The scale values of the adjectives in Table 1 should be equal, if they are measured on a ratio scale. Although the values are slightly different, the correlation between the two sets of scale values was .99, indicating a very strong relationship. The observed similarities between the two sets of scale values is highly respectable when one considers the complexity of the ratings involving negative-frequency adverbs (i.e., a combination such as *never kind* means something similar to *always cruel*).

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On the Learning of Morphological Rules: An Experimental Analogy

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Three experiments were conducted using modifications of a paradigm used by Esper (1925). Using the study-test procedure, *Ss* learned 16 paired associates in which the stimuli were 2-digit numbers and the responses were 2-letter pairs. Each single digit was associated with a letter to form a four-by-four matrix of 2-digit 2-letter stimulus-response pairs. Sixteen college *Ss* were presented 12 of the 16 pairs (Exp. I); 12 of the 16 pairs plus 4 irregular pairs (Exp. II); or 12 of the 16 pairs plus 2 irregular pairs (Exp. III), and were tested with the 16 stimuli in all cases. The irregular pairs were presented three times as often (Exp. II) or twice as often (Exp. III) as the regular pairs.

It was observed that the omitted pairs were learned quickly after the regularities of the presented pairs were learned; the irregular pairs were learned more rapidly than the regular pairs, and errors on the irregular pairs took the form of overgeneralization of the regular responses. It was assumed that the experimental conditions were analogous to the learning of verb inflection by children and the results were remarkably similar to the behavior of young children acquiring the morphological rules of verb inflection.

One of the many puzzling phenomena observed in children's acquisition of the English language is the manner in which verbs are inflected for past tense. Ervin (1964) has reported some data which confirm the less systematic observations of others that, after an initial period when no inflection is used, the irregular, or strong verbs, are correctly inflected for past tense. Subsequently, the child acquires the regularized form of the past tense and overgeneralizes the regular form to the irregular verbs. Thus, the child is first observed to use the correct past-tense forms *ran*, *came*, *broke*, *did*, etc., in the appropriate context and, at a later time, he begins to use the incorrect forms **runned*, **comed*, **breaked*, **doed*, etc. Such overgeneralization errors of the regular form of the past-tense inflection persist in the language of some children into the elementary school years. Overgeneralizations of this kind on the part of children are not limited to the inflection of past tense. Ervin (1964) reports them for pluralization as well. Nor are such generalizations confined to English, as Slobin (1966) has noted in connection with the acquisition of Russian.

There are at least four facts relevant to these observations that should be noted here. First, the irregular verb forms learned first are fewer in number than the regular forms; i.e., there are more regular than irregular verbs in English. Second, the irregular forms are used more frequently in the language than the regular forms; i.e., *come*, *go*, *do*, etc., occur more frequently than most individual regular verbs. Third, once the regularized inflection is acquired for a few verbs, it is applied to new instances as lexical additions are made to the vocabulary of verbs used by the child (Berko, 1958). Finally, the regularization rules are not applied to the irregular verb forms consistently.

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[2] The research was conducted by the second author while she was a NSF-URP summer fellow on Grant GY 975. She is now at the State University of Iowa.

Once the regular form is learned, the child uses the correct and incorrect forms interchangeably when inflecting the irregular verb forms.

The present series of experiments was designed as an attempt to replicate the observations of morphological rule acquisition under laboratory conditions that would allow more rigorous control of the variables involved in the phenomena observed. The paradigm employed by Esper (1925), in a study of what he considered the development of artificial linguistic categories, seemed particularly appropriate for use here. Esper presented *S*s with a paired-associate task that required learning two-syllable nonsense names for a set of pictorially represented stimuli which were of four shapes and four colors. The names in the first experiment were constructed such that the first syllable referred to the color and the second syllable to the shape. Thus, there were four color names and four shape names arranged in a four-by-four matrix to form 16 color-shape names. Using a modification of the study-test procedure, Esper presented 14 of the pairs during the study trials and tested on all 16 pairs. The results indicated that despite the fact that only 14 pairs were presented, all 16 pairs were learned. Learning was much more rapid in this experiment than in either a condition in which the names were bisected at a place other than the syllable boundary or a condition in which separate unrelated names were learned for each color-shape stimulus.

