$P_1 = \frac{a_1}{a_1 + a_2} (1 - a_2)^{s - 1}$$

$$P_2 = \frac{a_2}{a_1 + a_2} (1 - a_1)^{s - 1}$$

$$P_{12} = (P_1 + P_2) = 1 - \frac{a_1 (1 - a_2)^{s - 1} + a_2 (1 - a_1)^{s - 1}}{a_1 + a_2}$$

The important variables in these equations are a_1 and a_2 since the predicted values of P_1, P_2 and P_{12} depend on a_1 and a_2 and of course s. Trabasso & Bower estimate a_1 and a_2 from the learning rate of single cue control groups and use s as a free parameter to fit the observed values of P_1 and P_2. s could also be considered important, for if it is reified as a dependent variable, there are many things that could affect it. Trabasso & Bower (p. 211) list a few: exposure time of the stimuli, physical contiguity of relevant cues, coincidental tasks, age of the subject and encoding order. They predict that the number of two cue learners should decrease with shorter exposure time, that the closer the relevant cues are in the display the better the chance that they will be in the same s, and that coincidental tasks, such as counting backwards, would reduce the sample size. They also predict that increased separation between the relevant cues in a forced encoding order should decrease the probability of two cue learning. Finally, they predicted that younger children would have a smaller sample focus than adults.

The theory as presented has one major flaw. Trabasso & Bower (p. 178) demonstrated that in a relevant redundant cue problem using geometric figures, 50 overtraining trials (after a criterion run of 10 consecutive correct responses) significantly increased the number of two cue learners from 17 to 46 percent. This contradicts their sampling assumptions since their model does not allow for resampling after the solution focus has been obtained. To account for this discrepancy, they modified their model slightly and added a new probability, b, which is the probability that the focus hypothesis that is disconfirmed on a correct response trial may be replaced with probability b by another hypothesis (i.e., a cue with locally consistent response assignment). In their previous model, b, would have equaled 0. The modified model assumes that b does not equal 0 and this allows for continued testing of new hypotheses after the subject has already learned and is responding on the basis of a dominant correct hypothesis. Thus if b equals 0, the model will show no new learning after a criterion run, but with their modification if b equals 1 the subject will eventually learn one or more relevant redundant cues after the trial of last error.

They added one other variable to their modified model and this variable, h, is the probability that the second relevant cue is selected from the pool when a disconfirmed hypothesis is replaced on a trial. By proper choice of b and h the proportion of two cue solvers should increase significantly with the length of the criterion run. Thus their modified model permits a way to account for an increase in two cue solvers with overtraining. Their model also allows for some learning in a 'blocking' experiment, in which a formerly irrelevant cue becomes relevant following an initial run.

As can be inferred from the foregoing discussion the random-sample-of-strategies model would be severely undermined by a demonstration that subjects were using a single hypothesis on a trial rather than a subset of hypotheses. The results of a small pilot study run by the present writer will now be discussed and an attempt will be made to utilize these results to point out one possible weakness in the focus sample assumptions. The study was a concept identification problem with two relevant and redundant cues and two irrelevant cues. One group of subjects was run to a criterion of 15 consecutive correct responses. The second group stopped themselves when they felt that they had solved the problem (the solution trial). A total of 9 subjects were run in each group. In the group which stopped themselves at the solution trial only one of the subjects learned about both relevant dimensions. Whereas, in the group run to a criterion 6 of the subjects learned about both of the relevant dimensions. Using a Fishers exact test (two tailed), the results were significant ($p = .04$), indicating that subjects are predominantly learning the relevant cues serially.

The pilot study was run to answer a question about two cue learning: when is the second cue in a relevant redundant cue concept identification problem learned? Is it before the solution trial or after the solution trial? This pilot study suggests that it is predominantly learned after the solution trial. There were, however, a number of possible shortcomings in this pilot study. The solution trial group was not run to the same 15 consecutive correct response criterion as the criterion group. If this had been done, the number of two cue learners in both groups could have been compared. If the solution trial procedure has no effect on redundant cue learning, the number should be about the same. Also a questionnaire was used to determine which of the relevant cues the subjects had learned. This is felt to be a weaker method than using the actual dimensions on slides, because with a questionnaire the subject has to introspectively reconstruct the dimensions. With all due consideration for the possible methodological shortcomings of the pilot study, a full scale investigation was undertaken.

Method

<u>Subjects.</u> A total of 92 subjects, who had never before been in a concept identification experiment, were run. The data from 4 subjects was not used because they were unable to solve the problem. Subjects were taken from various psychology courses and were given course credit for their participation in the experiment. The subjects were randomly assigned to the experimental and control groups.

<u>Apparatus and stimuli.</u> Slides were rear projected on a translucent (frosted glass) 12 in. X 10 in. screen using a Kodak model RA 960 carousel projector. Placed on the lens of the projector was a Gerbrands model G1165 shutter apparatus. Latencies were taken using a Hunter Kloc Kounter model 120A and these latencies were manually recorded. The equipment was semi-automated and trials proceeded as follows:

1) The experimenter set the reinforcement switch and dialed up the next slide. He then pressed a switch which simultaneously reset the Kounter, opened the shutter, and restarted the Kounter.
2) When the subject responded, the shutter closed and the Kounter stopped. If the subject was correct a reinforcement light in front of the subject went on.
3) The experimenter recorded the latency and the subject's response.
4) The sequence began again and when the experimenter reset the reinforcement switch this turned out the reinforcement light.

The following dimensions were placed on slides for rear projection onto the screen:

