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EXPERIMENTAL STUDIES OF THE RELATION BETWEEN LANGUAGE AND COGNITION.

BY- HOROWITZ, ARNOLD E.

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THE RESEARCH REPORTED HERE CONCERNED THE RELATIONSHIP BETWEEN LANGUAGE AND COGNITION IN THE CONTEXT OF THE WHORF HYPOTHESIS ABOUT LANGUAGE AND CULTURE. EXPERIMENTS WERE CARRIED OUT INVESTIGATING THE EFFECT OF SOME LINGUISTIC AND REFERENT DIMENSION VARIABLES ON THE LEARNING OF MINIATURE LINGUISTIC SYSTEMS. A MINIATURE LINGUISTIC SYSTEM (MLS) IS A LIMITED, ARTIFICIAL LANGUAGE MADE UP OF NONSENSE SYLLABLES AND NONSENSE FIGURE REFERENTS ARRANGED IN RELATIONS ANALOGOUS TO THOSE IN NATURAL LANGUAGES. A TOTAL OF 210 ADULTS WERE ASKED TO LEARN THE NAMES OF THE REFERENTS WITHOUT BEING TOLD THERE WAS A LINGUISTIC SYSTEM UNDERLYING THE NAMES. THE CORE EXPERIMENTAL GROUPS EXPLORED THE LEARNING OF MLSS WHERE GRAMMATICAL STRUCTURE WAS HELD CONSTANT, AND THE REFERENT DIMENSIONS WERE PAIRED WITH STRUCTURAL UNITS IN ALL OF THE POSSIBLE COMBINATIONS ALLOWED BY THE SET OF DIMENSIONS AND UNITS USED. THE LEARNING OF THESE SYSTEMS WAS SIGNIFICANTLY AFFECTED BY BOTH GRAMMARS "AS A WHOLE" AND MORPHEME TYPES, AND THESE TWO VARIABLES INTERACTED SIGNIFICANTLY. THE RESULTS WERE DISCUSSED IN TERMS OF A MILLER AND CHOMSKY PERFORMANCE MODEL. THE MAJOR DETERMINANT APPEARED TO BE THE NATURE OF STRUCTURAL UNITS, WITH LESSER EFFECTS DUE TO REFERENT DIMENSIONS. SEVERAL ALTERNATIVE INTERPRETATIONS OF THE LEARNING PROCESS WERE GIVEN. THE AUTHOR CONCLUDES THAT ANY STRONG FORM OF THE WHORF HYPOTHESIS OVERSIMPLIFIES THE LANGUAGE-COGNITION RELATIONSHIP. (AUTHOR/JD)

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Hofstra University

Hempstead, New York

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INTRODUCTION

In psychology, one prevalent view of the relation between language and thought has seen thought as the primary process: thought occurs and may then be encoded into the language of the thinker. Languages may differ in their efficiency in communicating thought processes, but for the individual thinker, language is a separate, subsequent process, without determining effects on his cognitions.

In the 1940s, a linguist, B. L. Whorf (1956), published a series of articles proposing the exact opposite set of assumptions. He hypothesized that the structure of the language spoken is a primary determinant of the individual's cognitive processes. This point of view was not completely new (Humboldt, 1836; Sapir, 1921; Cassirer, 1953-57), but Whorf's presentations seem to have come at an appropriate time, and his work received much attention and discussion from psychologists and anthropologists.

There ensued much theoretical dispute about what came to be known as the Whorf hypothesis (Levi-Strass, et al., 1953; Hoijer, 1954; Henle, 1958). Empirically oriented psychologists published thoroughgoing methodological critiques (Lenneberg, 1953; Osgood and Sebeok, 1954; Lenneberg and Roberts, 1956; Brown, 1958; Fishman, 1960). The main conclusion of these were that either view---language determines thought, or thought determines language---in its 'strong form' is scientifically meaningless. What remains are the very real problems of the "What?", "How?", "When?", and "Who?" of the relationship between linguistic structure and cognitive processes.

The present program of research was instituted in the atmosphere of the general debate about the Whorf hypothesis---in which there existed very little experimental data that could be brought to bear on the issues. The Miniature Linguistic System (MLS) technique seemed a fruitful but unexploited means of getting such data. MLSs can be constructed to differ in ways analogous to differences in natural languages. Because of the limited scope of MLSs, these structural differences can be used as specifiable independent variables. In natural languages such close specification of differences is not feasible because of the complex interdependence of linguistic processes within languages. The object was to explore in detail the effects of some general kinds of linguistic variables on cognition. The dependent (cognitive) variables were measures of various aspects of the learning process.

Although artificial language material has been used in a variety of experiments, only 5 published studies, and 3 unpublished dissertations using MLSs, in the sense of a full linguistic system (Hockett, 1959), have been found in the literature. This ingenious technique was first proposed by Thumb (1907). Esper published a pioneer study using the MLS technique in 1925. His predicted extensive use of this technique has not eventuated. Esper's 1925 study compared the learning of two MLSs in which both phonetic and morphological variables were manipulated.

In 1933, he published an investigation of the effects of perceptual categories set up in the learning of an MLS on the subsequent categorization of the same kind of stimulus material.

D. L. Wolfle's Master's essay (1928) was a study of the previous learning of a manual code on the subsequent learning of an MLS using the manual operations as referents. He also ran an experiment (1932) comparing the learning of regular and irregular MLSs.

These early studies are marked by a lack of statistical sophistication and by discussion of problems and results in terms of an oversimplified and atomistic associationism. Very little about the learning of MLSs as systems could be inferred.

The present investigator started using the technique again in the early 1950s; his dissertation (1955) contains three experiments on the learning of MLSs. The first of these (Horowitz and Jackson, 1959) was designed to clarify conflicting interpretations of Esper's (1925) experiment which resulted from confounded variables. The other two extended the technique to study a problem in phonetic symbolism, and to a more complex linguistic structure. Rapoport and Horowitz (1960) carried the MLS technique up to the sentence level, and also began work on a mathematical model that allows inferences about the process of learning MLSs as systems. This model has been developed further, and applied to some of Horowitz' data, by Levant (1962).

Two kinds of structural variables were manipulated in the present series of experiments. These were what Morris (1946) calls syntactic and semantic rules. Syntactic rules are defined as the relations between symbols in a language code. Semantic rules are defined as the relations between symbols and referents in such a code. Operational details of these variables will be made clear in the explication of procedures and design.

The general program has been to set up MLSs that differ in a number of specifiable ways. The question asked in each of the comparisons to be made was: given a difference in linguistic structure, what are the differences in the process of learning these systems?

METHOD

General Design

An MLS is a set of nonsense syllables used as names for a set of nonsense figures. Relations among the syllables---or parts of syllables--- and those between the syllables and the figures (referents), are arranged in a manner analogous to the structural features of natural languages. Each group of Ss learn an MLS that differs systematically from the other MLSs to be investigated. These systematic differences in linguistic structure constitute the independent variables. The names are taught to Ss by a standard anticipation method. Instructions simply state that the task is to learn the names; the fact that they constitute a language system is not mentioned.

The derivational rules in Figure 1 can be used to generate 125 two-syllable names made up of three types of structural units (SUs). Rule 1 indicates that each name consists of three morpheme types. Rule 2 indicates that the first morpheme type is a consonant-vowel-consonant (CVC) syllable in initial position, and presents the five alternate sets of CVC syllables in the set. Rule 3 indicates that the second morpheme type is a vowel (V), and presents the five alternate sets. Rule 4 indicates that the third morpheme type consists of consonant-consonant (C-C) frames in final position, and presents the five alternate sets of frames. Rule 5 indicates that the process of forming a name is to take one alternate from each morpheme class and imbed the V in the C-C frame, forming a two-syllable pronouncable unit. These derivational rules define the morphological structure of the MLS.

Each of the morpheme types is tied to a referent dimension (RD), and each member of a set to a value of a dimension, by a semantic rule. This set of relations defines the semantic structure of the MLS.

Three RDs are used in any single MLS. The dimensions for most groups in this project have been Shape (Sh), Color (C), and Size (S). In group 29 and 30 (see Appendix A, Position (P), was substituted for Size. Each has 5 values; 5 different shapes; 5 different colors, etc., generating a possible 125 different figures. These 125 'things' constitute the universe of discourse in the MLSs in these experiments. Only 25 of these things were actually constructed, chosen by a Latin-Square procedure to be a representative sample of the total number of combinations. The examples at the bottom of Figure 1 illustrate how the linguistic structure specifies the names of nonsense figures in two different MLSs. The shapes were cut out of colored poster paper in the appropriate sizes and pasted on Bristol Board cards for presentation to Ss.

The design of this research in terms of differences in linguistic structure, variations on this structure, and groups run under each condition is presented in Table 1. Comparisons between rows and/or columns will allow determination of the affects of the manipulation of linguistic and referent variables.

Figure 1

Derivational Rules for MLSs[1]

Rule 1. Name — Morpheme X (Mx) + Morpheme Y (My) + Morpheme Z (Mz)

Rule 2. Mx — { foyg, gef, dəp, sawb, dus, .. } #2

Rule 3. My — { iy, ay, ah, uw, ɔw }

(1)

Rule 4. Mz — # [z, θ, j, k, š] (2) + [c, ž, d, v, g] (3)

Rule 5. (1), (2), (3) ⇒ (2), (1), (3)

<u>Examples</u>

Language VII: (Sh-C-S)

Figure Abl; (Shape A, blue, smallest size)- foyg # ziyc

Figure Arl; (" " red " ")- foyg # θiyž

Figure Brl; (Shape B, " " ")- dus # θiyž

Language XIV: (C-S-Sh)

Figure Abl- foyg # ziyc

Figure Arl- gef # ziyc

Figure Brl- gef # zuwc

1. Trager and Smith (1951) phonemic transcription.

2. # Indicates junction between syllables.

Table 1

MLS Groups[1] Run Under Different Conditions

Language[2]	A[3]	B[3]	C[3]	D[3]	E[3]
V	4				
	14				
(P) S-C-Sh	16	17	30	18	
	36				
VII	22				5
	23	26	29	27	6
Sh-C-S (P)	37				20
					21
XI					
C-Sh-S	30				
XII					
	32				
S-Sh-C	33				
XIII					
Sh-S-C	34				
XIV					
C-S-Sh	35				

1. Each group number differentiates a group of 10 Ss according to the coding system of the project.

2. Each MLS is identified by a Roman numeral and the order of the referent dimensions in names is given.

3. Column differences indicate the following variations in structure:
   A. Core Groups: invariant structure with all possible combinations of semantic order within names.
   B. Greater size differential between figures than in Core Groups.
   C. Position instead of size as referent dimension.
   D. Discontinuous morpheme in initial position.
   E. Different vowels as size morphemes than in Core Groups.

4. More than one group in a cell indicates replication. Details of Es and samples are presented in Appendix A.

Comparisons among the groups in the first column (Core Groups) will allow for estimation of the effects of changes in semantic rules with syntax and RDs held constant. Comparison between columns A and B will show the effect of making one of the RDs, Size, more discriminable. Column C indicates a substitution of Position for Size, and will show the effect of this variation. Column D indicates a simple change in syntax. In these two groups, Mx <u>followed</u> instead of preceded My-Mz. Column E indicates groups run to investigate phonetic symbolism—the inherent symbolic value of vowels to represent size differences (Newman, 1933).

The above are the main lines of the planned analysis, the purpose of which is to explore the effects of variations in syntactic and semantic rules on the learning of MLSs. The replications (see subjects below) allow for estimates of the stability of the results.

Subjects have been Harvard, Radcliffe, Michigan, and Hofstra undergraduates, equally distributed by sex. This heterogeneity was determined primarily by the author's academic peregrinations, but has produced certain advantages for generalizing <u>within</u> the undergraduate population. Of the 21 groups run, about one-third are replications using identical experimental conditions (indicated by more than one group per cell in Table 1) with sample Ss from different colleges. Comparisons among these replications will allow estimation of the stability of results under these sampling variations.

Exigencies of time, place, and working conditions during 13 years of data collection determined that a number of Es were involved in running Ss. This situation has disadvantages where E, sample, and experimental condition are confounded, but also allows for comparisons to find any E effects (Rosenthal, 1963). Details of samples, E, and experimental condition distribution are presented in Appendix A.

Ss were always assigned randomly to the conditions being run at any given time. There are 10 Ss per experimental group, a total of 210 in the study. Ss were run an hour a day. An average of about 10 hours per S was needed for the learning to be completed.

At different times and places, Ss were paid by the hour, volunteered, or were given extra credit in elementary psychology courses.

<u>Materials</u>

The CVC syllables used in these MLSs were chosen from a set of 800 such combinations. The syllables were constructed according to the Trager and Smith (1951) phonemic analysis of English. All 800 were tested by a word association technique in which choice of syllables to be used was made on the basis of slow reaction time. Further analysis of the original 800 syllables for other indices of association value and meaningfulness is now in progress by the present author in cooperation with J. B. Carroll of the Educational Testing Service.

Using the same Ss as for the protest of the nonsense syllables, ten nonsense shapes were tested for meaningfulness. The five shapes with the greatest communality of response to the question, "What does this figure look like?" were eliminated. The five shapes used in the experiments are shown in Figure 2.

The figures were made in five colors; red, yellow, green, blue, and orange (Milton-Gradley Tonal Poster Papers 19P, 13P, 11P, 25P, and 15P). The figures were varied in size by starting with a figure 2.00 $cm.^2$ and doubling the area to produce five figures of graduated size. In Groups 17, 18, 26, 27, size was varied by starting with the same smallest size and trebling the area. In groups 29 and 30, all the figures were 7.85 $cm.^2$, and their placement on the cards was varied (the four quandrants or center) instead of size.

The 25 figures used as referents in these experiments were chosen from the 125 possible combinations of five shapes, five colors, and five sizes (or positions) by a Latin Square procedure so that each shape appeared in combination with each color and size (or position) once.

The shapes were traced on the poster paper of the selected color, and in the selected size, cut out, and pasted on five by seven inch (the larger series on eight by ten) white, matte, bristol board cards. The cards were sprayed with clear acrylic plastic to allow for periodic cleaning.

Procedure

The experiments were conducted in small rooms. Ss sat across a table from E, separated by a low screen behind which E kept his materials and did the recording. Facing the S was a small stand on which the referent cards were placed.