The first experiment in the present series is a replication of the first Esper experiment with different stimulus and response materials and omitting four rather than two pairs in the study trials. In Exp. II, the four omitted pairs were replaced and presented as four irregular pairs with additional training provided on the irregular pairs relative to the regular pairs. Experiment III employed both the omission and irregular conditions of the first two experiments. The conditions employed were considered to be analogous to the language-acquisition problem facing the child in attempting to learn the English verb-inflection system for past tense.

Experiment I

Method

Subjects. A total of 17 summer introductory psychology students at the Pennsylvania State University volunteered as *S*s and were given points toward their final grade for their participation. One *S* was discarded for failure to reach the learning criterion within 25 trials. Since Exp. I was run concurrently with the two following experiments, every third *S* who appeared in the laboratory was assigned to Exp. I. When a *S* failed to reach criterion in any of the experiments, the next *S* to appear was assigned as a replacement.

Design and List. Each *S* was required to learn a 16-pair list of two-digit-number stimuli and two-letter responses. The study-test procedure was used with the modification that only 12 pairs were presented during the study trials, but 16 stimuli were presented during the test trials. The same 12 pairs were always presented in the study trials so that the *S* had to learn four responses without ever seeing the responses.

TABLE 1

Stimuli and Responses Used in Exps. I, II, and III[a]

Stimuli	Stimuli 1	2	3	4
6	VM* (DL)	VF	VG	VK
7	HM	HF* (PC)	HG	HK
8	RM	RF	RG* (TJ)	RK
9	XM	XF	XG	XK* (WS)

[a] The numbers were presented as two-digit stimuli and the responses as letter pairs. The responses with asterisks were not presented in Exp. I. The responses in parentheses were presented as irregular pairs in Exp. II and III. See text.

Table 1 presents, in matrix form, the stimuli and responses used. The stimuli consisted of the numbers in the ranges 61–64, 71–74, 81–84, and 91–94. The responses were the letter pairs *vm**, *vf*, *vg*, *vk*, *hm*, *hf**, *hg*, *hk*, *rm*, *rf*, *rg**, *rk*, *xm*, *xf*, *xg*, and *xk**. As may be seen in the matrix, each single digit has a corresponding single letter as a response. The responses marked by an asterisk indicate those pairs which were omitted from the study trials. Each of the individual digits composing the stimuli and each of the individual letters composing the responses was omitted once and only once in the four omitted stimulus-response pairs.

The letter pairs selected for responses have low bigram frequencies except for the slightly higher frequencies of those pairs involving the letter *r*. The associative frequencies in both forward and backward directions were minimized. Both the bigram and the associative-frequency data were taken from Underwood and Schulz (1960).

Procedure. The study-test procedure was used with a 4-sec joint presentation of the stimulus and response on the study trials, a 4-sec anticipation interval on the test trials, and a 4-sec interval between list presentations. The materials were presented on a Lafayette memory drum (Model 303B). The stimuli were typed as two-digit numbers with no space between them and the responses were typed in capital letters with no space between them. Four random orders were used for the study trials and four different random orders for the test trials. The *S*s were read standard study-test paired-associate instructions. No indication was given that some of the pairs on the test trials would not be presented on the study trials. A criterion of three successive errorless trials was used, but if *S* failed to reach that criterion within 25 trials, the experiment was terminated and the data for that *S* were not analyzed. A correct response was scored when the correct letter pairs were given in the correct order.

Results

The mean number of trials to criterion on the entire list was 12.37 ($SD = 4.24$). The mean number of trials to the criterion of three successive errorless trials for the sets of presented and omitted pairs was 12.19 and 11.87, respectively. The difference between these means is significant, $t(15) = 2.44$, $p < .05$.

Since there were unequal numbers of each type of pair, the analyses of correct responses were conducted in terms of proportion correct for this and subsequent experiments. When the proportion correct over trials to criterion was summed, the mean total proportion correct for the presented pairs was 6.45, and for the omitted pairs, 5.42. The difference between these means is significant, $t(15) = 4.14$, $p < .01$. Thus, it may be seen that while a smaller proportion of correct responses was made on the omitted pairs, criterion was actually met in significantly fewer trials.