Insert Figure 1 About Here

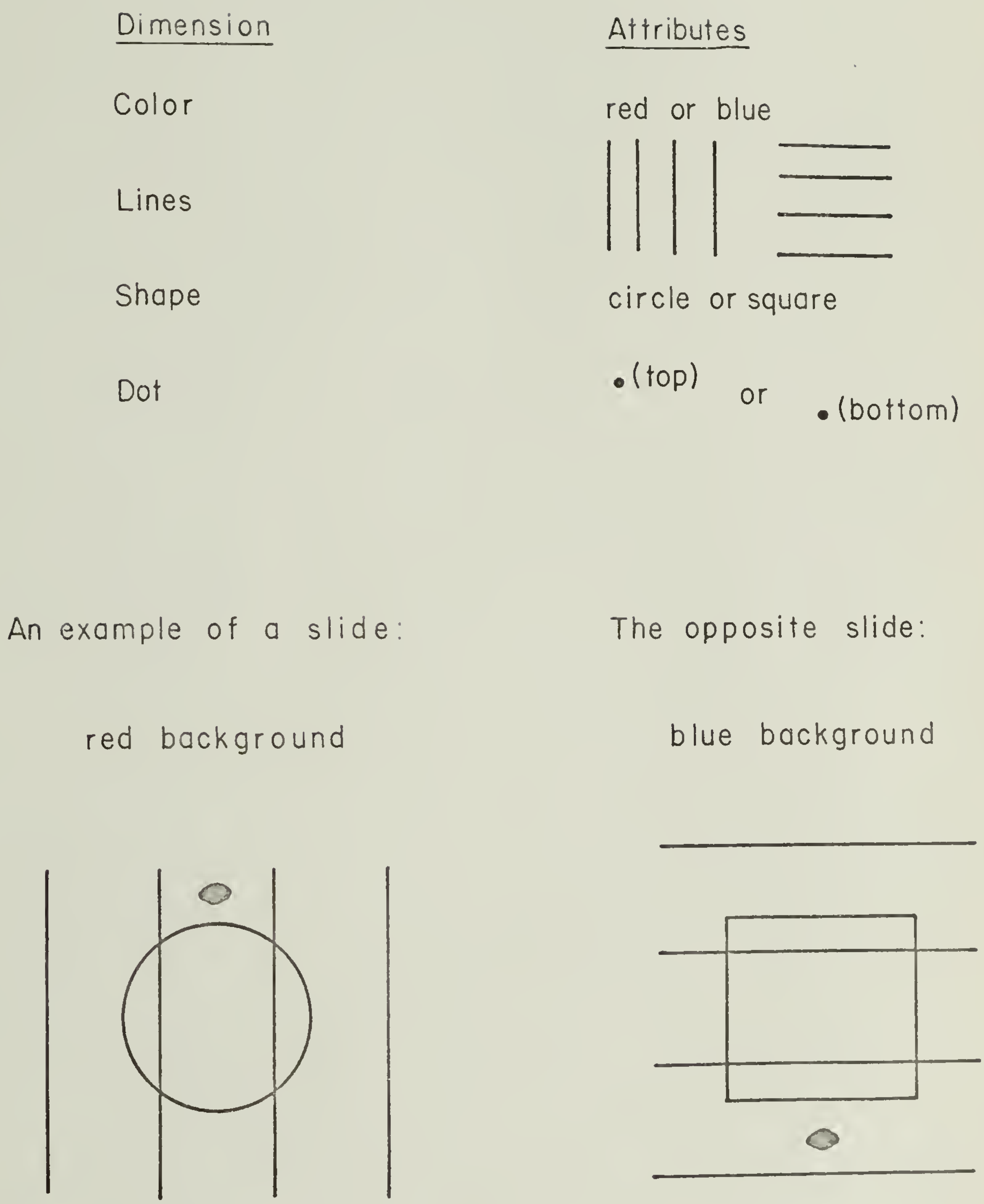

FIG. I. SLIDE DIMENSIONS AND TWO POSSIBLE SLIDES

With four binary dimensions there were 16 possible slides. There were also slides of single attributes (i.e., just a circle) for use in testing the subject's system of classification.

Procedure. All subjects were given a concept identification problem with two relevant and redundant dimensions and two irrelevant dimensions. The following four combinations of relevant dimensions were randomly selected: dot and lines, color and shape, dot and shape, and color and lines. There were five different orders of presentation of the slides for each combination. The subject was seated in front of the screen and a three button console which was used to signify his system of classification for each slide. The left button was tagged ALPHA, the right button was tagged BETA and the center button was untagged. One group of subjects (CR group) was run to a criterion of 15 consecutive correct responses. The second group (ST group) was instructed to press the center button when they felt that they had solved the problem. They stated their solution and then continued on to the criterion of 15 consecutive correct responses, including the correct trials before they pressed the center button. The instructions given to the subject are reprinted in Appendix A.

The ST group, following the solution trial and at the end of the criterion run, and the CR group, at the end of the criterion run, were asked to fill out the following questionnaire:

When were you supposed to press the:

a) ALPHA button ______________________

b) BETA button ______________________

After completion of the questionnaire, both groups were asked to classify the slides with only one dimension present at a time. They were instructed to classify these slides using the same system of classification that they used in solving the original problem. If they were not sure of the system of classification for a particular slide or if either button would be correct, they then were instructed to press the center button.

Latencies were taken and recorded on all trials, except the trials on which the single dimension slides were classified. They were recorded from the time that the shutter opened until the subject responded.

Results

The major dependent variable of the present study, the number of one and two cue learners at criterion and at the solution trial, is shown in Table 1.

Insert Table 1 About Here

There was no significant difference between the number of one and two cue learners in the CR and ST groups at criterion. There is a significant difference, however, between the number of one and two cue learners in the ST group at criterion and at the solution trial ($\chi^2(1) = 11.40$, $p < .001$). There is also a significant difference between the number of one and two cue learners in the CR group at criterion and the ST group at the solution trial (χ^2 (1) = 9.78, $p < .005$).

The mean total errors, mean trial of last error and the solution trial of the various groups are shown in Table 2. The overall mean for

Insert Table 2 About Here

total errors was 2.63 and for the trial of last error 5.20 trials. Individual protocols for the subjects' total errors, trial of last error and solution trial are shown in Appendix B.

An analysis of variance was computed to compare total errors for one and two cue learners in the CR and ST groups. The Analysis of Variance Table is shown in Appendix C and a graph of the results is presented in Figure 2. There are no significant main effects but there is a significant

TABLE 1

Number of one and two cue learners.

		one cue learners	two cue learners
at criterion	CR group	28	18
	ST group	27	19
at solution trial	ST group	41	5

TABLE 2

Mean total errors, trial of last error and solution trial for various groups.

	CR group			ST group				
	one cue learners	two cue learners	total	one cue learners	two cue learners	total	one cue total	two cue total
Total errors	2.55	3.05	2.76	3.51	1.00	2.51	3.02	2.06
Trial of last error	5.11	6.05	5.64	6.66	1.78	4.76	6.02	3.97
Solution trial*				5.40	4.94	5.22	5.40	4.94

* Trials after the trial of last error

Insert Figure 2 About Here

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interaction ($F = 6.48$; df = 1.86; $p < .025$) between solution type and groups. The rapid learning of the two cue solvers in the ST group, appears to account for the interaction. Scheffe's multiple comparison method was used to test all possible contrasts (see Myers, 1972). Of the six possible contrasts the only one significant was the one between the one and two cue learners in the ST group.

A similar analysis with the trial of last error leads to the same results. There are no main effects but the interaction is significant ($F = 6.12$; df = 1.86; $p < .025$). A test of all possible contrasts found only one to be significant and as with total errors that was between the one and two cue learners in the ST group. This interaction is shown in Figure 3.