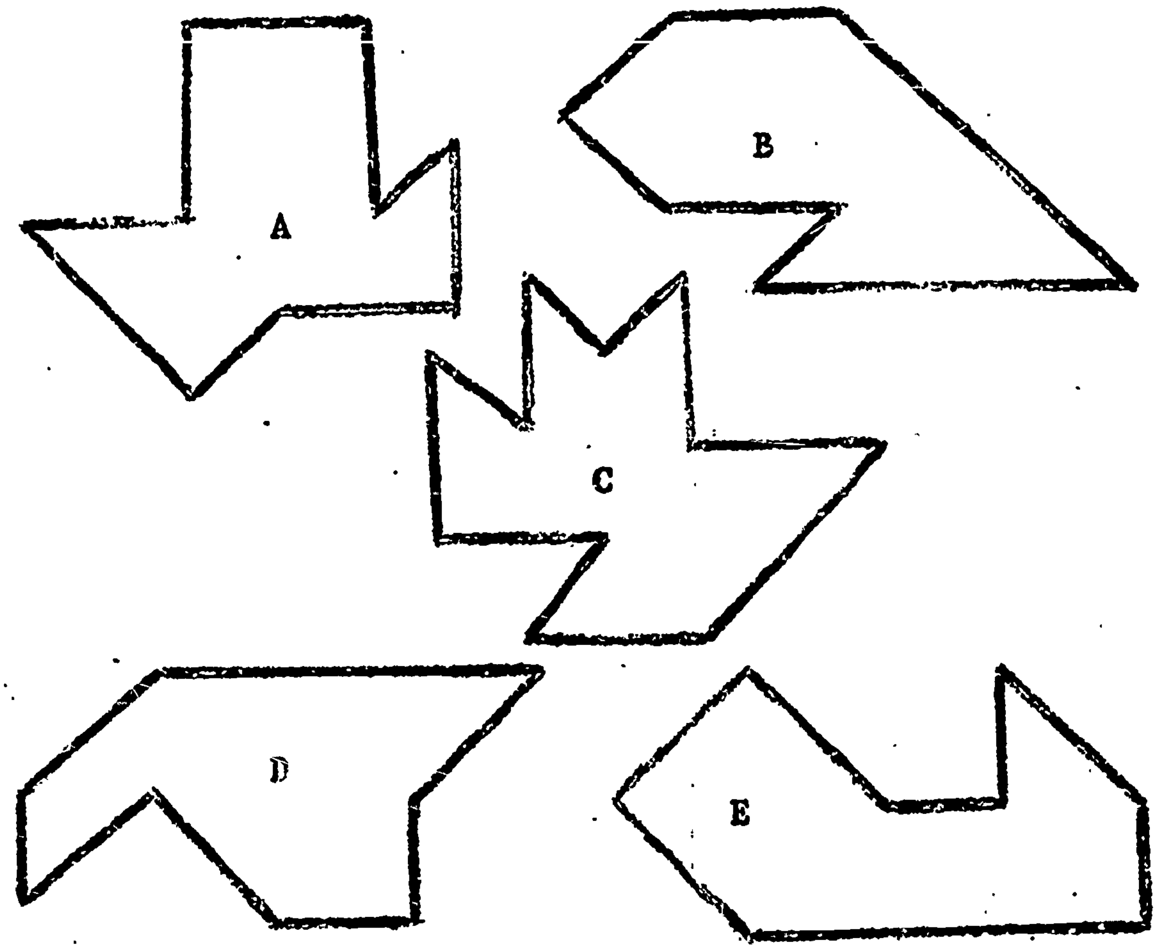
Each time through, the cards were presented in a different random order. The first time through, E presented the card and said the name, which S repeated. On every time through after this, the cards were presented and S had 15 seconds in which to give the name. At the end of the 15 seconds, E said the correct name and S repeated it. The criterion was three times through the figures with all responses correct. The systematic nature of the names was not made explicit in the instructions. Ss' responses were recorded in phonemic transcription (Trager & Smith, 1951), giving an essentially complete reproducibility of the verbal responses. Comments and questions from Ss were also recorded. This record of the verbal responses allows derivation of a variety of dependent variables indicative of aspects of the learning process.

MLSs and Independent Variables

Given the linguistic structure specified by the rules in Figure 1, there are six different ways of pairing RDs with SUs to produce 'languages' with different semantic structures at the morphological level. These are the six MLSs in the left header column of Table 1.

FIGURE 2

Shapes of Referents



This variation in semantic structure is the independent variable within the Core Groups (Column A, Table 1). In these Groups, the size differential was made by doubling (S2) the area of figures.

The Groups in Column B had figures that were differentiated in size by a trebling (S3) of the areas. Those in Column C had figures where position differences were substituted for size differences. The six cells of Table 1 made up of the first two rows and the first three columns therefore constitute a design in which semantic structure and RD were varied orthogonally.

In the Groups in Column D, a modification was made in the linguistic structure specified in Figure 1. Mx was made the second syllable of the name, and the syllable constituted by Rule 5 was the first syllable. For example, the name of Figure Ab1, given as /foyg # ziyc/ in Figure 1, became /ziyc # foyg/ in Group 27. The four cells of Table 1 made up of the first two rows, Columns B and D, therefore constitute a design where semantic structure and order/position of the discontinuous morpheme are independently varied.

The second row of Table 1, Columns A and E, make up a design testing the effect of vowels scaled for phonetic symbolic value. Newman (1933), using a paired comparison procedure, scaled the effectiveness of a set of vowels for symbolizing differences in size. The set of vowels in My are among these that Newman gives scale values for. In MLS VII (Table 1), My is the Size Morpheme. In Groups 5 and 6, there was agreement between the scaled value of the vowels and the size of the referents: the smallest size was paired with the smallest scale value, the next larger size with the vowel with the next larger scale value, and so on. In Groups 20 and 21, the sizes of referents, and the scaled value of the vowels were reversed: the smallest size was paired with the vowel with the largest scale value, the next larger size with the vowel with the next lower scale value, and so on. In Groups 22 and 23, there was no relation between the size of figures and the scale values of the vowels paired with them.

If the scaled phonetic symbolic values of the vowels are effective in the more complex MLS situation (Bentley and Varon, 1933), Groups 5 and 6 should learn faster than the Groups in Column E of Table 1. The reversal of scale value of vowels and the size of referents may interfere with learning. In that case, Groups 22 and 23 should learn faster than Groups 20 and 21. However, if the phonetic symbolic value of vowels is 'built into' Ss, as their scalability would indicate, than the learning of these MLSs might show the same kind of phenomena as that reported by Kendler, Kendler and Wells (1960). Their experiment demonstrated that verbal children learn reversal shifts faster than nonreversal shifts, whereas for pre-verbal children ease of learning is in the opposite direction. The implication is that verbal Ss can use linguistically based cognitive structures to counterbalance S-R relations in an experimental situation that would be interfering for a nonverbal organism. If the phonetic symbolic scale is effective in the MLS situation, Groups 20 and 21 may learn faster than Groups 22 and 23.

The above four designs specify the experimental manipulations made in these experiments: difference in semantic rules with linguistic structure hold constant (Column A, Table 1); referent demension differences (Rows 1 and 2, Columns A, B, and C); a 'syntactic' difference (Rows 1 and 2, Columns B and D) and differences in phonetic symbolic relations (Row 2, Columns A and E).

Dependent Variables

This report will present the results of analysis of one direct and one indirect measure of the time it took Ss to learn the MLSs.[1]

The direct measure is the number of series (times through the referent cards) to reach criterion. Analysis is separated into total learning time (TLT)---the number of series to reach criterion for the MLS as a whole, and for each morpheme type separately.

Experimentor and sample differences seem to reflect 'capacity' differences amongst Ss (Tolman, 1932) and criterion differences amongst Es (Swets, Tanner, & Birdsall, 1964) and not differences between experimental conditions (see Results below). Taking the proportion of number of series to criterion for each morpheme type to the TLT (M/TLT) eliminates most of the E and sample differences, gives a clearer picture of the learning process. Full tabulations of these two measures are given in Appendix C.

[1] The machine analysis of this data and the derived measures are discussed in Appendix B.

RESULTS

Sample Differences

Groups 14 (MLS V), 22 (MLS VII), 36 (MLS V), and 37 (MLS VII) were all run by one experimentor (E1), but 12 and 22 were with Sample 1 and 36 and 37 with sample 3. A two way Analysis of Variance (ANOV) on TLT showed a significant different (5%) between MLSs and a significant (1%) interaction between MLSs and samples. A two between Ss, one within Ss ANOV of number of series to criterion for morphemes produced significant differences between samples (5%), MLSs (1%), and the interaction between these variables (1%). There was no significant differences among morphemes. From Table 2, it can be seen that the means and standard deviations for Group 36 on this measure seem inordinately large.

Since the main interest of this research is the process of learning as affected by differences in MLSs and morphemes, such sample differences, and particularly interactions between samples and the variables of interest make interpretation extremely difficult. If different samples of Ss learn MLS differently, it places severe limitations on any generalization about the learning process and the manipulated variables. The M/TLT measure mentioned in the previous section gives a picture of the process uncontaminated by possible differences in the abilities of Ss. Figure 3A shows the difference to be compensated for: the curves for both Groups learning MLS V are similar but that for Group 36 is displaced upward because this group took much longer to learn. Figure 3B, shows the same functions with M/TLT as the plotted dependent measure; the curves for MLS V are much closer together. ANOV of M/TLT confirms the impression from Figure 3B. There are significant differences (1%) due to MLS, Morphemes, and their interaction. The sample difference is not significant, nor are any of the other interactions. This indicates that use of the M/TLT measure is warranted in interpretation of process as free from individual differences.

Experimentor Differences

E1 and E2 each ran half the Ss in Groups 6, 21, and 23, all from sample 2. These groups all were MLS VII but with different referent size-phonetic symbolic value of vowel relations as outlined above. ANOV of TLT produced a significant (1%) difference between Es with no significant difference among the groups due to the difference in phonetic symbolic relations. ANOV of the number of series to criterion for morphemes showed a significant (1%) difference between Es and among morphemes (1%) with no other significant difference or interaction. Figure 4A, where number of series to criterion for the morpheme types are averaged over groups for the two Es is shown, indicate that the process was similar, but that E1's Ss took longer to learn. Again this impression is confirmed by ANOV of the M/TLT measure, where only the Morpheme difference was significant (1%).

Groups 29 (MLS VII) and 30 (MLS V), where position was substituted for size as an RD, where split between E1 and E6, both working with

TABLE 2

Sample Differences

Group	Sample	MLS		Number of Series to Criterion: TLT	CVC#	#C-C	#-V-	M/TLT: CVC#	#C-C	#-V-
14	1	V	X̄	28.6	22.9	20.3	25.0	.814	.726	.876
			SD	5.6	6.9	5.7	5.7	.209	.187	.109
36	3	V	X̄	49.6	41.0	36.6	46.7	.818	.773	.933
			SD	22.1	20.1	15.9	21.7	.129	.156	.056
22	1	VII	X̄	31.7	13.4	16.9	29.7	.486	.574	.923
			SD	9.2	3.6	3.4	10.2	.262	.166	.070
37	3	VII	X̄	27.6	12.6	16.1	26.3	.483	.674	.949
			SD	7.8	1.4	4.4	8.1	.148	.234	.099

Note: All groups run by E 1. N = 10 per cell.