Although 4 *S*s reached criterion prior to the tenth trial, an analysis was made of the proportion of correct responses for the two types of pairs over the first 10 trials, errorless performance beyond criterion to Trial 10 being assumed for those 4 *S*s. Figure 1 presents the mean proportion correct for the presented and omitted pairs over the 10 trials, with the data of the 4 *S*s who reached criterion prior to Trial 10 included. An analysis of variance of

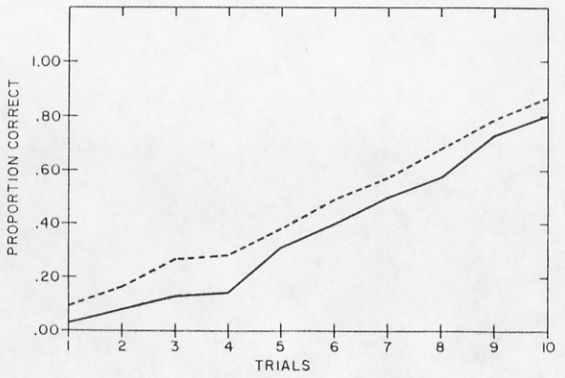

Fig. 1. Mean proportion correct for the presented and omitted pairs on Trials 1–10. (Exp. I). – – – Presented pairs; ——— Omitted pairs.

these data indicated that the difference between the presented and omitted pairs is significant, $F(1, 15) = 13.93$, $p < .005$, as is the effect of Trials, $F(9, 135) = 28.27$, $p < .001$. The interaction between Pair Type and Trials did not reach an acceptable level of statistical significance, $F(9, 135) = 1.40$.

Experiment II

Method

Subjects. A total of 23 *Ss* was drawn from introductory psychology classes. The data of 5 *Ss* were discarded for failure to reach criterion within 25 trials, and 2 additional *Ss* were discarded because of procedural errors made by *E*.

Design and Procedure. The same test list of stimuli was used in Exp. II as in Exp. I. The difference between the two experiments was in the material presented in the study trials. Instead of omitting four stimulus-response pairs, four pairs were presented three times each. The four additional pairs, indicated in Table 1, were 61-dl, 72-pc, 83-tj, and 94-ws. The number stimuli of these pairs are those which were omitted from presentation in Exp. I. The responses are irregular in the sense that they do not make use of any of the letters of the other regular pairs in the matrix. Thus, in Exp. II the study trials included 24 pairs; one presentation of each of the 12 regular pairs and three presentations of each of the four irregular pairs. The test trials presented each of the 16 stimuli only once.

The irregular letter pairs are low in bigram and associative frequencies (Underwood and Schulz, 1960). Four different random orders of the study trials were used, with the restriction that no repeated pair was presented twice in succession. In all other details, Exp. II was conducted in the same manner as Exp. I.

Results

The mean number of trials to criterion on the total list was 17.12 ($SD = 4.88$). The mean trials to criterion for the two different parts of the list; i.e., the regular and the irregular pairs were 17.06 and 12.00, respectively. The difference between these two means is significant, $t(15) = 4.44$, $p < .01$. The mean proportion correct over all trials for the regular pairs was 9.30, and for the irregular pairs, 13.33. The difference between these two means is significant, $t(15) = 8.80$, $p < .01$.

Figure 2 presents the mean proportion of correct responses for the first ten trials for the two types of pairs. No *S* reached criterion prior to the tenth trial. Analysis of variance of these data revealed a significant effect of Pair Type, $F(1, 15) = 82.64$, $p < .001$; Trials, $F(9, 135) = 46.25$, $p < .001$; and Pair Type by Trials interaction, $F(9, 135) = 4.35$, $p < .001$.

In an effort to determine whether acquisition of the regular pairs of the matrix influenced performance on the irregular pairs, an examination was made of the errors that occurred on the irregular pairs after a criterion of one errorless trial had been reached. A total of 45 errors was made by 13 *Ss*. Of these errors, 26 were errors that involved regularization of the response according to the matrix of responses for the regular pairs. In 11 of the 26 errors, both letters of the regular form were given in correct order, while the other 15 errors included only one letter from the regularized response. In the latter case, when only one letter from the regular form was used, it always occurred in the correct order. There were 13 errors of omission and six errors of other kinds; i.e., neither regularization errors nor omissions. On the regular pairs, 15 errors, 9 omissions, and 5 partial (one letter correct and one incorrect) errors were made by five *Ss* after the criterion of one errorless trial had been reached.