Insert Figure 3 About Here

The subjects' written classification of the relevant dimensions at the end of the criterion run was compared to the single dimension classification at the end of the criterion run. The correspondence between the two is shown in Table 3. The subject was classified as a one or two cue learner by his statement of which dimensions he learned and he was also classified as a one or two cue learner by his classification of the single dimension slides.

Insert Table 3 About Here

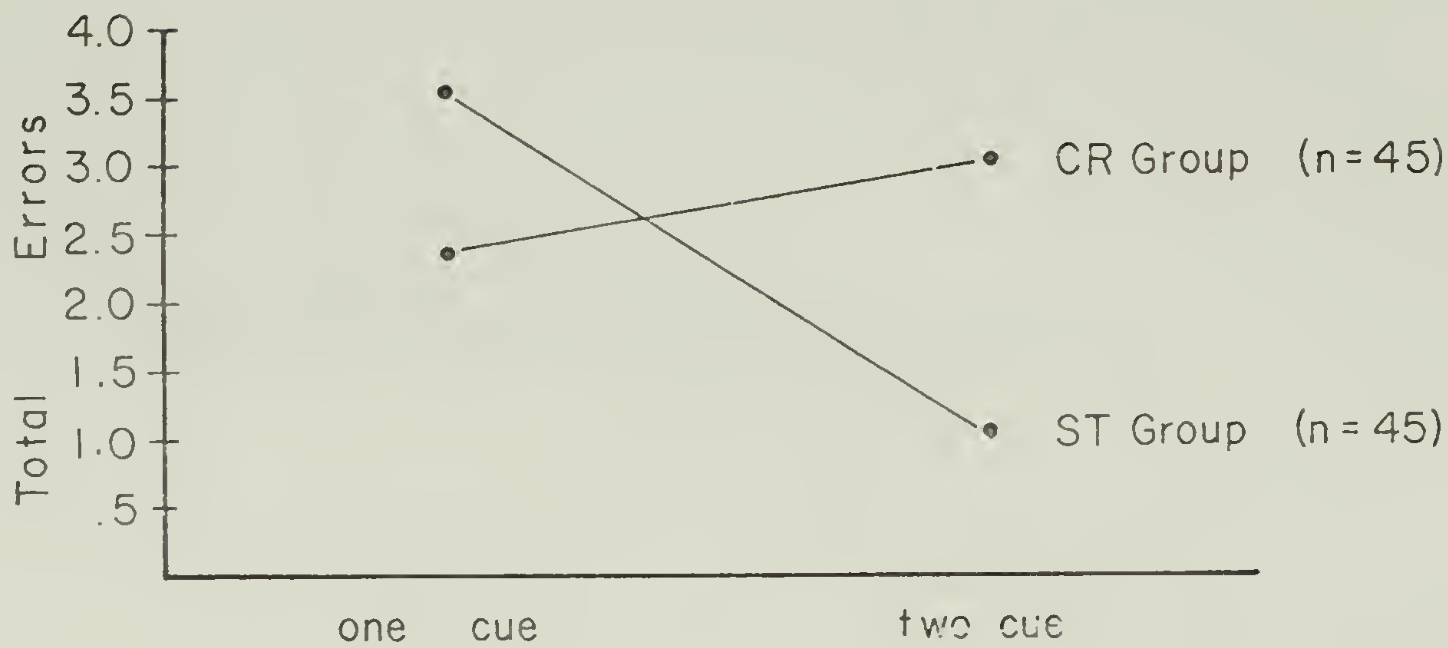

FIG. 2. TOTAL ERRORS IN THE CR AND ST GROUPS FOR ONE AND TWO CUE LEARNERS.