FIGURE 3

Sample Differences

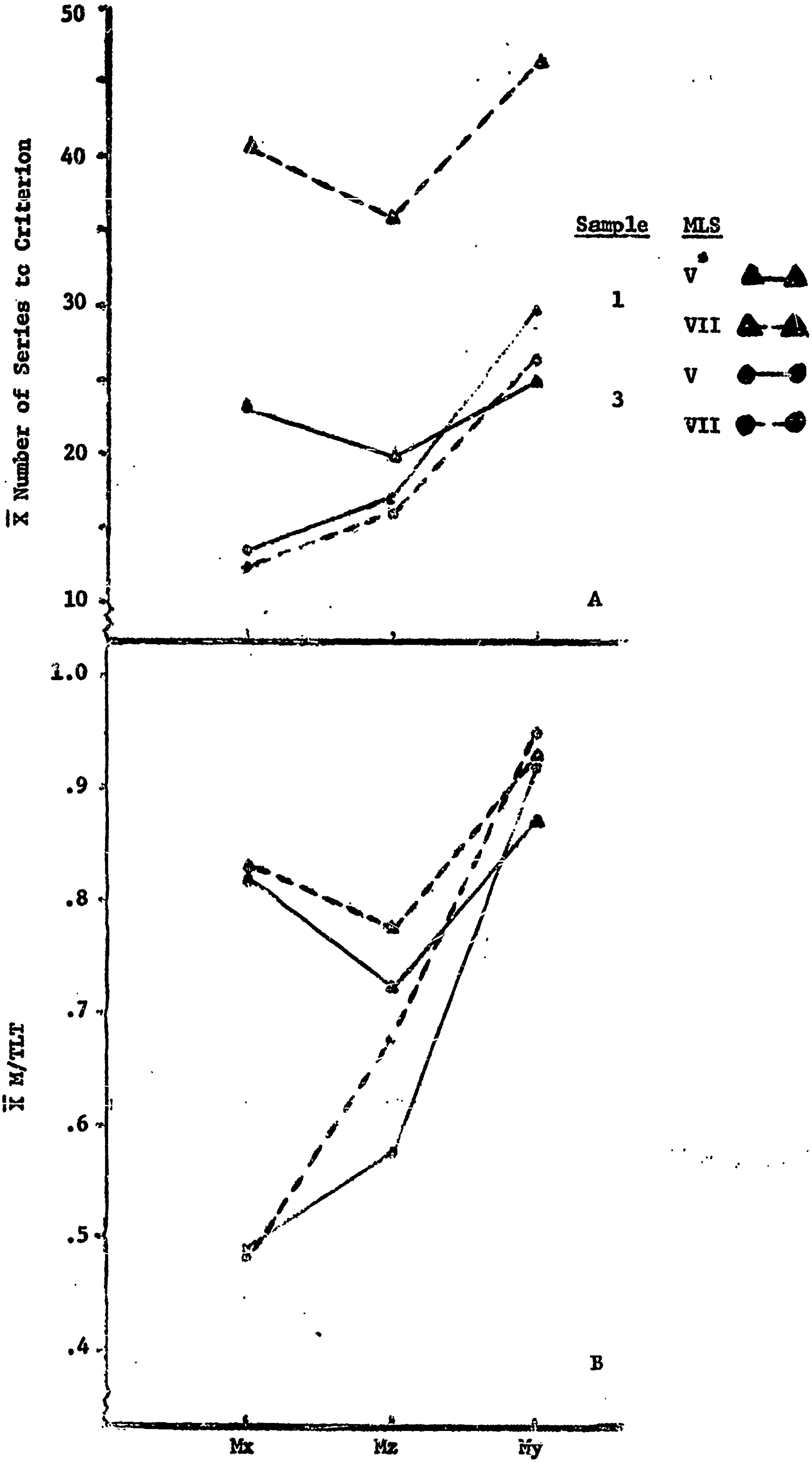


TABLE 3

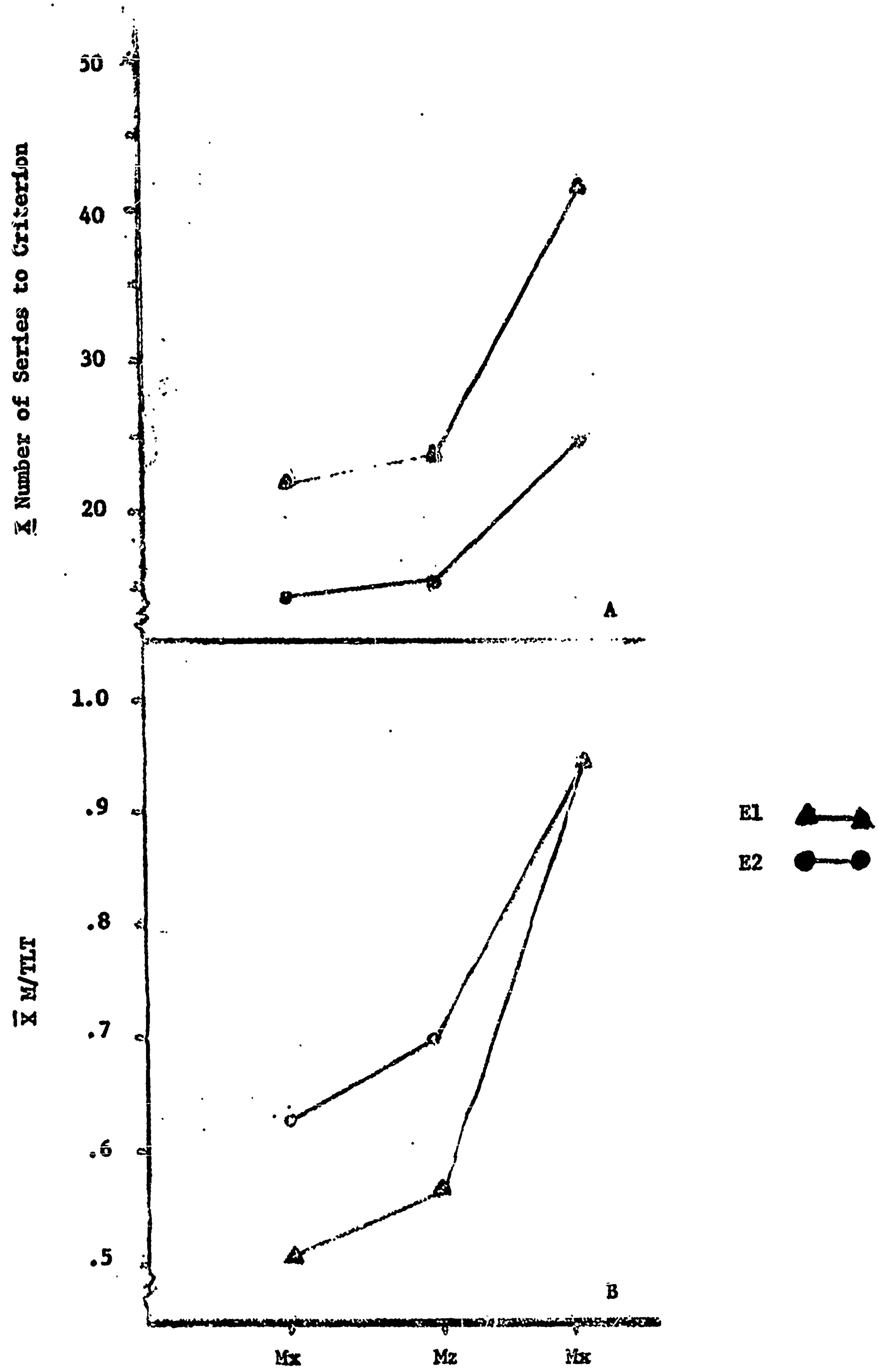
Experimentor Differences

Group	E		Number of Series to Criterion				M/TLT		
			TLT	CVC#	#C-C	H-V-	CVC#	#C-C	#-V-
6	1	$\bar{X}$	52.2	28.4	26.0	51.0	.510	.554	.952
		SD							
6	2	$\bar{X}$	26.8	15.8	12.0	25.0	.704	.487	.902
		SD							
21	1	$\bar{X}$	39.0	15.6	24.2	37.4	.445	.619	.964
		SD	11.2	2.9	7.5	10.8	.175	.089	.062
21	2	$\bar{X}$	28.6	13.8	18.4	26.8	.545	.635	.937
		SD	11.9	3.8	11.0	11.9	.237	.152	.094
23	1	$\bar{X}$	39.4	22.4	21.2	36.2	.562	.523	.922
		SD	7.6	9.9	8.0	6.8	.206	.141	.056
23	2	$\bar{X}$	22.2	12.8	14.8	22.2	.619	.675	1.000
		SD	5.7	4.6	4.1	5.7	.250	.097	.000
All 3	1	$\bar{X}$	43.5	22.1	23.8	41.5	.505	.565	.946
All 3	2	$\bar{X}$	25.9	14.1	15.1	24.7	.623	.699	.946

Note: All groups were from sample 2, with MLS VII .N = 5 per cell.

FIGURE 4

El/E2 Differences



sample 2. ANOV of TLT showed no significant differences, and of number of series to criterion for morphemes only the Morpheme difference was significant (5%). The same analysis of the M/TLT measure produced significant (5%) differences between both Es and Morphemes. Figure 5, where M/TLT is plotted, indicates the proportion of TLT of the morphemes, relative to each other was similar for both Es, the overall M/TLT was higher for E6. This suggests that though the process was similar, E6 was using a more stringent perceptual criterion in judging the correctness of responses. E6 was less experienced, both linguistically and with the experimental situation, than E1, and may well have been 'leaning over backwards'.

Sample and Experimentor Differences Confounded

Several times during the years of running these studies, circumstances---and error---caused sample 1 and E differences to be confounded over experimental conditions. If wide differences in the results occurred among these confounded conditions, it would seriously complicate interpretation of the process and limit the generalizability of findings. Paradoxically, similarity of results under these confounded conditions may very well imply greater generalizability.

Groups 14, 16, and 36, all MLS V, were run with samples 1, 2, and 3 respectively, but E1 ran Groups 14 and 36, and E5 ran Group 16. Means and SKs for these groups are presented in Table 6. One way ANOV showed a significant (5%) difference among Groups and a one between Ss, one within Ss ANOVs on number of series to criterion for morphemes showed significant differences due to both Groups (5%) and Morphemes (1%). The same analysis on the M/TLT measure, however, gave only a 1% difference among Morphemes with both Groups and the interaction being non-significant. Once again, despite the E and sample differences, the measure most closely reflecting the learning process is stable and doesn't interact with non-process variables.

Groups 32 and 33, both MLS XII, were run by E1 with sample 3, and by E4 with sample 2. There was no significant difference between the groups on TLT, but both Morphemes and the interaction between Morphemes and Groups was significant (1%) in an ANOV of number of series to criterion for morphemes. With the M/TLT measure both Groups, Morphemes, and their interaction were significantly (1%) different. Figure 6 presents the curves for Groups 32 and 33. Both groups show the V shaped function between Morpheme and M/TLT, but Group 33 is displaced upwards, and the interaction is reflected in a steeper left leg for this group. The vertical displacement between E1 and E4 in Figure 6 is similar to that between E1 and E6 in Figure 5, and may be due to the same reason. No immediate speculation presents itself for the interaction, and this finding must cast some uncertainty on the general picture of the stability of the learning process given in all the comparisons above. Only Group 32 is used in any further analysis to be reported here.

Groups 18 (MLS V) and 27 (MLS VII) were run with two samples and three Es (Table 7). However, ANOV of TLT and number of series to criterion for morphemes showed only the difference among morphemes

TABLE 4

Experimentor Differences

Group	MLS	E		Number of Series to Criterion				M/TLT		
				TLT	LVC#	#C-C	#-V-	CVC#	#C-C	#-V-
29	VII	1	$\bar{X}$	29.0	19.4	23.0	25.6	.659	.783	.855
			SD	7.1	7.3	8.2	8.9	.134	.137	.155
29	VII	6	$\bar{X}$	21.4	16.4	19.2	20.2	.761	.886	.956
			SD	4.1	5.6	3.5	4.6	.176	.092	.048
30	V	1	$\bar{X}$	33.6	21.0	26.4	28.2	.650	.784	.842
			SD	15.2	13.6	14.2	12.4	.291	.207	.098
30	V	6	$\bar{X}$	40.8	36.4	37.8	39.6	.835	.873	.960
			SD	33.6	33.4	35.1	33.3	.133	.119	.071

Note: Both groups were from sample 2. N= 5 per cell.