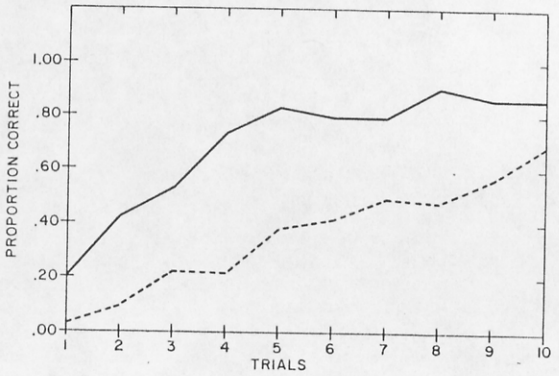

FIG. 2. Mean proportion correct for the irregular and regular pairs on Trials 1–10. (Exp. II). --- Regular pairs; —— Irregular pairs.

Experiment III

Method

Subjects. A total of 23 *Ss* was drawn from introductory psychology classes. The data of seven *Ss* were discarded because they did not reach criterion by Trial 25. Half of the *Ss* were randomly assigned to each of the two forms of the list used.

Design and Procedure. Experiment III employed a combination of the conditions of the two previous experiments. The same 12 regular pairs were used, but two pairs were omitted as in Exp. I, and two irregular pairs were presented as in Exp. II. The irregular pairs were presented twice during the study trials rather than three times as in Exp. II. One-half of the *Ss* had the stimuli 61 and 83 omitted and the irregular pairs 72-pc and 94-ws presented, while the other half of the *Ss* had the stimuli 72 and 94 omitted and the irregular pairs 61-dl and 83-tj presented. The irregular pairs were presented only twice in order to achieve an equal number of presentations in the study and test trials. Thus 16 pairs were presented on the study trials, 12 regular pairs and two presentations of each of the two irregular pairs, and 16 stimuli were presented on the test trials, 12 regular-pair stimuli, two omitted regular-pair stimuli and two irregular-pair stimuli. In all other respects, Exp. III was conducted in exactly the same manner as the previous two experiments.

Results

The mean number of trials to criterion on the entire list was 17.12 ($SD = 4.04$). The mean trials to criterion for the three different types of pairs in the list; i.e., the regular presented pairs, the irregular pairs and the omitted regular pairs, were 15.94, 10.06, and 14.56, respectively. The differences among these means are significant, $F(2, 30) = 10.71$, $p < .001$. The difference between the means of the presented regular pairs and the omitted regular pairs is significant, $t(15) = 5.14$, $p < .01$, as is the difference between the irregular and the omitted regular pairs, $t(15) = 4.71$, $p < .01$.

The mean proportion of correct responses over all trials was 10.01 for the regular presented pairs, 8.34 for the omitted regular pairs, and 11.87 for the irregular pairs. The differences among these means are significant, $F(2, 30) = 8.25$, $p < .005$. The difference between the means of the regular presented pairs and the regular omitted pairs is significant, $t(15) = 3.68$, $p < .01$, as is the difference between the means for the presented regular pairs and the irregular pairs, $t(15) = 4.58$, $p < .01$.

Figure 3 presents the mean proportion correct for the first ten trials on the three types of pairs. One *S* reached criterion prior to the tenth trial and is included in Fig. 3, and the analyses of the data make the same assumption as the corresponding analysis of Exp. I. Analysis of variance of these data revealed a significant effect of Pair Type, $F(2, 30) = 12.27$, $p < .001$, and Trials, $F(9, 135) = 29.10$, $p < .001$, but the interaction between Pair Type and Trials was not significant, $F(18, 270) = 1.27$. The mean proportion correct for the presented regular pairs was 3.76, for the omitted regular pairs 2.69, and for the presented irregular pairs, 6.09. The difference between the presented regular pairs and the omitted regular pairs is significant, $t(15) = 4.20$, $p < .01$, and the difference between the presented regular pairs and the irregular pairs is also significant, $t(15) = 5.17$, $p < .01$.