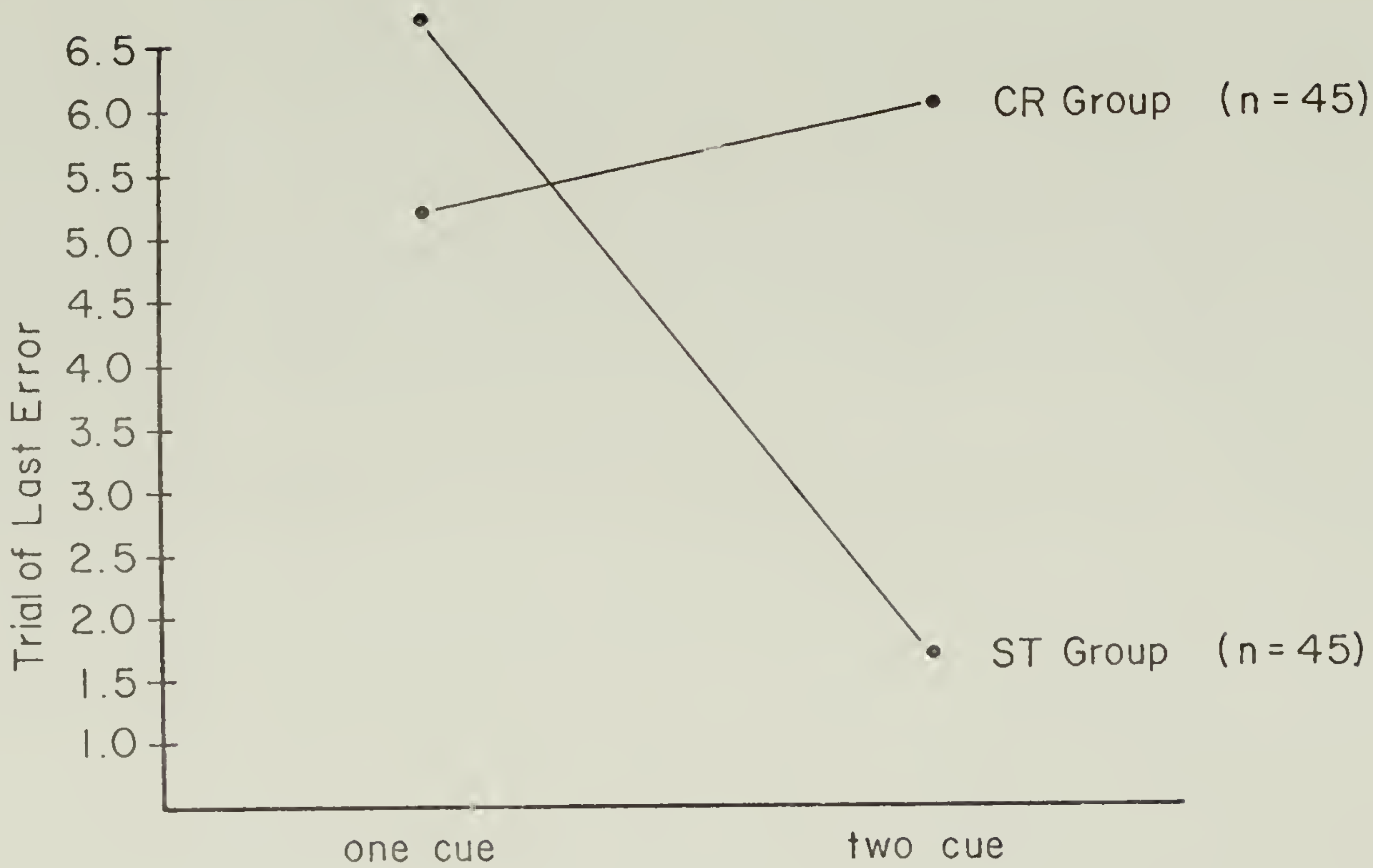

FIG. 3. TRIAL OF LAST ERROR IN THE CR AND ST GROUPS FOR ONE AND TWO CUE LEARNERS.

TABLE 3

Agreement between written classification and slide classification of cues by the subjects.

		Written classification	
		one cue	two cue
Slide classification	one cue	27 Ss CR group 22 Ss ST group	2 Ss CR group
	two cue	1 S CR group 5 Ss ST group	16 Ss CR group 19 Ss ST group

Using the subjects' classification of the single slides as the criterion for designating subjects as two cue learners, a χ^2 was computed to determine if there was a significant difference between the methods of classification at criterion. The χ^2 was not significant.

Latencies recorded during the criterion run were submitted to an analysis of variance in a 2 (groups) X 2 (solution type) X 15 (trials of the criterion run) factorial design. The Analysis of Variance Table is presented in Appendix E.

Figure 4 shows the mean latencies for one and two cue learners, illustrating the significant main effect of solution type and the decline in latencies over the trials of the criterion run. On all the graphs are plotted the mean latencies of the trial of last error and three trials prior. These trials are plotted to give an indication of the trend of the pre-criterion run latencies.

Insert Figure 4 About Here

Figure 5 shows the interaction between groups over the trials of the criterion run.

Insert Figure 5 About Here

Mean pre-solution latencies computed for each subject were submitted to a 2 (groups) X 2 (solution type) factorial analysis of variance. The results show only a main effect of solution type, although the main effect of groups does approach significance. Appendix F is the Analysis of Variance Table for this design and the effect is shown in Figure 6.

Insert Figure 6 About Here

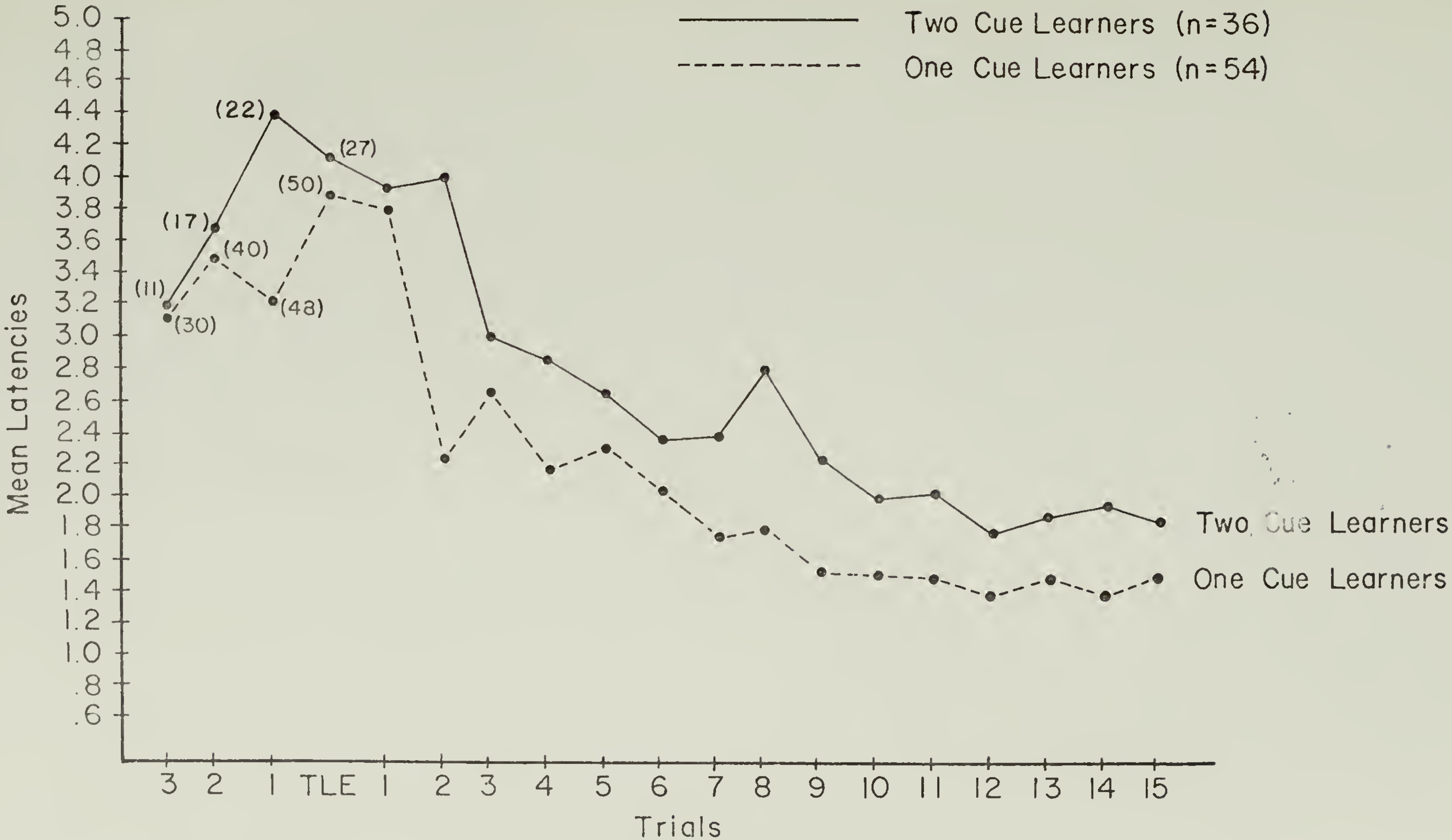

FIG. 4. MEAN LATENCIES FOR ONE AND TWO CUE LEARNERS
(NOTE: n FOR EACH POINT IS AS ABOVE EXCEPT WHERE INDICATED)