FIGURE 5

El/E6 Differences

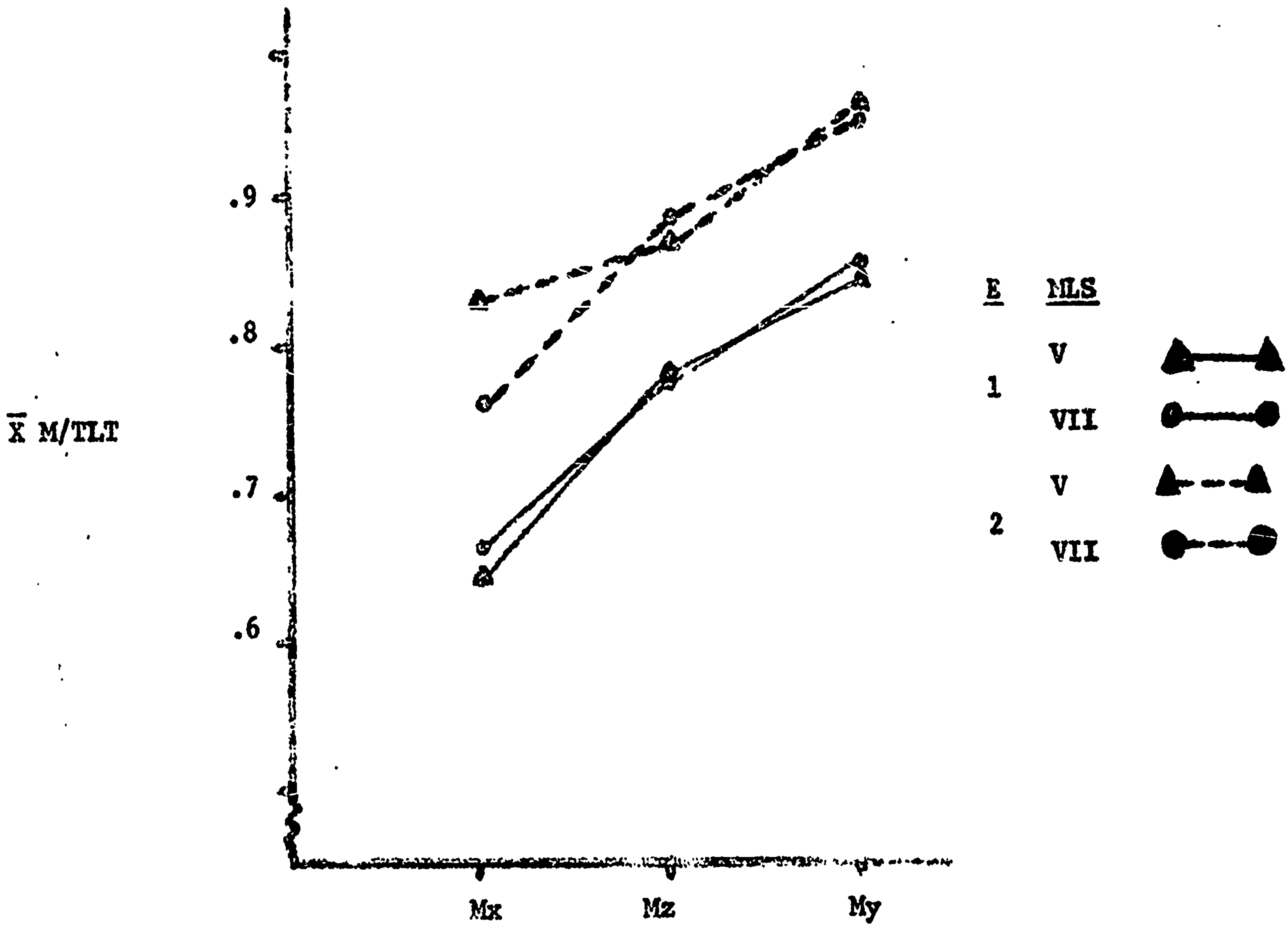


FIGURE 6

El/Sample 3 - E4/Sample 2 Differences

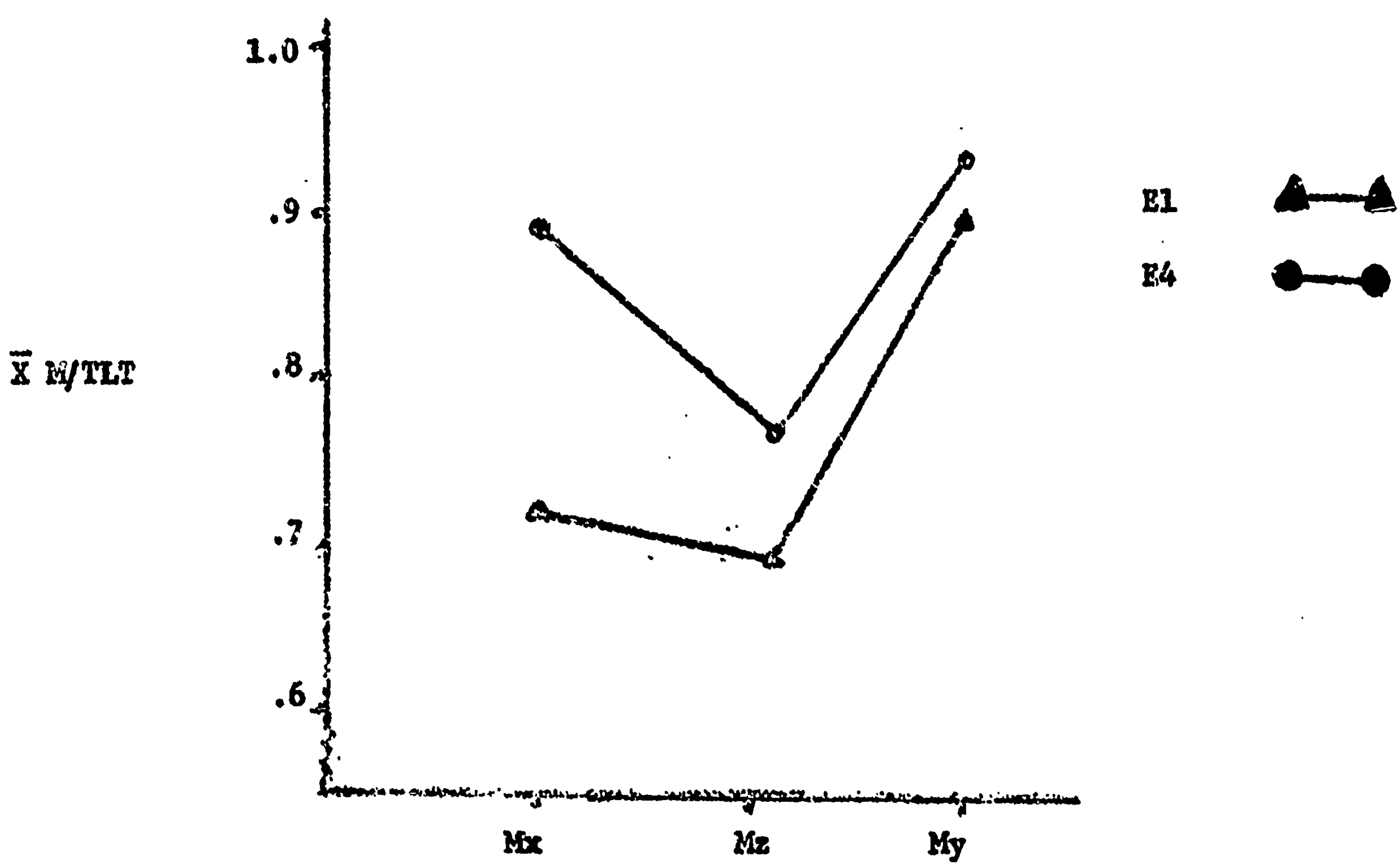


TABLE 5

Experimenter and Sample Differences Confounded

Group	E	Sample	MLS		TLT	CVC#	#C-C	#-V-	CVC#	#C-C	#-V-
14	1	1	V	$\bar{X}$	28.6	22.9	20.3	25.0	.814	.726	.876
				SD	5.6	6.9	5.7	5.7	.209	.187	.109
16	5	2	V	$\bar{X}$	32.0	28.2	23.5	30.5	.859	.746	.947
				SD	13.04	14.02	9.7	13.1	.151	.161	.075
36	1	3	V	$\bar{X}$	49.6	41.0	36.6	46.7	.818	.773	.933
				SD	22.1	20.1	15.9	21.7	.129	.156	.056
32	1	3	XII	$\bar{X}$	37.0	25.6	23.7	34.0	.722	.689	.891
				SD	13.4	8.3	6.7	15.2	.174	.174	.166
33	4	2	XII	$\bar{X}$	28.8	25.5	20.6	27.1	.885	.763	.932
				SD	10.2	9.2	6.8	10.6	.078	.209	.055

Note: N = 10 per cell.

TABLE 6

Experimentor and Sample Differences Confounded

Group	E	Sample	MSS		TLT	#CVC	C-C#	-V-#	#CVC	C-C#	-V-#
					Number of Series to Criterion				M/TLT		
18	1	3	V	$\bar{X}$	29.6	23.8	18.6	27.6	.814	.644	.916
				SD	5.5	5.7	3.1	7.6	.151	.126	.093
18	3	2	V	$\bar{X}$	32.4	26.0	26.4	32.0	.792	.800	.976
				SD	11.1	12.3	12.5	11.6	.136	.136	.047
27	1	3	VII	$\bar{X}$	23.2	11.8	14.4	23.0	.601	.723	.990
				SD	12.0	3.4	3.1	12.0	.246	.208	.019
27	4	2	VII	$\bar{X}$	27.0	19.2	21.6	26.6	.680	.793	.985
				SD	8.4	9.0	7.7	8.4	.140	.111	.019

Note: N = 5 per cell.

to be significant (1%). With the M/TLT measure, only the Mor. variable and the Morpheme by language interaction was significant (. and 5% respectively). Here again, it is the variables of importance for interpreting the learning process that produce significant differences, not the sample and/or E variables.

Referent Dimension Differences

The six cells of Table 1 consisting of the first three columns and the first two rows make up a design to test the effect of varying RD over two MLSs. The differential between sizes in column A was a doubling of the area: the differential in column B was trebling it. Given the same MLS, the S3 difference should be easier to learn due to greater discriminability of the sizes. In column C, position was substituted for size as an RD. This also may be viewed as producing greater discriminability.

For this comparison, all groups were from sample 2, though the Es varied. To discount this E variation, only analysis of the M/TLT measure will be discussed, though the other measures are presented in Table 8. ANOV showed significant differences between ,:Ss (5%), and among morphemes (1%). The interactions between RD and Morphemes, and that between MLSs and Morphemes were also significant (5%). The shape of the function is clearly different (Figure 7) when Position is substituted for size as an RD. There is a steadily rising proportion of TLT as SUs go from Mx to Mz to My. With MLS V, the size variation does not effect the shape or level of M/TLT. In MLS V (Groups 16 and 17) Mz is learned faster than My, with Mx learned at an intermediate rate, and little or no difference between the two groups. MLS VII (Groups 23 and 26) is learned at a generally faster rate than MLS V, but there is a different shaped function due to the CVC#-S2 morphemes being learned at a faster rate than the CVC#-S3 morphemes. The patterning of points at Mx and the close clustering at My would seem to preclude difference in discriminability as determining variable.

Syntactic Variation

Rows one two, columns B and D of Table 1 specifies a design for evaluating the effect on MLS learning of interchanging the order of Mx and the syllable produced by Rule 5 (Figure 1) from My and Mz. Both Es and samples were confounded in this comparison so that the results of the TLT and number of series to criterion for morphemes analyses can only be generalized with caution.

ANOV of TLT produced a significant (5%) difference for both MLSs and Order. From Figure 8A, it can be seen a significant interaction would be expected---which may have been washed out by the rather extreme S variance in Group 17. ANOV of the number of series to criterion for morphemes yielded significant differences for Order (5%), MLSs (1%), and Morphemes (1%), with no significant interactions. The M/TLT measure produced only a Morpheme difference at the 5% level. These results present no clear cut effects of the syntactic variation on MLS learning.

TABLE 7

Referent Dimension Differences

Group	Mx	My	MLS		TLT	CVC#	#C-C	#-V-	CVC#	#C-C	#-V-
16	S2	Sh	V	$\bar{X}$	32.0	28.2	23.5	30.5	.859	.746	.947
				SD	13.0	14.0	9.7	13.1	.151	.162	.075
23	Sh	S2	VII	$\bar{X}$	30.8	17.6	18.0	29.2	.591	.599	.961
				SD	10.9	9.1	7.1	9.4	.231	.143	.056
17	S3	Sh	V	$\bar{X}$	46.5	35.0	33.6	45.7	.805	.745	.956
				SD	21.2	14.5	16.1	22.1	.168	.136	.092
26	Sh	S3	VII	$\bar{X}$	31.0	22.0	19.9	29.1	.704	.651	.945
				SD	9.8	10.1	8.5	8.9	.205	.167	.057
30	P	Sh	V	$\bar{X}$	37.2	28.7	32.1	33.9	.742	.828	.901
				SD	26.3	26.6	27.4	25.7	.244	.175	.104
29	Sh	P	VII	$\bar{X}$	25.2	17.9	21.1	22.9	.710	.845	.895
				SD	6.9	6.7	6.6	7.6	.164	.132	.122

Note: All groups were from sample 2. Mz was the color morpheme in all these groups. N = 10 per cell.

FIGURE 7

Referent Dimension Differences

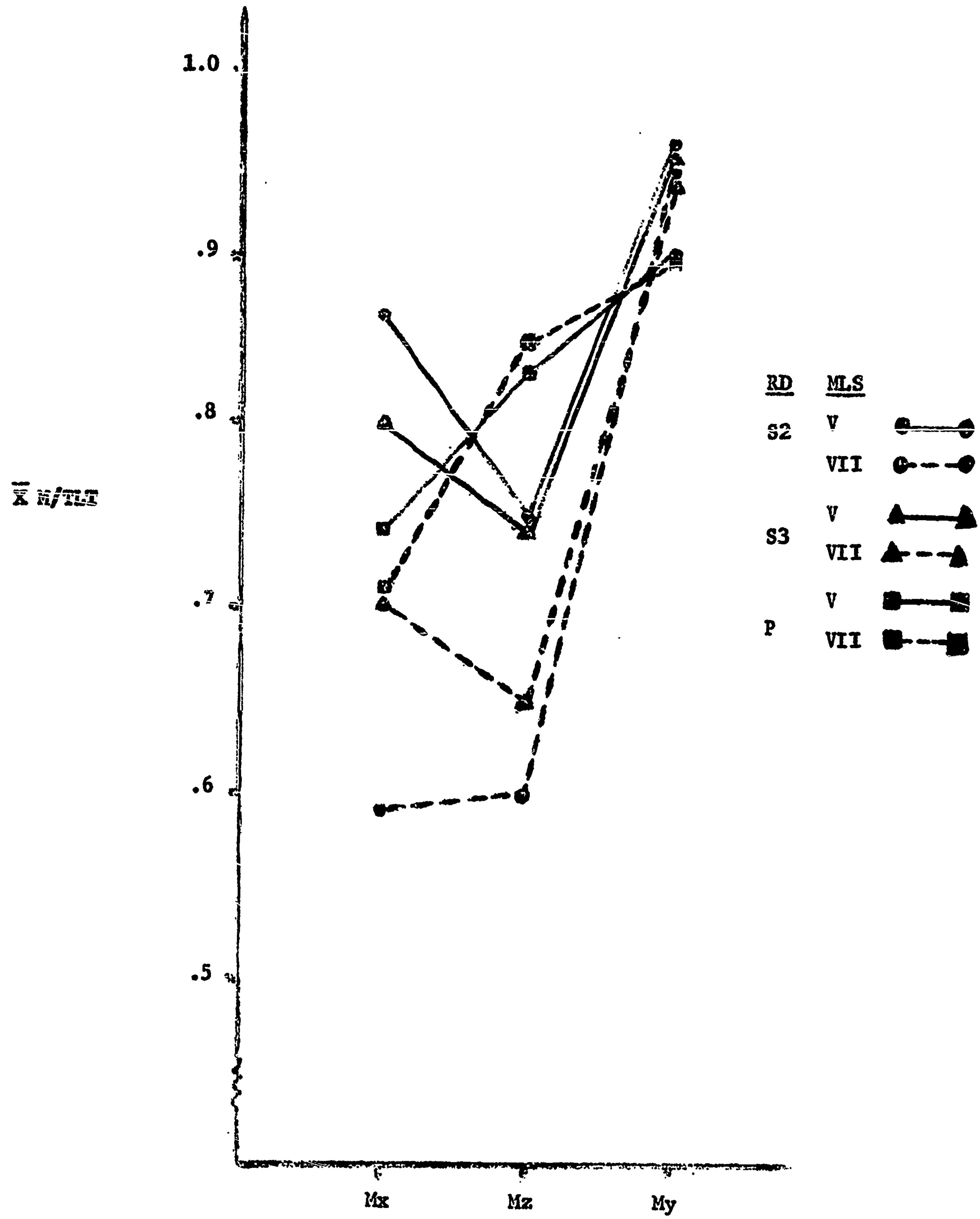


TABLE 8

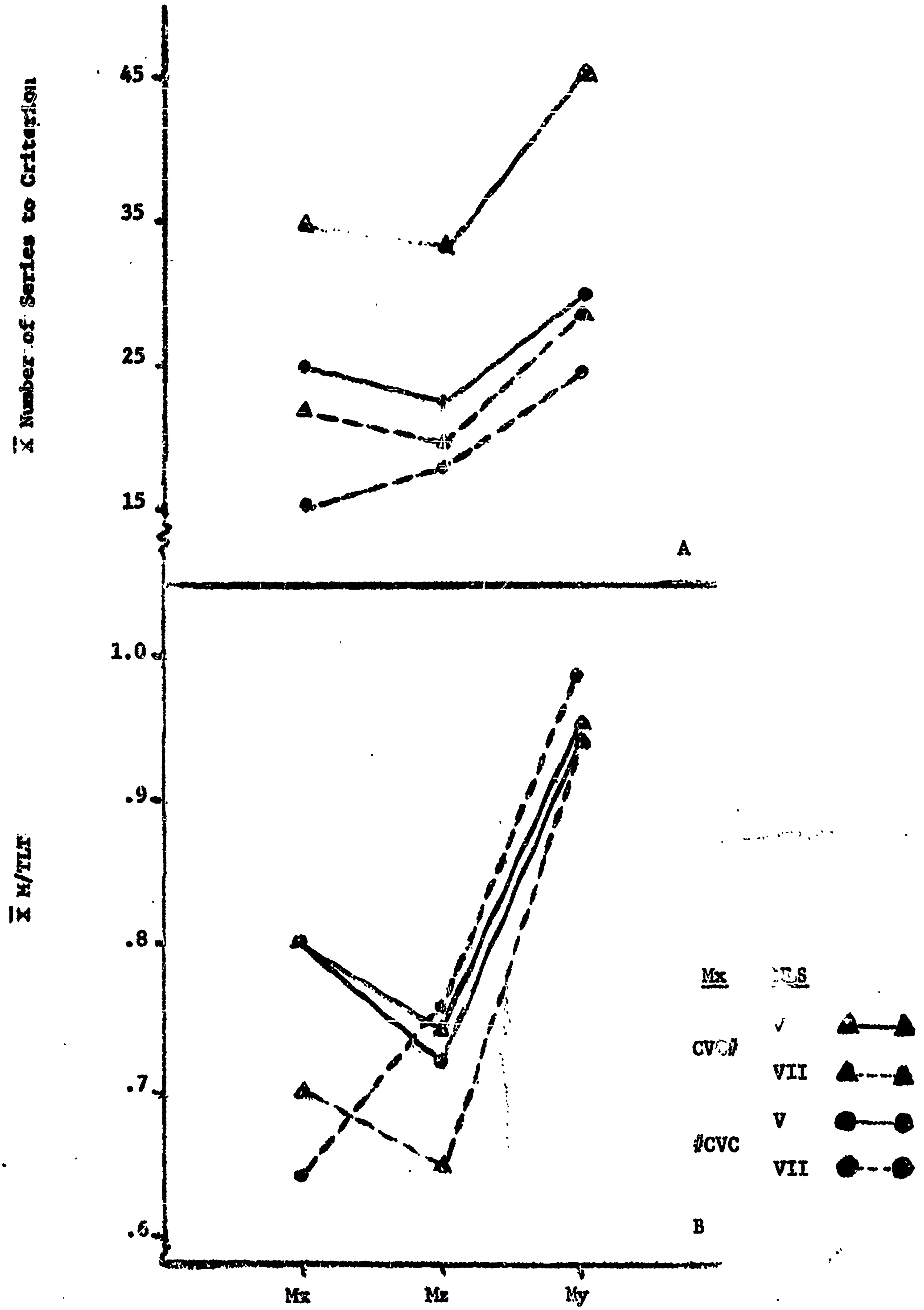
Order Difference

				Number of Series to Criterion				M/TLT		
Group	Mx	MLS		TLT	CVC	C-C	-V-	CVC	C-C	-V-
17	cvc#	V	$\bar{X}$	46.5	35.0	33.6	45.7	.805	.745	.956
			SD	21.2	14.5	16.1	22.1	.168	.136	.092
26	cvc#	VII	$\bar{X}$	31.0	22.0	19.9	29.1	.704	.651	.945
			SD	9.8	10.1	8.5	8.9	.205	.167	.057
18	#cvc	V	$\bar{X}$	31.0	24.9	22.5	29.8	.803	.722	.946
			SD	8.9	9.7	9.9	10.1	.144	.152	.080
27	#cvc	VII	$\bar{X}$	25.1	15.5	18.0	24.8	.641	.758	.988
			SD	10.5	7.7	6.9	10.5	.204	.171	.019