As in Exp. II, an analysis was made of the errors that occurred after a criterion of one errorless trial had been reached on the type of

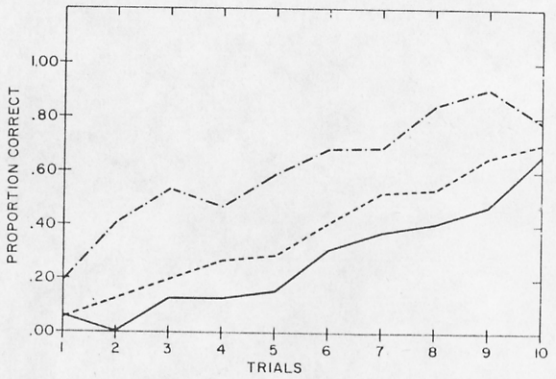

FIG. 3. Mean proportion correct for the irregular, regular presented and regular omitted pairs on Trials 1–10. (Exp. III). – – –Presented pairs; —— Omitted pairs; —·— Irregular pairs.

pair considered. A total of 18 errors, 4 omissions, and 14 partial errors, were made by 7 *Ss* on the presented regular pairs after a criterion of one perfect trial had been reached; 18 errors, 5 omissions, and 13 partial errors, were made by nine *Ss* on the omitted regular pairs; and 69 errors were made by 12 *Ss* on the irregular pairs. It is not possible to make a direct comparison of the total numbers of errors since the trials-to-criterion measures were significantly different for the three groups of pairs. However, the kinds of error made on the irregular pairs are of interest. Of the 69 errors made, 46 were errors of regularization and the other 23 were omissions. Of the 46 regularization errors, 12 were partial regularizations; i.e., only one of the letters followed the rule of the regular pairs, while the other 34 were complete regularization errors. Examination of the errors after three trials to criterion revealed that 34 errors were made on the irregular pairs by eight *Ss* and, of these, 14 were omissions and 20 were regularization errors. Included in the 20 regularization errors were five partial regularization errors.

DISCUSSION

Despite the methodological differences between Exp. I and the first experiment reported by Esper (1925), there is a close correspondence in the results of the two experiments with respect to the acquisition of the presented and omitted pairs. It is clear, in both cases, that the mean proportion of correct responses on the presented pairs is consistently higher over the early trials of acquisition than the proportion correct for the omitted pairs. It is equally clear however, that little difficulty is encountered in learning the omitted pairs once the matrix system has been learned. Examination of the performance of individual *Ss* suggests that little progress is made on the omitted pairs until the relationships between numbers and letters begin to be learned, and then performance on the omitted pairs rises rapidly. The *Ss* differ in the manner in which the system is acquired. Some seem to discover the whole system at once and performance rises to criterion rapidly; others spend considerable time learning individual pairs and then suddenly comprehend the system and, after a slight dip in performance, quickly master the entire list and still others seem to acquire a part of the system, e.g., the first-digit and first-letter relation or a subset of two digit-response pairs and subsequently fill in the rest of the relations to fill out the matrix. Performance on the omitted pairs lags behind until all, or part of the matrix, is learned when performance on the omitted pairs is indistinguishable from that on the pairs which have been presented. The relation between performance on the presented pairs and that on the omitted pairs was characteristic of both Exp. I and Exp. III. The often sudden awareness of the matrix relationship, or some part of it, between the regular stimuli and responses was characteristic of all three experiments and was often marked by *Ss*' comments during the learning task.

Experiment II clearly demonstrated that performance on the more frequently presented irregular pairs was markedly superior to performance on the regularized pairs. The three-to-one ratio of presentation was reflected by correct performance on the irregular pairs from the very first trial for most *Ss*. While performance was markedly superior on the irregular pairs and criterion was reached significantly sooner than on the regularized pairs, it is of interest to note that errors did occur after one errorless trial (and even after three successive errorless trials); but of more significance is the fact that the errors were overgeneralizations of the regular-pair responses in the majority of cases.

Experiment III confirmed the results of both previous experiments in most details. Performance differences on the irregular pairs were not quite so large as in Exp. II, probably due to the fact that the study-trial presentation ratio of irregular to regular pairs was only 2:1 rather than 3:1. Errors on the irregular pairs were more frequent after one errorless trial in Exp. III than Exp. II and were nearly as great after three successive errorless trials in Exp. III as after one errorless trial in Exp. II. The greater number of errors may be due either to the smaller amount of practice provided or some interaction with the omitted pairs which were included in Exp. III. The general nature of the relations among the various pair types, however, agreed substantially with that in the other two experiments and gives little indication of any major changes in performance as a function of having all three experimental conditions present in the same list. Despite this finding, it would be of interest to determine more specifically the influence of various ratios of regular and irregular forms in this context, along with determining what proportion of regular pairs in the matrix is necessary to establish the generalization of the regularized rule.