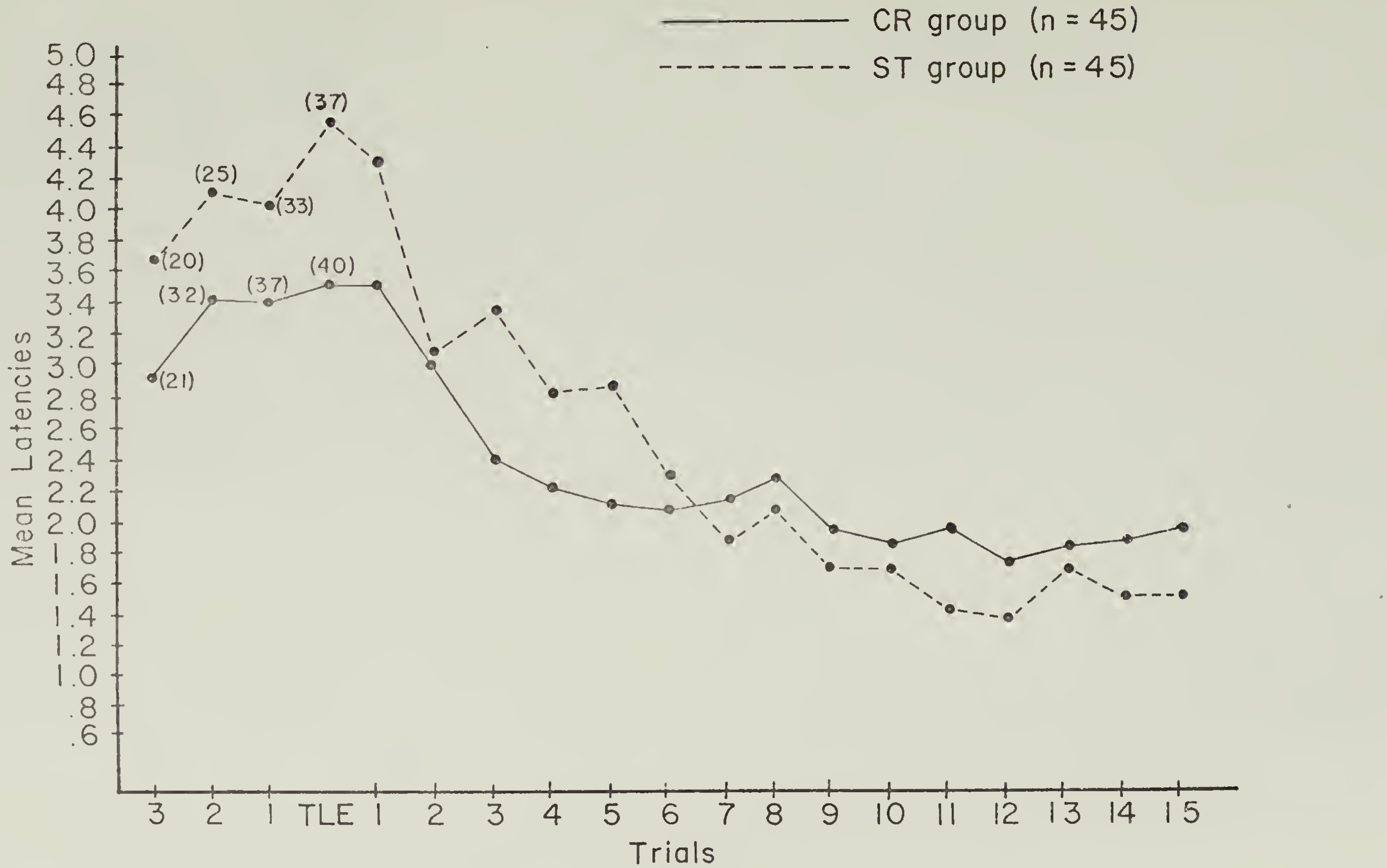

FIG. 5. MEAN LATENCIES FOR THE ST AND CR GROUPS
(NOTE: n FOR EACH POINT IS AS ABOVE EXCEPT WHERE INDICATED)

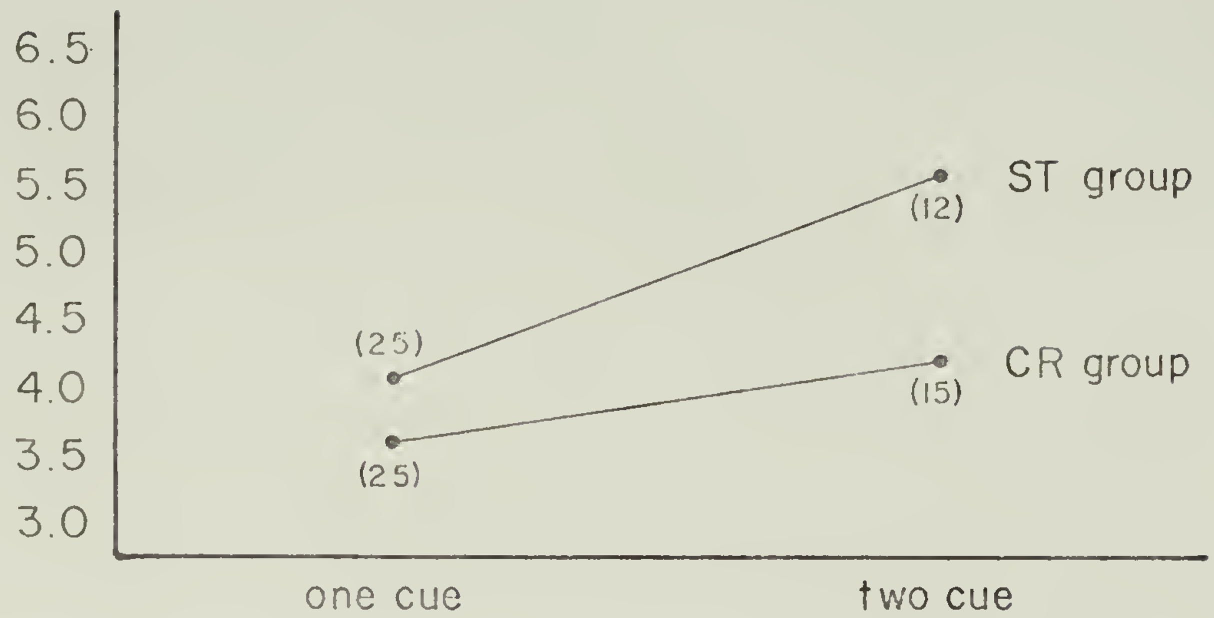

FIG. 6. PRE-SOLUTION LATENCIES IN THE CR AND ST GROUPS FOR ONE AND TWO CUE LEARNERS. (NOTE: NUMBERS IN PARENTHESIS REPRESENT n FOR EACH POINT).