Note: N = 10 per cell.

FIGURE 8

Syntactic Difference



Variation in Phonetic Symbolic Relations

The set of variations of the My-scaled vowel relation (Row two, columns A and E of Table 1) produced no differences in MLS learning attributable to it. Only the difference among Morphemes was significant (1%). Figure 9 presents the mean M/TLT for each condition. The only implication to be drawn is to increase the impression of stability of MLS learning.

The Core Groups

Comparisons among the Core Groups, where the SU-RD pairings were made in the six possible combinations (Column A of Table 1) are the ones most directly related to the general problem of the relation between linguistic structure and cognition. As embodied in this design, the questions to be asked are about the effects of the semantic structures of MLSs as systems, and about the effects of the SU-RD pairings embedded in the MLSs. The question about the relative effects of RDs and SUs independently on the learning of these MLSs cannot be answered directly with the present design.[2] An attempt will be discussed below to get an extremely rough estimate of these effects.

Means and SDs for the learning measures on the Core Groups are presented in Table 10. One way ANOV of TLT shows a significant (5%) difference among MLSs. MLSs, Morphemes, and their interaction are significantly different at the 1% level by ANOV of the number of series to criterion for morphemes. The same analysis of the M/TLT measure produced a significant difference among MLSs (5%), Morphemes (1%), and their interaction (1%). In figure 10A, the groups are ordered along the abcissa by TLT, and the mean number of series to criterion for SUs is plotted. It is clear that TLT goes up in parallel with time to learn My---regardless of the RD paired with #-V- and the other RD-SU pairings in the MLSs. Time to learn Mx and Mz vary erratically with both RD and the other pairings. Figure 10B confirms the impression that rate of learning My is the main determinant of TLT. M/TLT remains constant and high over all MLSs while the curves for the other two SUs vary unsystematically.

In Figure 11, the M/TLT for RD-SU pairings is averaged over MLSs and plotted. This gives the best available picture of the relative effects of RD and SU. Proportion of TLT goes up directly with SU, the slope of this function varies with RD. How much of these functions are due to interactions with MLSs as a whole and/or the other pairings within MLSs cannot be estimated, but the impression is strong that differences in SUs account for much more of the variance than differences in RDs. The lack of significant main effect due to RD in the design aimed directly at this variable, also strengthens this interpretation.

[2] The psychophysical problems involved in trying to construct such variations as Sh-Sh-Sh, or C-S-C that would be reasonably comparable with the present RD variations seem insurmountable with present methodology. Statistical estimation is also impossible: in the incomplete lattice design that these groups make up, RD and SU are confounded with the MLS and Morpheme main effects and cannot be extracted as independent sources of variance.

FIGURE 9

Phonetic Symbolism

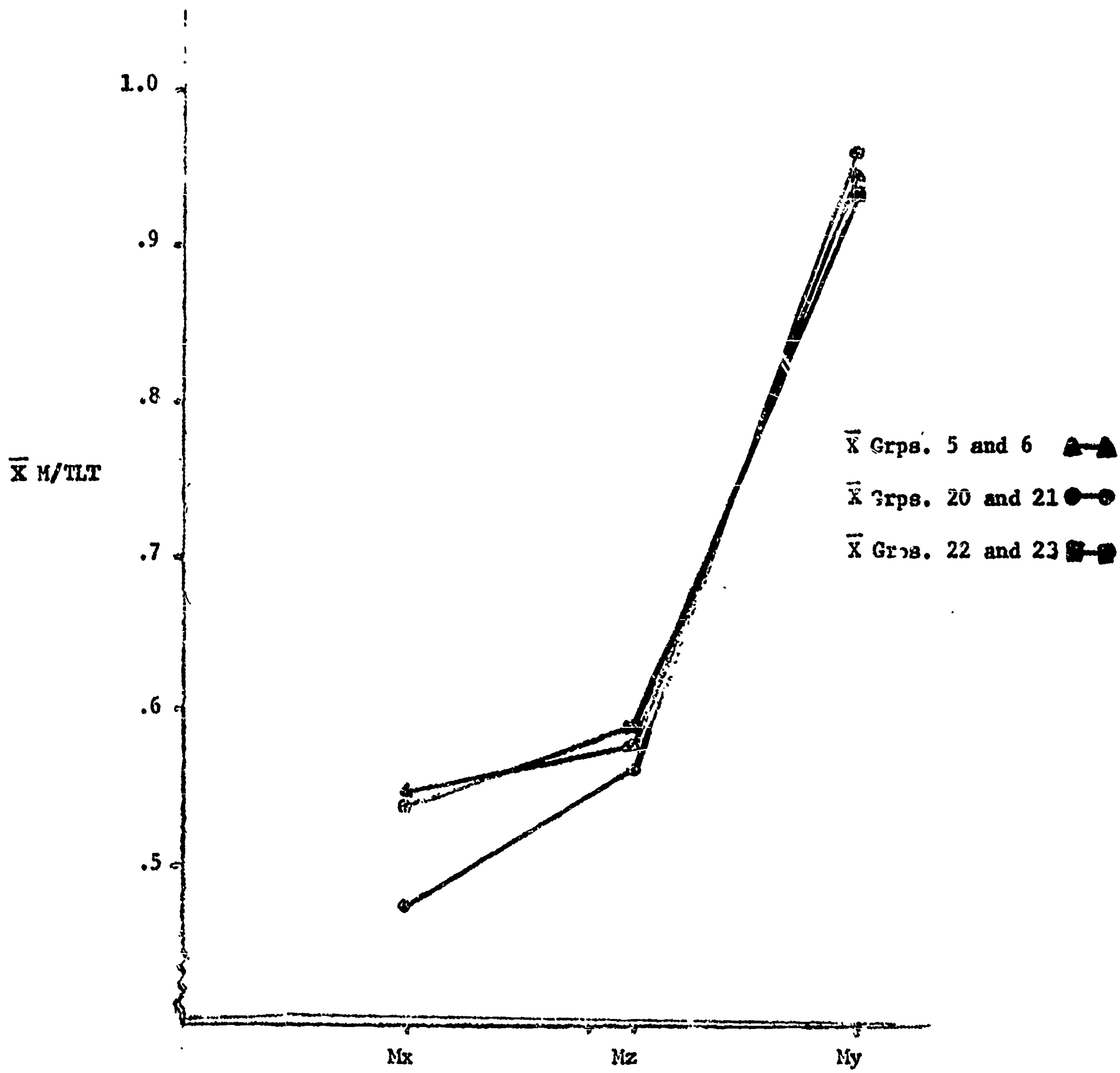


TABLE 9

Core Groups

Group						Number of Series to Criterion				M/TLT		
Mx	Ms		My	MLS		TLT	CVC#	#C-C	#-V-	CVC#	#C-C	#-V-
C	S2	31	Sh	XI	$\bar{X}$	38.4	16.4	18.8	37.6	.485	.556	.981
					SD	15.5	5.5	6.2	15.3	.195	.190	.038
S2	C	32	Sh	XII	$\bar{X}$	37.0	25.6	23.7	34.0	.722	.689	.891
					SD	13.4	8.3	6.7	15.2	.174	.174	.166
Sh	C	34	S2	XIII	$\bar{X}$	36.9	14.4	32.5	33.6	.399	.889	.911
					SD	8.7	7.8	8.6	10.1	.187	.138	.155
C	Sh	35	S2	XIV	$\bar{X}$	33.0	18.8	29.0	31.2	.585	.869	.937
					SD	10.6	9.9	9.1	11.0	.263	.103	.069
S2	Sh	36	C	V	$\bar{X}$	49.6	41.0	36.6	46.7	.818	.773	.933
					SD	22.1	20.1	15.9	21.7	.129	.156	.056
Sh	S2	37	C	VII	$\bar{X}$	27.6	12.6	16.1	26.3	.483	.674	.949
					SD	7.8	1.4	4.4	8.1	.148	.234	.099
					$\bar{X}$	-	13.5	21.3	39.0	.441	.623	.935
					$\bar{X}$	-	17.6	26.4	33.8	.535	.724	.901
					$\bar{X}$	-	33.3	30.8	32.0	.770	.879	.965

Note: All groups run by E 1 with sample 3. N = 10 per group.

FIGURE 10

Core Groups

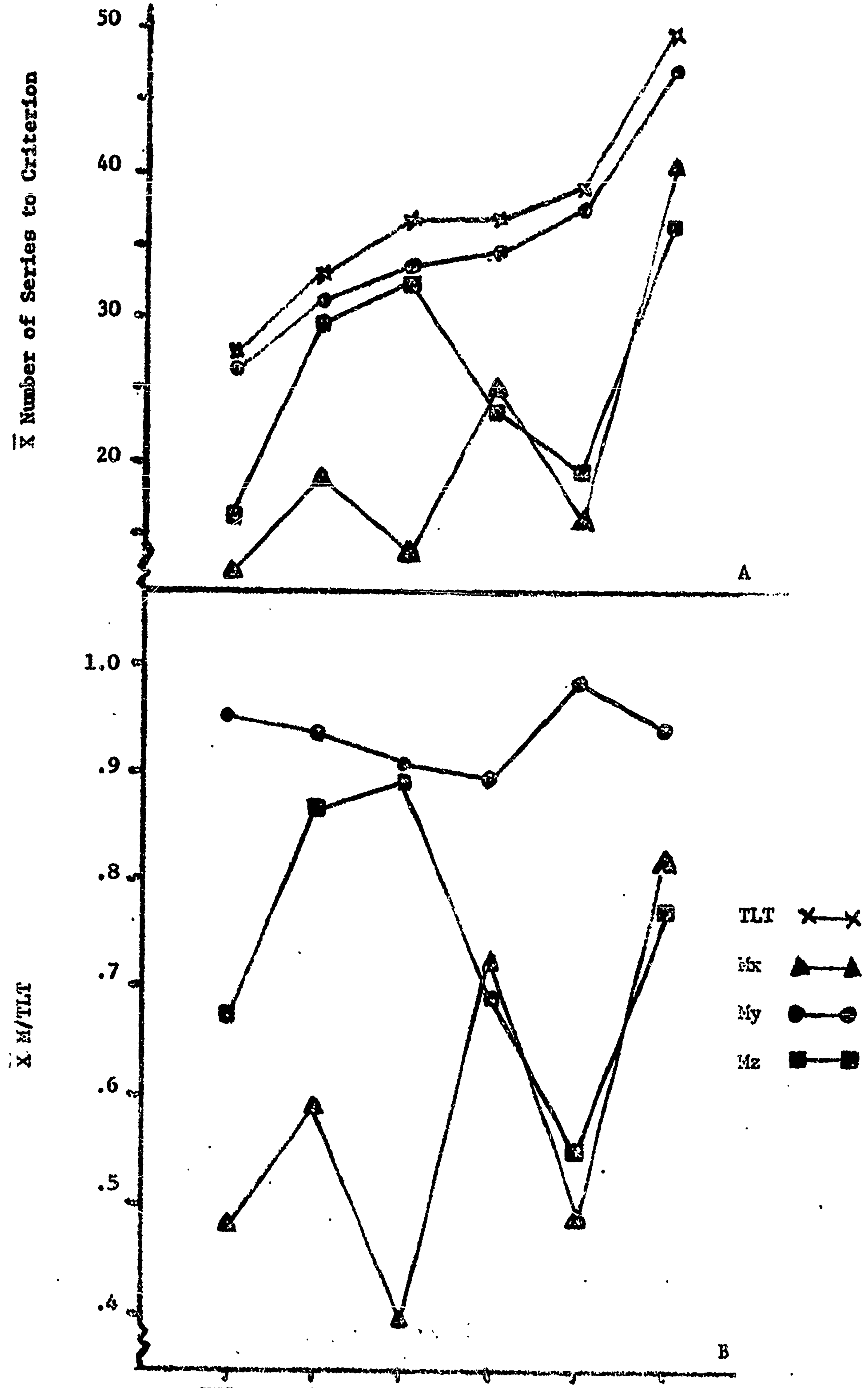
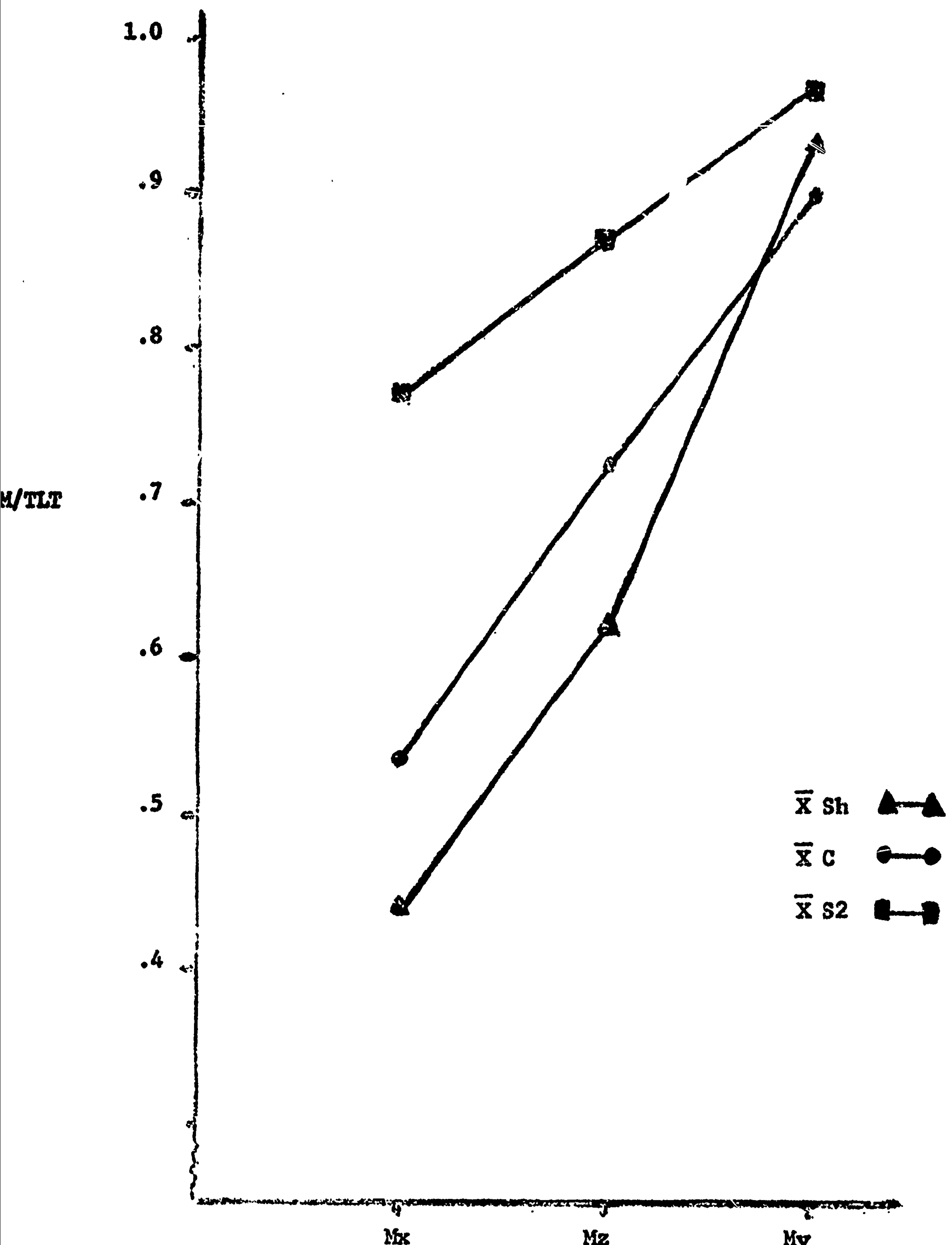