While the analogy between the learning of inflections for past tense and the conditions of the present experiments is not perfect, the similarity between the findings obtained in these three experiments and those reported by Ervin (1964) for children's acquisition of past-tense inflection of verbs is remarkable. In Exp. III, which combines all of the conditions inherent in the analogy, the more frequently encountered irregular forms were learned first, followed by the acquisition of the regularized forms presented less frequently but in larger numbers, and finally, errors on the irregular forms occurred which reflected the regularized system. It was also noted that, in many cases, the regularization of the irregular forms occurred well before criterion was reached on the regular pairs, in line with the observation made by Ervin that in some cases the first observed instance of children's regularized tense inflection occurs with an irregular verb. Finally, the regularized form is readily applied to new instances never specifically trained.

The errors on the irregular pairs which occurred after considerable practice of the correct responses, and the fact that the errors that do occur tend to be overgeneralization errors, suggest that *Ss* fail to make appropriate discriminations among the stimuli requiring regular and irregular responses. Thus, one might predict from the present data that variables such as stress, fatigue, and other distracting kinds of event might influence the probability with which the child will make errors of overregularization in past-tense inflections of the strong verbs. If the difference in the number of errors that occurred on the irregular pairs after criterion in Exp. II and Exp. III may be

attributed to the difference in amount of practice on the irregular pairs, it might be predicted, other things equal, that children who have relatively more practice on the irregular verbs would be less likely to make overgeneralization errors in the inflection of irregular verbs. It would appear that the experimental paradigm used in these studies might prove highly useful in the investigation of the influence of such variables on performance as well as the investigation of concepts or rules relevant to other aspects of language and its acquisition.

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Asymmetry of S-R and R-S Associations with the Direction of Recall Equated[1]

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Following the suggestion by Richardson (1960), it was reasoned that the direction during recall must be equated in order to make meaningful comparisons between forward and backward learning with pairs consisting of different S and R materials. Using adjective-number and number-adjective pairs it was found that R-S recall exceeded S-R recall when the materials recalled were single-digit numbers, but the reverse was true when the items recalled were adjectives. The results were interpreted as contrary to a principle of associative symmetry.

In the area of backward or R-S learning, earlier views had been that although backward associations do exist, they are invariably weaker than forward or S-R associations (e.g., Jantz and Underwood, 1958). In contrast, Asch and Lindner (1963) reported data suggesting that in some instances R-S recall may even be greater than S-R recall. However, they compared the S-R recall of a number-trigram list with the R-S recall of the same list. Richardson (1960) suggested that such comparisons may be invalid due to potential differences in "difficulty" of learning in the S-R and R-S directions. For example, it might be easier to learn TABLE-CLOTH than CLOTH-TABLE. If so, differences between S-R and R-S recall might reflect differences in difficulty rather than differences between the strength of forward and backward associations.

Equating the availability of stimulus and response members would reduce the problem of difficulty. However, as Horowitz, Norman, and Day (1966) have pointed out, the problem may still be present owing to the existence of serial associations, grammar rules, and word-association hierarchies. In order to compare S-R and R-S recall without confounding from difficulty, Richardson advocated that the R-S recall of an A-B list be compared with the S-R recall of a B-A list so that direction of S-R and R-S learning would be the same. If such comparisons are made with the Asch and Lindner data, the reported superiority of R-S recall disappears. The present study provides an instance of R-S superiority employing comparisons that control for difficulty.

Method

The *Ss* were 48 freshman psychology students whose participation fulfilled a course requirement. None of the *Ss* had participated in previous verbal learning experiments. For half the *Ss*, learning materials consisted of the following pairs of numbers and Thorndike-Lorge AA adjectives: 7-KIND, 4-WISE, 3-DEEP, 9-SOFT, 5-RICH, 1-BUSY, 2-GRAY, 6-THIN, 8-COOL. Stimulus and response members were reversed for the remaining *Ss*. A Lafayette drum was used to present the items successively with the stimulus alone for 2 sec, followed by the response alone for 2 sec. The intertrial interval was 2 sec. The *Ss* were required to pronounce the stimulus and anticipate the response, with instructions to guess when they did not know the correct response. All *Ss* were taken to a criterion of 5/9 correct on a single trial.

Upon *S*'s reaching criterion, the drum was stopped and recall instructions were given. Twelve *Ss* in each

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