Discussion

On the basis of the random-sample-of-strategies model put forth by Trabasso & Bower (1968) a significant difference would not be expected between the number of two cue learners in the ST group at criterion and the ST group at the solution trial. A significant difference also would not be expected between the number of two cue learners in the ST group at the solution trial and the CR group at criterion. However, both of these differences are obtained.

Though Trabasso & Bower do not talk in terms of a solution trial, Levine (1969), who coined the term, defines it as the trial at which the subject has exhausted his subset of irrelevant hypotheses. At that time he has solved the problem. If both relevant dimensions were in the subset at the solution trial the subject would have learned about both. In the present experiment, fourteen of the nineteen subjects in the ST group who were two cue learners at the end of the criterion run, learned (or noticed) the second relevant dimension after the solution trial. If the subjects were using a focus subset sampling strategy, one would not expect the difference that has been obtained.

It might be argued that stopping the subject at the solution trial and having him state his solution (though he is not told of the correctness or incorrectness of his solution) in some way disrupts his strategy. The main results do not seem to bear this out. There is no significant difference between the number of two cue learners in the ST and CR groups at criterion. This, of course, is using the written classification of the subjects as the standard in identifying subjects as two cue learners. Using the data from the subjects' classification of the single slides to designate them as one or two cue learners still does not result in a significant difference between the two groups.

One result that may weaken the argument that there is no significant difference between the two groups is the significant interaction in errors of solution type and group. There seems to be no reasonable explanation for this interaction and most likely it is simply sampling error. If, in a replication of this procedure the same results are obtained, it could raise doubts about the validity of the methodology used in this and Levine's (1969) experiment.

The overall results for total errors and trial of last error for the two groups do not suggest that having the subject stop and state his solution in any way increases the likelihood of his becoming a two cue learner. There is no significant difference in total errors and trial of last error between the two groups and as previously mentioned there is no significant difference between the overall one and two cue learners at the end of the criterion run.

This experiment, which is an attempt to test the validity of the subset sampling assumptions, has produced results incompatible with these assumptions. Applying the same results to the all-strategies-at-a-time model similarly shows it to be inadequate. One alternative is the one-strategy-at-a-time model.

The results seem to require this interpretation. Yet, the all-or-none one-look model of Bower & Trabasso (1964) and the one-look attentional model elaborated by Zeamon & House (1963) cannot account for these data.

In fact, Trabasso & Bower (1968) developed their multiple look model because they felt that their one-look model could not explain two cue learning. Yet the results of this experiment require a one-look interpretation.

By making a small extension of Zeamon & House's model, Shepp, Kemler & Anderson (1972) have shown that a one-look model can predict and account for two cue learning. More importantly for one-look interpretations, Kemler & Anderson (1972) have shown that a one-look model can predict most of the data that Trabasso & Bower (1968) have presented to support their multiple model. The Kemler and Anderson models are all-or-none one-look models; that is, learning, both attentional and instrumental, for a particular dimension is completed in a single trial. With this assumption and the fact that the Zeamon & House model does not require the subject to attend to the same dimension on each trial it is possible for a one-look model to predict two cue learning. The ability of a one-look interpretation to account for two cue learning makes it possible to fit the results of this study into a one-strategy-at-a-time model.

A second key finding of this study is that two cue learners take longer to respond than one cue learners. This result is shown in Figure 4. The results are especially interesting because two cue learners are consistently slower, that is, even prior to the trial of last error two cue learners are taking longer to respond. It might be argued that two cue learners are using a multiple look strategy and one cue learners are using a one look strategy, but the main results of the study suggest this interpretation is wrong, in that two cue learners tend to learn about each cue one at a time.

In this study there is only one result which seems to give an indication of what two cue learners are doing with the extra time that they take to respond. These data are in Figure 7 which shows the two cue learners in the ST group broken into two sub-groups and compared with the one cue learners in the ST group. Prior to trial 9 of the criterion run

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Insert Figure 7 About Here

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there is no definite trend in the data but after this trial there appears to be some trend. The subjects who had learned about both relevant dimensions by the solution trial are taking consistently longer to respond than both the one cue learners and the two cue learners who had learned about only one of the relevant dimensions by the solution trial. The difference in latencies between the two sub-groups was not significant but it is possible to speculate that the subjects who had learned about both relevant dimensions by the solution trial were being controlled by both relevant dimensions. By this it is meant that they were not responding until they had searched for and 'found' both relevant dimensions. On the other hand, those who had learned about only one of the relevant dimensions by the solution were being controlled by only one of the relevant dimensions. That is, they responded when they had searched for and 'found' only one of the relevant dimensions and presumedly this would be the relevant dimension that they had stated as their solution at the solution trial. Thus it seem plausible to theorize that stopping the subjects at the solution trial and having them state their solution seems to have affected the subjects' performance. It may be that the dimension the subjects state as