FIGURE 11

Mean RD Per SU in Core Groups

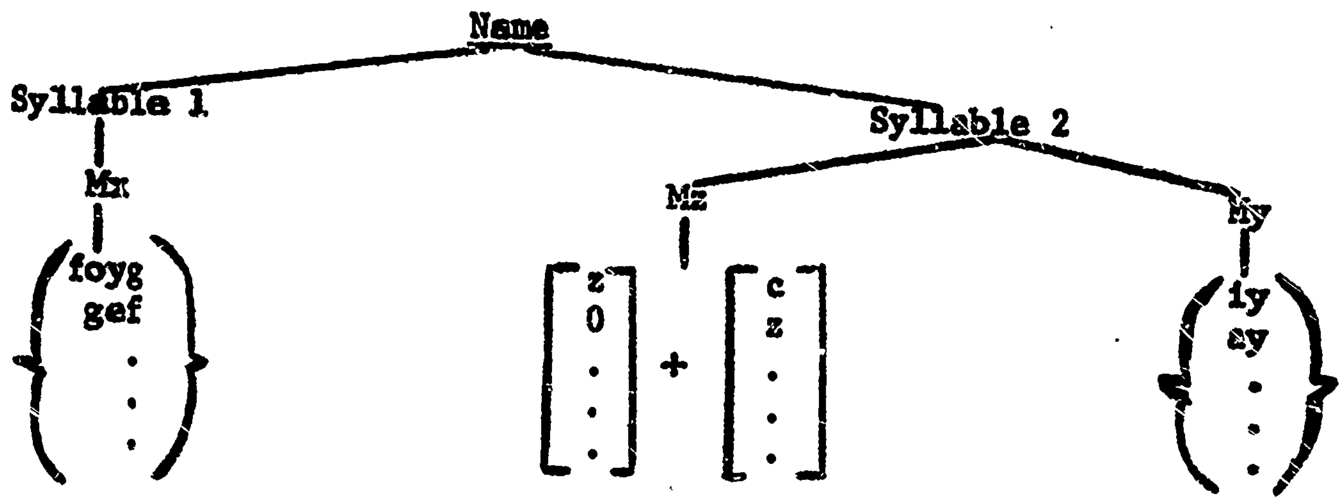


DISCUSSION

Using a model proposed by Chombsky (1963, Miller and Chomsky, 1963), the learning of the MLSs in these experiments can be interpreted in terms of the phrase structure grammar of Figure 12. Levant's work (1962) with the Rapoport model (1956, 1960, Rapoport and Horowitz, 1960)

Figure 12

Competence Model of an MLS



indicates that Ss first learn that there are three morpheme types (Levant does not indicate whether there is a previous stage of breaking the name into two syllables). The learning of morphemes, (the pairings of particular phonemic combinations and particular RD values) comes after the discovery that there are three morpheme types. The distribution of learning times for morphemes is ordered by morpheme type. As implied by Figure 11, the order of learning morpheme types seems to be primarily determined by SU and only secondarily by RD. The consistent finding of significant Morpheme main effects in all the analyses reported, with the lack of RD main effects in the design to evaluate this variable is consistent with this interpretation.

There seem to be several possible hypotheses about the source of this predominance of SU effects in MLS learning. The first is that it comes from the greater complexity of the right hand branch of the grammar. Once Syllable 1 and 2 are separated, the process from Syllable 1 to morphemes is linear; from Syllable 2, there is another branching into Morpheme types before reaching the level of morphemes. This extra branching from Syllable 2, may be what delays the learning of My and Mz. This interpretation, however, provides no rationale for the consistent learning of Mz faster than My. Yngve's hypothesis (1961) that the left-most nonterminal symbol in the last line of the already constructed derivation is always processed first, is consistent with grammar as presented in Figure 12, and with the finding that Mz is consistently learned before My. However, the results of these experiments cannot be taken as confirming the Yngve hypothesis: Figure 12 was constructed, and the morpheme types ordered, to make this point about his depth hypothesis. The Mx-Mz-My order came out of the data, and was not predicted from the Yngve model.

The order in which the morpheme types were learned probably could not be derived from any purely linguistic model, or certainly none of the ones being currently discussed. On an intuitive basis, it could be proposed that English speakers are not familiar with the discontinuous morpheme construction. This may be true, despite the existence of this type of construction in the paradigm of English 'irregular' verbs. But this intuitive notion would again provide no basis for predicting that Mz would be learned faster than My.

Psychological considerations may provide such a basis. Though discriminability differences could not make sense out of the pattern of results when one RD was substituted for another, differences in the discriminability of SUs may account for the order of <u>their</u> learning within MLSs. Again intuitively, it seems clear that differences among /CVC/s should be more easily discriminable than those between /C-C/s, which in turn, should be more discriminable than /-V-/s embedded in a consonant frame. The work at Haskins Laboratory tends to show, in general, that vowels are less discriminable than consonants (A. M. Liberman, Personal Communication).

Neither linguistic (the complexity of branching), not psychological (relative discriminability of SUs) hypothesis, would seem a complete account of the process of learning MLSs. Probably both factors account for some variance and further work on this question is necessary.

Relative rate of learning is ordered shape, color, size with both Mx and Mz (Figure 11). With My, the points are much closer together, and it is probably not sensible to discuss the fact that there is only one disagreement---out of only six possible orders---in My from that found in the other two morpheme types. Discriminability of RDs <u>within</u> MLSs may provide a clue to the order of rate of learning over differences in SUs. There seems no doubt that the differences among S2 were more difficult to discriminate than those among Shape and Color. There were a substantial minority of Ss who spontaneously stated that there were only three sizes (In our culture, everything comes in Small, Medium and Large.) as opposed to five shapes and five colors. This difficulty in discrimination may account for the high level and shallow slope of the S2 function in Figure 11. It is difficult to carry this notion over to account for the observed superiority of shape over color in learning rate. The colors were chosen to be highly discriminable and should have been learned faster than the shapes: which, as can be seen in Figure 2, were unfamiliar and there were indications from Ss comments that Shapes A and C were rather confusable.

Considerations of codeability (Brown and Lenneberg, 1954) may serve to throw light on the order of RD learning rates. We have no information on three of Brown and Lenneberg's measures of codeability; reaction time, communality, and S reliability. The average number of syllables, and the average number of words that one would need to name the shapes used in these experiments would seem to preclude the Shape RD coming out more codeable than Color---or Size---if the RDs of these MLSs were run through a codeability testing.

Starting from the RD order findings in Figure 11, the analysis of process can be carried one step further. In ordering the Core Groups MLSs by TLT (Figure 10A), it was found that curve for My followed the TLT curve very closely. The groups were ordered by the Sh-C-S order of mean M/TLT of the RDs per SUs. For example, ordering Mx by RD order produces the semantic structure Sh-C-S, Sh-S-C, C-Sh-S, C-S-Sh, S-Sh-C, S-C-Sh, which corresponds to the order of MLSs, VII, XIII, XI, XIV, XII, V. The data for mean M/TLT with the groups ordered thusly for Mx is plotted in Figure 13, and for Mz and My in Figures 14 and 15 respectively. Not surprisingly, as Mx is paired successively with shape, color, and size, the proportion of TLT taken to learn it goes up, while Mz varies unsystematically (Figure 13). The same is true of MLSs ordered by the RD of Mz (Figure 14). As would be expected from Figure 10B, M/TLT for My remains high and constant over both these orderings. When the MLSs are ordered by the RD of My (Figure 15), M/TLT for My presents the same picture of constancy and Mx varies erratically. The interesting finding under this ordering is that the proportion of TLT taken to learn Mz goes fairly steadily down. This observation probably represents one or more of the interactions that cannot be evaluated within the limitations of the present design and analyses---no immediate hypotheses present themselves.

The above discussion has been of the MLS learning process in the Core Groups where RD variables have been constant and counterbalanced over MLSs. The framework developed there will now be applied to the results of the other variables in these experiments.

Sample and E differences, supposedly residing in 'ability' and 'criterion' differences, could affect the process in many ways and further explication of them must wait on fuller understanding of the basic MLS learning process. Whether this will hinge on the difficult problem of the 'two psychologies' (Gagne, 1967), only time will tell.

The question asked about the effectiveness in the MLS situation of vowels scaled for phonetic symbolic value seems answered with a clear negative. Perhaps the relations manipulated here would have an effect if the morpheme was made an 'ending' in the fashion of most Indo-European languages rather than embedded in a discontinuous morpheme as in the present investigation.

The learning of MLSs V and VII remained essentially constant under the change from S2 to S3 referents. When Position was substituted for Size as an RD, the differences between MLSs V and VII were washed out. The M/TLT-Morpheme function (Figure 7) with Position as an RD is the same as the simple SU function of Figure 11. If discriminability of RDs within MLSs is an important variable, as suggested above, this finding could be further pursued with sets of RDs that are controlled and varied psychophysically.