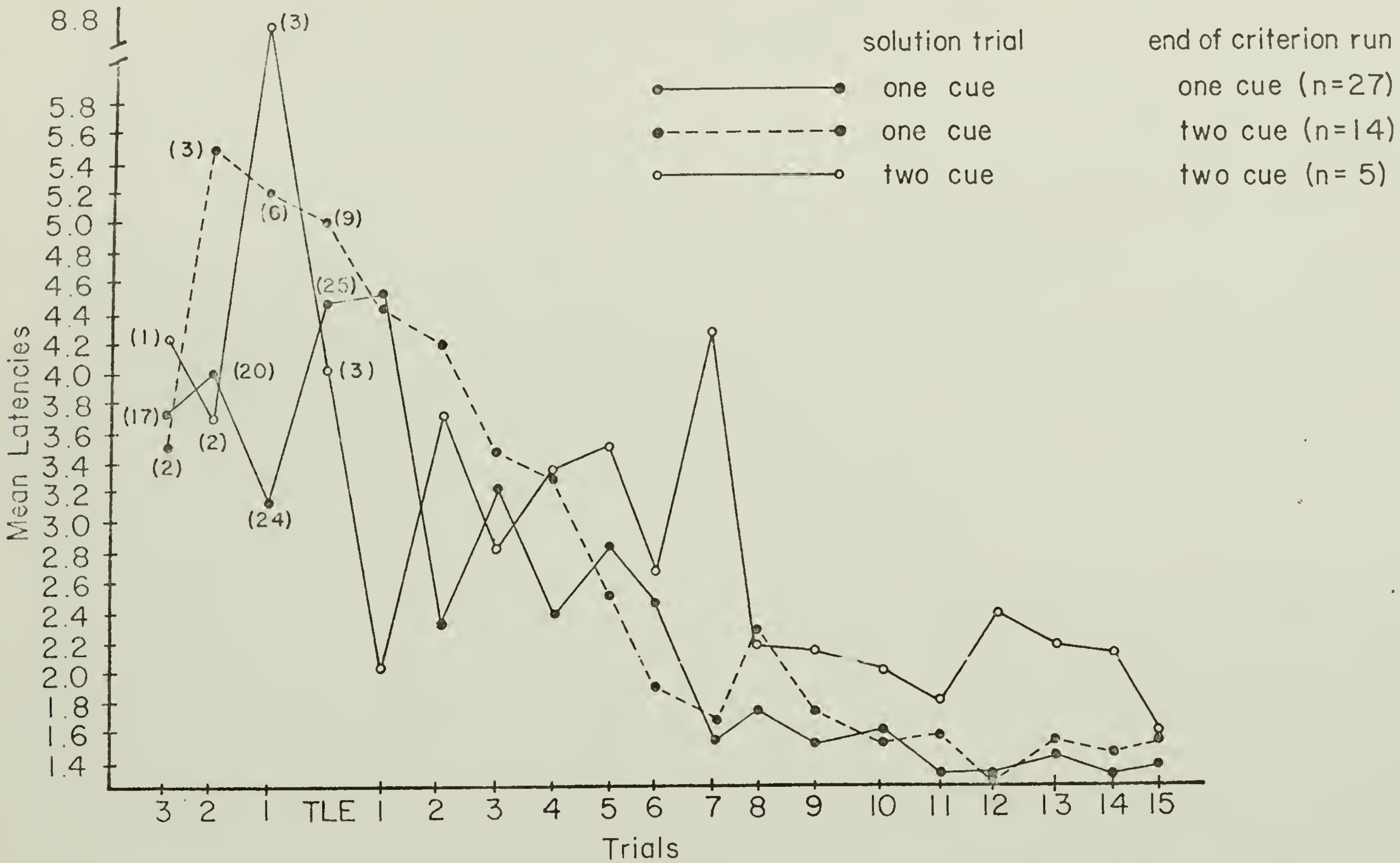

FIG. 7. MEAN LATENCIES IN THE ST GROUP FOR ONE CUE LEARNERS, TWO CUE LEARNERS AT CRITERION AND SOLUTION TRIAL, AND ONE CUE LEARNERS AT SOLUTION TRIAL BUT TWO CUE AT CRITERION. (NOTE: n FOR EACH POINT IS AS ABOVE EXCEPT WHERE NOTED.)

their solution to the problem thus become controlling dimensions and are reflected in the length of their latencies.

A second interpretation is that individual differences are operating here in that two cue learners are simply different than one cue learners and this is reflected in their latencies. There, of course, are no data in this study to support this speculation. A very simple study would be needed to confirm or disconfirm this interpretation. The independent variable would be the amount of time that the subject could look at the slide. If two cue learners are two cue learners simply because they take more time to look at the slide, and thus have more time to notice the second relevant dimension, then the group that had the longest amount of time to look at the slides should have the largest number of two cue learners. If in fact the difference in response latencies is more a symptom than a cause of individual differences between one and two cue learners, there should be very little difference in the number of two cue learners in the different groups.

A second significant difference in latencies, the decline over the trials of the criterion run (Figure 4) was expected from what Levine (1969) and Erikson et al. (1966) had previously found. This is a consistent finding in concept identification studies. Levine explains this decline in latencies from the trial of last error to the solution trial in terms of the subset sampling assumption. From the trial of last error to the solution trial the subject is reducing the size of his subset and the smaller the subset the faster the latency. At the solution trial the subject, by definition, has solved the problem and thus his latencies have reached their lower asymtote. Levine argues that if the subject were using a one-strategy-at-a-time model his latencies should be at their lower asymtote at the trial of last error. This is not necessarily true. If one makes the likely assumption that the subject at the trial of last error, though only sampling one dimension, is not completely confident of his solution, one can explain this latency decline within the framework of a one-look model. The subject becomes more and more confident as he tests his solution on trials subsequent to the trial of last error and his increasing confidence is manifested in shorter latencies. Finally, at the solution trial when the subject is completely confident of his solution his latencies level out at their lower asymtote.

If this interpretation is to be taken seriously some device or process would have to be postulated to explain why increasing confidence results in shorter response time. Though Falmagne (1970) does not consider such a device, she does give this interpretation to latency decline in her hypothesis model for concept identification. She says that it is natural to postulate that the latency of a response is inversely related to the strength of the current hypothesis. She goes on to say that the decrease in latencies during a sequence of correct responses (for example from the TLE to the ST) would result from the increment in the strength of that hypothesis under positive reinforcement.

The last significant result, the interaction between groups and trials of the criterion run is difficult to interpret except post-hoc. The cross over occurs at approximately trial 6 of the criterion run at which time the ST group responds more rapidly. Since the average solution trial is trial 5, it seems probable that the subjects in the ST group are more confident after stating their solution and thus respond a bit faster than the subjects in the CR group. Though the subject is not informed of the correctness of his solution, simply stating it and not being told that he is wrong may make the subject feel that he does have the correct solution and he thus responds faster. There appears to be no other readily available interpretation for this interaction.

The results of the present study point to a one-look strategy as the strategy used by a substantial number of the subjects in the experiment. Most of the results of the study confirm this interpretation. The one conflicting result is the data of the ST group two cue learners. They are solving the problem significantly faster (fewer errors and earlier trial of last error) than the other three groups in the problem. This may simply be a sampling error and a replication of the procedure will answer that question. If it is not sampling error, then it weakens the assumption that there is no difference in the solution strategy of the ST and CR groups. If there is a difference: if the ST group two cue learners are using a different strategy or if stopping the subject at the solution trial (or simply knowing he is going to be stopped) changes a subject's strategy, then the major finding of this study is put in doubt.

The longer latencies of two cue learners is a novel finding in concept identification research. No one has specifically made this comparison. More studies are needed to determine the generality of this finding and if it is confirmed then studies are needed to ascertain why two cue learners take longer to respond.

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Appendix A

Instructions given to both ST and CR groups:

This is an experiment in concept identification. With the data compiled from your participation in this experiment, we hope to be able to more fully understand how people acquire and utilize information about the way that their environment is organized.