FIGURE 13
Core Groups Ordered by RD of Mz

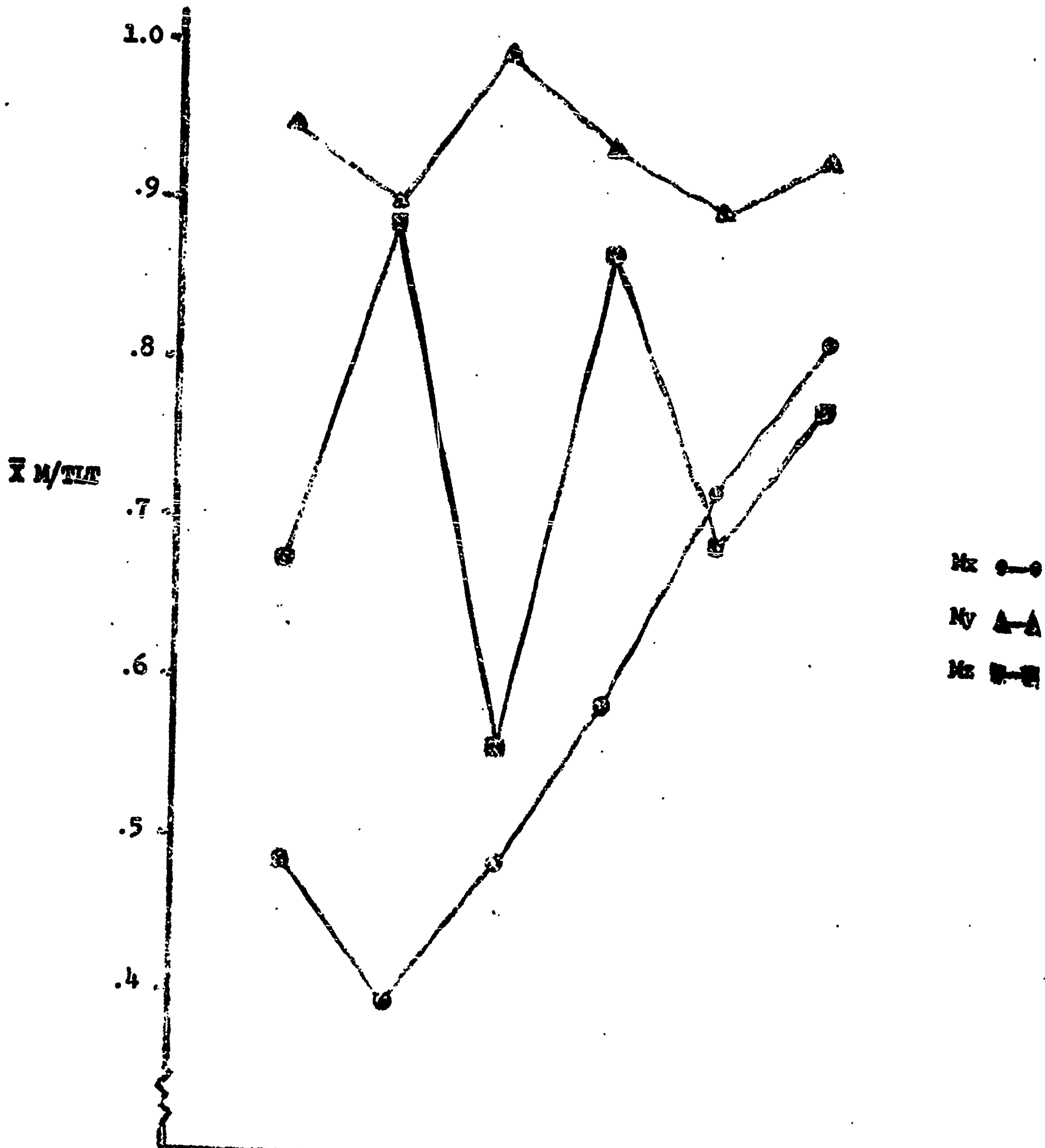


FIGURE 14

Core Groups Ordered by RD of Mz

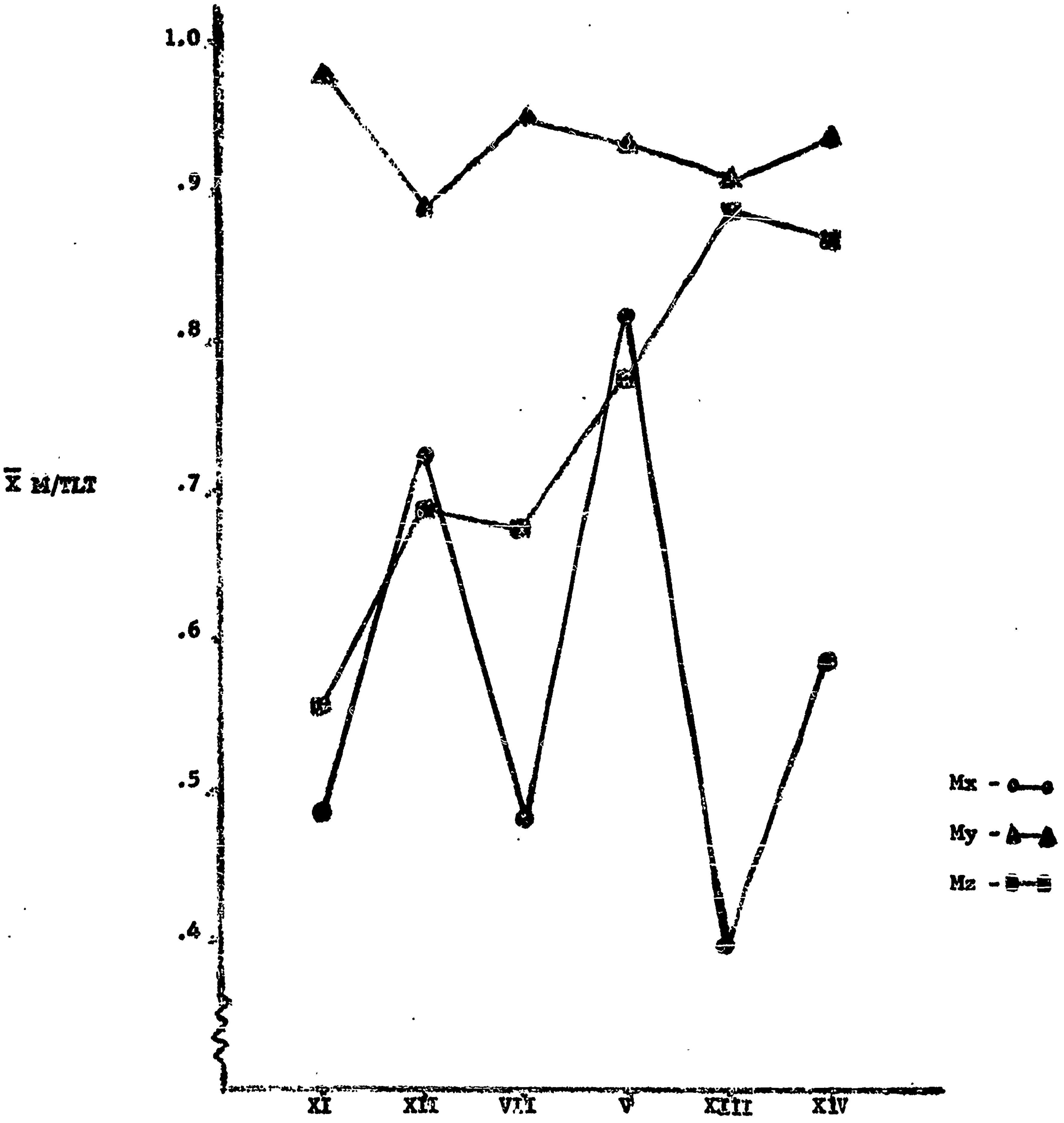
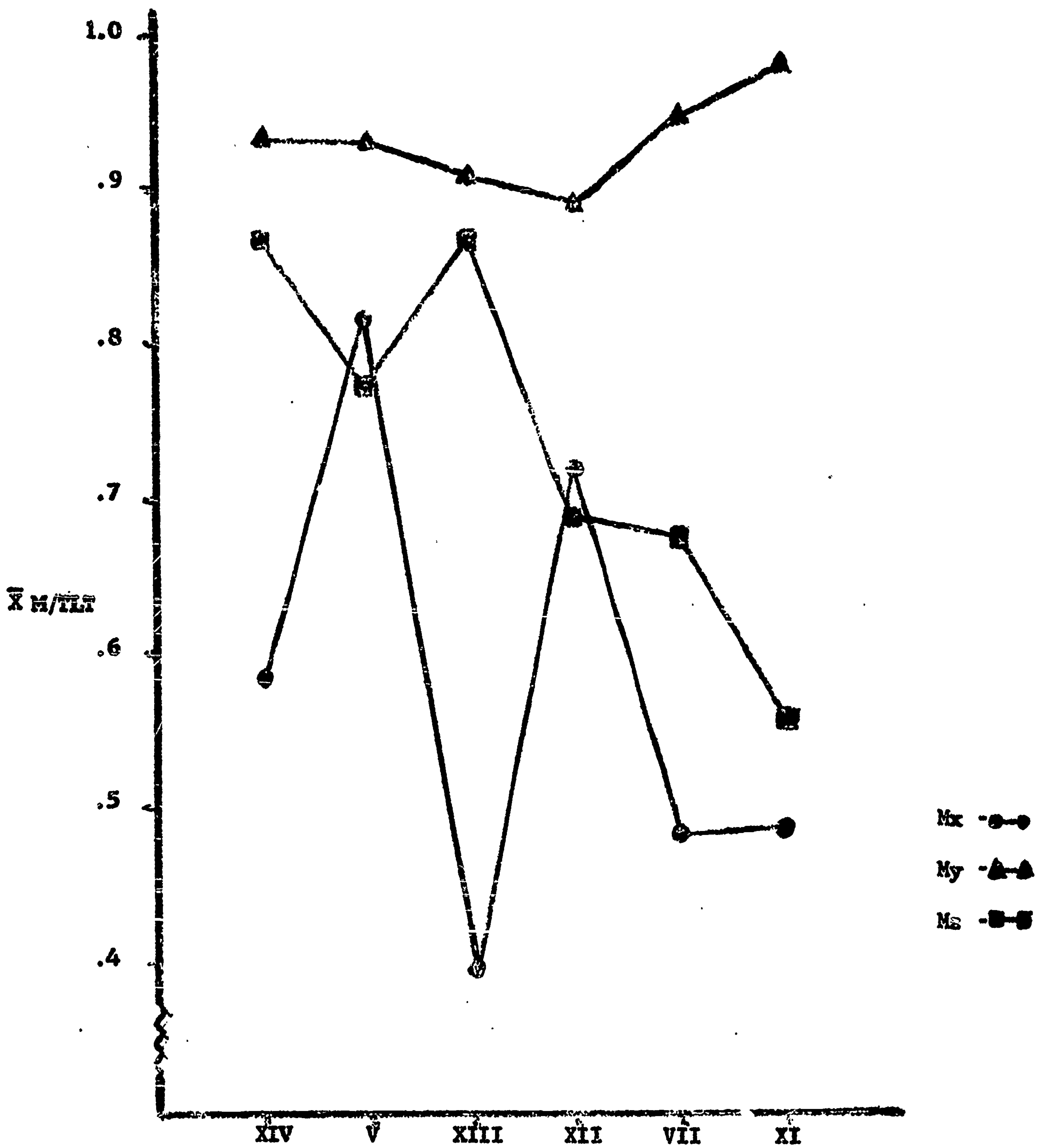


Figure 15

Core Groups Ordered by RD of My



The syntactic variation in the position of the discontinuous morpheme can be seen as merely as a reversal of the first branching of the model in Figure 12, putting the more complex branch structure on the left. The MLSs with this grammatical structure did learn significantly faster than with the complex branching on the right (Table 8). Here is some possible support for Yngve's model (1961). If complex analysis is done first, the load on immediate memory would be less detrimental to 'holding' the simpler unit than vice-versa. A CVC syllable probably has a good deal of unit-sequence character (Underwood & Postman, 1960) and unless attacked immediately may be more resistant to analysis because of this cohesiveness. This factor would seem to affect the whole learning process, since only the Morphemes difference remains significant for the M/TLT measure.

CONCLUSIONS AND IMPLICATIONS

Always the beautiful answer who asks a more beautiful question.

e. e. cummings

There is only one conclusion coming directly out of the results of these experiments that one would want to take a real stand on: the phonetic symbolic relations as manipulated did not have an effect on the learning of the MLS. Other findings, very properly at this stage of investigation, raise more problems than they settle.

Put in the context where this research originally arose, this series of manipulations of variables in the MLS situation demonstrate, as if another were really needed, that the relation between linguistic structure and cognition is extremely complex. Although results here indicate that structural variables account for the preponderance of variance being accounted for by structural differences, there are important indications that other variables do certainly interact with structural variables in the learning of MLSs. Here is empirical evidence that any strong form of the Whorf Hypothesis is oversimplifying the language-cognition relation.

Perhaps the major implication of these studies is the usefulness of the MLS experiment for investigating the complexities of language behavior. The control achievable and the amount of information derivable should make the use of MLSs widespread, perhaps even the 'tool of preference' in studying these phenomena. In connection with this, one major limitation on all the results must be mentioned. All the Ss were native speakers of English. Whether the problem is conceptualized in terms of associative interference or of S-R compatibility (Fitts and Deininger, 1954), there is no evaluation of how the long established linguistic and cognitive structures of English speaking Ss may interact with new ones required to learn MLSs. It would be most interesting to replicate at least some of these experiments with speakers of a non-Indo-European language. Cross-cultural research is extremely expensive and time consuming (as witness the SSRC Southwest Project in Comparative Psycholinguistics) and methodologically "fluky". American psychology must face up, however, to the severe limitations on the generalizability of many of its findings---not only in the language behavior area where it is most obvious---placed on them by lack of cross-cultural comparisons.

SUMMARY

A series of experiments were carried out investigating the effects of some linguistic and referent dimension variables on the learning of Miniature Linguistic Systems. A Miniature Linguistic System is a limited, artificial language made up of nonsense syllables and nonsense figure referents arranged in relations analogous to those in natural languages. Subjects were asked to learn the names of the referents without being told that there was a linguistic system determining the names. This experimental situation seems ideal for studying the relation between language and cognition under specifiable and controllable conditions.

The cr experimental groups explored the learning of Miniature Linguistic Systems where grammatical structure was held constant, and the referent dimensions were paired with structural units in all possible combinations allowed by the set of dimensions and units used. The learning of these systems was significantly affected by both grammars 'as a whole' and morpheme types, and these two variables interacted significantly. The results were discussed in terms of a Miller and Chomsky performance model. The major determinant appeared to be the nature of structural units, with lesser effects due to referent dimensions. Several alternative interpretations of the learning process were presented.

In a set of Minature Linguistic Systems where a syntactic difference was introduced, the overall time to learn was different for the syntactic differences, but the intra-language process seemed uneffected.

When different referent dimensions were substituted in systems of the same structure, there was no direct difference produced by these differences but they did interact significantly with the main effects due to grammatical system and morpheme type. Several alternate interpretations of these findings were discussed.

A test of the effectiveness of vowels scaled for size used as Size Morphemes produced no differences among groups where the referent size, scaled value of the vowel morpheme relation was varied.

Both subject and experimentor differences were found in the overall time to learn language systems, but there were only minor interactions between these variables and those manipulated to gain understanding of the learning process.

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APPENDIX A

Distribution of Experimental Conditions, Samples, and Experimentors

MLS	GROUP	SU			RD			SAMPLE	E
		Mx	My	Mz	Mx	My	Mz		
VII	5	cvc#	#v-v-	#c-c	Sh	S2	C	1	*
"	6	"	"	"	"	"	"	2	1/2
V	14	"	"	"	S2	Sh	"	1	1
"	16	"	"	"	"	"	"	2	5
"	17	"	"	"	S3	Sh	"	2	3
"	18	#cvc	-v-#	c-c#	"	"	"	2/3	1/3
VII	20	cvc#	#-v-	#c-c	Sh	S2	"	1	1
"	21	"	"	"	"	"	"	2	1/2
"	22	"	"	"	"	"	"	1	1
"	23	"	"	"	"	"	"	2	1/2
"	26	"	"	"	"	S3	"	2	4
"	27	#cvc	-v-#	c-c#	"	"	"	2/3	1/4
"	29	cvc#	#-v-	#c-c	"	P	"	2	1/6
V	30	"	"	"	P	Sh	"	2	1/6
XI	31	"	"	"	C	S2	Sh	3	1
XII	32	"	"	"	S2	C	"	3	1
XII	33	"	"	"	S2	"	"	2	4
XIII	34	"	"	"	Sh	"	S2	3	1
XIV	35	"	"	"	C	Sh	"	3	1
V	36	"	"	"	S2	"	C	3	1
VII	37	"	"	"	Sh	S2	"	3	1

* Where samples or Es are split, half of each group was from each sample, and/or half run by each E.