On each trial of the experiment a slide will appear on the screen. You must decide whether you think the slide is an ALPHA or a BETA on the basis of the characteristics of the slide. For example, it could be a circle or a square (show slides 1 and 2) or it could be red or blue (show slides 3 and 4) or it could have vertical or horizontal lines (show slides 5 and 6) and finally it could have a dot at the top or at the bottom (show slides 7 and 8). The completed slides that you will be seeing will look like this one (show slide 9) which is red with a square with vertical lines and the dot is at the top. Whereas, this slide (show slide 10) is blue with a circle with horizontal lines and the dot is at the bottom. Thus as you can see there are a number of different combinations of characteristics for each slide. Are there any questions on the characteristics of the slides?

As mentioned, on each trial of the experiment a slide will appear on the screen. On the basis of the characteristics of the slide you are to classify each slide as an ALPHA or BETA. Notice near the extreme left on your console is a button labeled ALPHA and that near the extreme right is a button labeled BETA. You are to indicate your decision about whether the slide is an ALPHA or a BETA by pressing the appropriate button. When you have made your choice the slide will go off and if you were correct in your classification then the light above the screen will come on. If the light does not come on then you will know that you were incorrect. After a few seconds the light will go off and after a few more seconds a new slide will appear and you are to continue the same procedure. Are there any questions about the procedure?

Continuation of instructions for CR group only:

Disregard the center button since it does not have any relevance to this experiment. When you have made a fairly large number of consecutive correct responses, the experimenter will signal the end of the problem. You will then be given further instructions. Are there any questions? Begin when you see the first slide.

Continuation of instructions for ST group only:

When you feel that you have solved the problem, that is, when you know the system of classification for the ALPHA's and BETA's press the center button. At that time you will be asked your system of classification. You will then be given some more trials until you have satisfied a criterion of a fairly large number of consecutive correct responses. At that time the experimenter will signify the end of the problem. You will then be given further instructions. Are there any questions? Remember, when you feel that you have solved the problem press the center button. Begin when the first slide appears.

Further instructions for both groups after the criterion run:

I will now be presenting slides with the same dimensions but with only one dimension present at a time and I would like you to classify them using the same system of classification that you used in solving the original problem. That system is still good in classifying these slides. If you're not sure of the classification or if either button would be correct then press the center button. The light above the screen will not be used during these trials. Are there any questions? Begin when you see the first slide.

Appendix B

B-1 Subjects protocol for TE, TLE and ST for one and two cue learners in the ST group . . . .

B-2 Subjects protocol for TE and TLE for one and two cue learners in the CR group . . . .

B-1 Subjects protocol for TE, TLE and ST for one and two cue learners in the ST group.

	One Cue Learners			Two Cue Learners		
Subject	TE	TLE	ST*	TE	TLE	ST*
1	2	3	4	0	0	5
2	3	7	5	1	2	4
3	12	18	5	2	3	6
4	3	7	5	4	6	5
5	4	10	2	0	0	4
6	1	2	3	0	0	5
7	3	5	5	2	3	5
8	4	8	7	2	4	6
9	6	11	3	0	0	5
10	2	4	5	1	2	4
11	2	3	9	1	1	4
12	2	8	10	1	1	4
13	1	2	5	0	0	4
14	1	1	5	1	1	7
15	7	10	6	0	0	4
16	1	3	5	1	2	4
17	1	5	5	0	0	4
18	2	2	6	1	2	5
19	1	2	7	1	7	8
20	2	6	5			
21	4	8	10			
22	11	21	5			
23	0	0	7			
24	7	11	5			
25	11	18	4			
26	2	5	5			
27	0	0	5			

* ST is expressed in terms of the number of trials after the TLE

B-2 Subjects protocol for TE and TLE for one and two cue learners in the CR group.

One Cue Learners

Subject	TE	TLE
1	3	8
2	1	2
3	1	6
4	0	0
5	7	19
6	0	0
7	5	17
8	2	3
9	1	3
10	2	3
11	2	3
12	1	2
13	4	7
14	[illegible]	3
15	2	2
16	1	3
17	1	3
18	0	0
19	2	4
20	4	6
21	2	7
22	1	2
23	5	9
24	5	9
25	8	12
26	5	10
27	2	4
28	1	1

Two Cue Learners

TE	TLE
1	1
0	0
11	20
1	3
7	13
2	6
1	3
8	16
1	11
3	4
11	18
2	2
0	0
2	3
2	5
0	0
1	1
3	3

Appendix C

Analysis of Variance for a 2 X 2 factorial design for total errors.

A (two levels) = CR and ST groups

B (two levels) = one and two cue learners

SV	df	SS	MS	F	
Total	89	725.9			
A	1	1.34	1.34	.17	Not Significant
B	1	21.99	21.99	2.89	Not Significant
AB	1	49.20	49.20	6.48	$p < .025$
S/AB	86	653.37	7.59		

Appendix D

Analysis of Variance for a 2 X 2 factorial design for trial of last error.

A (two levels) = CR and ST groups

B (two levels) = one and two cue learners

SV	df	SS	MS	F	
Total	89	2444.1			
A	1	20.53	20.53	.81	Not Significant
B	1	95.41	95.41	3.77	Not Significant
AB	1	154.78	154.78	6.12	$p < .025$
S/AB	86	2173.48	25.27		

Appendix E

Analysis of Variance for a 2 X 2 X 15 factorial design for the latency data

A (two levels) = CR and ST groups

B (two levels) = one and two cue learners

C (fifteen levels) = trials of the criterion run

SV	df	SS	MS	F	
Total	1349	4661.07			
Between S	89	1604.17			
A	1	5.64	5.64	.36	Not Significant
B	1	137.36	137.36	8.88	$p < .005$
AB	1	16.47	16.47	1.06	Not Significant
S/AB	86	1330.27	15.47		
Within S	1260	3056.90			
C	14	583.49	41.68	21.48	$p < .001$
AC	14	64.05	4.57	2.36	$p < .005$
BC	14	44.14	3.15	1.62	Not Significant
ABC	14	26.34	1.88	.97	Not Significant
SC/AB	1204	2338.47	1.94		

Appendix F

Analysis of Variance for a 2 X 2 factorial design for pre-criterion latencies.

A (two levels) = CR and ST groups

B (two levels) = one and two cue learners

SV	df	SS	MS	F	
Total	73	276.99			
A	1	11.16	11.16	3.23	Not Significant
B	1	20.48	20.48	5.93	$p < .01$
AB	1	3.31	3.31	.95	Not Significant
S/AB	70	242.04	3.45		