APPENDIX B

Machine Analysis and Data Extracted

The coding and punching the data from the original protocols took almost two years, beginning before the contract period and running through a great part of it. The data analysis was planned in four stages.

The first stage was a series by series ordering by response number from the random order in which the figures were presented. The three parts of the response (the three morphemes) were categorized as correct, intralist confusion, extralist response, or no response. This information was punched in a highly condensed form but still generated three cards of output for every two of input. This output is the base of further analyses. It is in a form that hopefully will provide the source for any new analyses that may be carried out in the future: it is essentially a complete reproduction of the original protocols categorized in the above terms.

The second stage derived measures for each S's performance from the previous output. These measures included learning criteria of increasing stringency, end-curve stability measures, rate measures for series by series progress, and confusion matrices.[1]

Stage three of the analysis derived group summaries of the S measures extracted in the previous stage.

Stage four was---and is---planned as the 'open-ended' tracking down of interpretable features of the findings from the most obvious indicators to lower levels that would allow illucidation of the process of learning MLSs and the effects of the manipulated variables. It was at this point that errors in the analysis, despite the many checks built into the process up to this point, began to show up and the time consuming process of tracking them down for correction began.

By this time, the project was well into the six month extension of the contract year and a decision was made to present the final report aiming for breadth of coverage by reporting only the analysis of time to learn measures. This decision was made in order to demonstrate the interesting findings coming out of these experimental manipulations, and the general usefulness of the MLS situation.

There is thus still a mass of unreported data in a highly available form, and the work will continue during the coming year while the author is on half-time leave.

1 Special acknowledgement must be made here of the diligence and skill of Stephen Josephson, who did this complex programming and helped the project in many other ways.

GROUP 5

S	TLT	NUMBER SER.S TO CRIT. CVC& SHAPE	&C-C COLOR	&-V- SIZE2	MORPH/TLT CVC& SHAPE	&C-C COLOR	&-V- SIZE2
1	23	13	16	22	0.565	0.695	0.956
2	40	15	25	39	0.375	0.625	0.975
3	19	13	12	19	0.684	0.631	1.000
4	31	12	20	26	0.387	0.645	0.838
5	17	16	16	17	0.941	0.941	1.000
6	45	19	20	45	0.422	0.444	1.000
7	18	9	17	17	0.500	0.944	0.944
8	39	10	16	38	0.256	0.410	0.974
9	35	15	17	35	0.428	0.485	1.000
10	37	11	23	37	0.297	0.621	1.000
MEAN	30.40	13.30	18.20	29.50	0.48571	0.64450	0.9689
SD	9.81	2.86	3.62	9.90	0.19254	0.17371	0.0475

GROUP 6

		NUMBER SER.S TO CRIT.			MORPH/TLT		
	TLT	CVC& SHAPE	&C-C COLOR	&-V- SIZE2	CVC& SHAPE	&C=C COLOR	&-V- SIZE2
S							
1	16	15	11	16	0.937	0.687	1.000
2	44	15	17	44	0.340	0.386	1.000
3	61	31	40	61	0.508	0.655	1.000
4	65	15	19	63	0.230	0.292	0.969
5	74	71	30	70	0.959	0.405	0.945
6	37	13	20	37	0.351	0.540	1.000
7	24	12	21	24	0.500	0.875	1.000
8	21	17	12	21	0.809	0.571	1.000
9	37	16	13	35	0.432	0.351	0.945
10	16	16	7	9	1.000	0.437	0.562
MEAN	39.50	22.10	19.00	38.00	0.60701	0.52031	0.9423
SD	20.05	17.04	9.29	20.08	0.27537	0.17136	0.1284

GROUP 14

S	TLT	NUMBER SER.S TO CRIT. CVC& SIZE2	&C-C COLOR	&-V- SHAPE	MORPH/TLT CVC& SIZE2	&C-C COLOR	&-V- SHAPE
1	25	24	20	21	0.960	0.800	0.840
2	21	21	15	18	1.000	0.714	0.857
3	32	18	16	19	0.562	0.500	0.593
4	20	20	16	18	1.000	0.800	0.900
5	30	20	23	30	0.666	0.766	1.000
6	36	36	18	30	1.000	0.500	0.833
7	34	30	34	30	0.882	1.000	0.882
8	31	31	25	30	1.000	0.806	0.967
9	34	14	14	33	0.411	0.411	0.970
10	23	15	22	21	0.652	0.956	0.913
MEAN	28.60	22.90	20.30	25.00	0.81354	0.72556	0.87579
SD	5.55	6.89	5.74	5.74	0.20911	0.18663	0.10856

GROUP 16

	NUMBER SER.S TO CRIT.				MORPH/TLT		
	TLT	CVC& SIZE2	&C-C COLOR	&-V- SHAPE	CVC& SIZE2	&C-C COLOR	&-V- SHAPE
S							
1	19	14	14	17	0.736	0.736	0.894
2	61	60	26	61	0.983	0.426	1.000
3	38	30	30	38	0.789	0.789	1.000
4	26	26	20	26	1.000	0.769	1.000
5	28	19	27	27	0.678	0.964	0.964
6	49	45	46	43	0.918	0.938	0.877
7	33	32	26	32	0.969	0.787	0.969
8	21	21	12	16	1.000	0.571	0.761
9	25	24	22	25	0.960	0.880	1.000
10	20	11	12	20	0.550	0.600	1.000
MEAN	32.00	28.20	23.50	30.50	0.85865	0.74641	0.9466
SD	13.04	14.02	9.70	13.07	0.15134	0.16157	0.0752

GROUP 17

	NUMBER SER.S TO CRIT.				MORPH/TLT		
S	TLT	CVC& SIZE3	&C-C COLOR	&-V- SHAPE	CVC& SIZE3	&C-C COLOR	&-V- SHAPE
1	49	42	30	49	0.857	0.612	1.000
2	86	31	37	86	0.360	0.430	1.000
3	47	36	36	47	0.765	0.765	1.000
4	13	12	9	9	0.923	0.692	0.692
5	45	43	37	43	0.955	0.822	0.955
6	29	19	19	29	0.655	0.655	1.000
7	50	47	42	50	0.940	0.840	1.000
8	22	19	18	20	0.863	0.818	0.909
9	48	38	37	48	0.791	0.770	1.000
10	76	63	71	76	0.828	0.934	1.000
MEAN	46.50	35.00	33.60	45.70	0.79416	0.73413	0.9556
SD	21.17	14.51	16.07	22.07	0.16797	0.13550	0.0923

GROUP 18

		NUMBER SER.S TO CRIT.			MORPH/TLT		
	TLT	C-C& COLOR	-V-& SHAPE	&CVC SIZE3	C-C& COLOR	-V-& SHAPE	&CVC SIZE3
S							
1	38	23	38	24	0.605	1.000	0.631
2	50	50	50	50	1.000	1.000	1.000
3	17	14	15	15	0.823	0.882	0.882
4	23	19	18	20	0.826	0.782	0.869
5	34	24	33	33	0.705	0.970	0.970
6	27	19	27	21	0.703	1.000	0.777
7	30	26	30	20	0.866	1.000	0.666
8	23	15	19	19	0.652	0.826	0.826
9	36	16	36	19	0.444	1.000	0.527
10	32	19	32	28	0.593	1.000	0.875
MEAN	31.00	22.50	29.80	24.90	0.72214	0.94616	0.8027
SD	8.86	9.89	10.05	9.67	0.15229	0.07951	0.1441

GROUP 20

		NUMBER SER.S TO CRIT.			MORPH/TLT		
	TLT	CVC& SHAPE	C-C& COLOR	&-V- SIZE2	CVC& SHAPE	C-C& COLOR	&-V- SIZE2
S							
1	30	8	16	30	0.266	0.533	1.000
2	29	20	21	29	0.689	0.724	1.000
3	40	10	21	38	0.250	0.525	0.950
4	38	9	11	37	0.236	0.289	0.973
5	38	22	27	38	0.578	0.710	1.000
6	20	16	13	20	0.800	0.650	1.000
7	59	13	12	59	0.220	0.203	1.000
8	34	11	13	29	0.323	0.382	0.852
9	29	15	15	29	0.517	0.517	1.000
10	19	11	9	19	0.578	0.473	1.000
MEAN	33.60	13.50	15.80	32.80	0.44621	0.50091	0.9776
SD	10.85	4.45	5.28	10.78	0.20133	0.16306	0.0445

GROUP 21

		NUMBER SER.S TO CRIT.			MORPH/TLT		
S	TLT	CVC& SHAPE	C-C& COLOR	&-V-SIZE2	CVC& SHAPE	C-C& COLOR	&-V-SIZE2
1	14	14	10	13	1.000	0.714	0.928
2	49	18	40	49	0.367	0.816	1.000
3	31	17	20	31	0.548	0.645	1.000
4	54	18	28	54	0.333	0.518	1.000
5	44	17	27	43	0.386	0.613	0.977
6	25	9	15	25	0.360	0.600	1.000
7	22	10	15	22	0.454	0.681	1.000
8	33	18	12	25	0.545	0.363	0.757
9	44	10	34	37	0.227	0.772	0.840
10	22	16	12	22	0.727	0.545	1.000
MEAN	33.80	14.70	21.30	32.10	0.49499	0.62715	0.95043
SD	12.66	3.49	9.84	12.56	0.21450	0.12518	0.0807

GROUP 22

	NUMBER SER.S TO CRIT.				MORPH/TLT		
	TLT	CVC& SHAPE	C-C& COLOR	&-V- SIZE2	CVC& SHAPE	C-C& COLOR	&-V- SIZE
S							
1	34	13	16	31	0.382	0.470	0.91
2	25	10	16	24	0.400	0.640	0.96
3	48	14	17	48	0.291	0.354	1.00
4	29	13	20	28	0.448	0.689	0.96
5	15	15	13	13	1.000	0.866	0.86
6	37	12	12	37	0.324	0.324	1.00
7	23	22	14	18	0.956	0.608	0.78
8	34	10	24	30	0.294	0.705	0.88
9	29	16	19	25	0.551	0.655	0.86
10	43	9	18	43	0.209	0.418	1.00
MEAN	31.70	13.40	16.90	29.70	0.48582	0.57337	0.923
SD	9.19	3.58	3.38	10.19	0.26205	0.16555	0.070

GROUP 23

		NUMBER SER.S TO CRIT.			MORPH/TLT		
	TLT	CVC& SHAPE	C-C& COLOR	&-V- SIZE2	CVC& SHAPE	C-C& COLOR	&-V- SIZE2
S							
1	12	12	9	12	1.000	0.750	1.000
2	27	21	19	27	0.777	0.703	1.000
3	33	10	17	29	0.303	0.515	0.878
4	41	19	23	39	0.463	0.560	0.951
5	44	40	33	37	0.909	0.750	0.840
6	20	11	13	20	0.550	0.650	1.000
7	26	13	20	26	0.500	0.769	1.000
8	26	7	13	26	0.269	0.500	1.000
9	50	24	24	47	0.480	0.480	0.940
10	29	19	9	29	0.655	0.310	1.000
MEAN	30.80	17.60	18.00	29.20	0.59077	0.59894	0.96109
SD	10.88	9.07	7.09	9.37	0.23075	0.14279	0.05553

GROUP 26

S	TLT	NUMBER SER.S TO CRIT. CVC& SHAPE	C-C& COLOR	&-V-SIZE3	MORPH/TLT CVC& SHAPE	C-C& COLOR	&-V-SIZE3
1	23	19	14	23	0.826	0.608	1.000
2	37	20	14	37	0.540	0.378	1.000
3	16	10	12	15	0.625	0.750	0.937
4	24	19	21	23	0.791	0.875	0.958
5	39	39	25	33	1.000	0.641	0.846
6	21	9	15	21	0.428	0.714	1.000
7	36	36	23	31	1.000	0.638	0.861
8	45	17	25	45	0.377	0.555	1.000
9	25	17	10	24	0.680	0.400	0.960
10	44	34	40	39	0.772	0.909	0.886
MEAN	31.00	22.00	19.90	29.10	0.70423	0.64709	0.9449
SD	9.81	10.06	8.49	8.92	0.20453	0.16700	0.0572

GROUP 27

		NUMBER SER.S TO CRIT.				MORPH/TLT		
	TLT	C-C& COLOR	-V-& SIZE3	&CVC SHAPE	C-C& COLOR	-V-& SIZE3	&CVC SHAPE
S							
1	13	10	13	7	0.769	1.000	0.538
2	37	26	37	33	0.702	1.000	0.891
3	17	14	17	7	0.823	1.000	0.411
4	45	18	45	15	0.400	1.000	0.333
5	9	9	9	9	1.000	1.000	1.000
6	33	30	32	25	0.909	0.969	0.757
7	23	15	22	16	0.652	0.956	0.695
8	29	27	29	15	0.931	1.000	0.517
9	21	17	20	16	0.809	0.952	0.761
10	24	14	24	12	0.583	1.000	0.500
MEAN	25.10	18.00	24.80	15.50	0.75806	0.98785	0.64078
SD	10.53	6.89	10.52	7.72	0.17068	0.01898	0.20394

GROUP 29

		NUMBER SER.S TO CRIT.			MORPH/TLT		
	TLT	CVC& SHAPE	C-C& COLOR	-V-& POSIT	CVC& SHAPE	C-C& COLOR	-V-& POSIT
S							
1	25	18	23	23	0.720	0.920	0.920
2	32	24	21	28	0.750	0.656	0.875
3	14	12	14	12	0.857	1.000	0.857
4	25	24	24	24	0.960	0.960	0.960
5	25	22	22	25	0.880	0.880	1.000
6	39	31	38	36	0.794	0.974	0.923
7	18	11	13	10	0.611	0.722	0.555
8	31	13	20	31	0.419	0.645	1.000
9	23	14	17	21	0.608	0.739	0.913
10	20	10	19	19	0.500	0.950	0.950
MEAN	25.20	17.90	21.10	22.90	0.71011	0.84471	0.8953
SD	6.92	6.68	6.60	7.56	0.16449	0.13179	0.1216

GROUP 30

		NUMBER SER.S TO CRIT.			MORPH/TLT		
	TLT	CVC& POSIT	C-C& COLOR	-V-& SHAPE	CVC& POSIT	C-C& COLOR	-V-& SHAPE
S							
1	23	16	20	20	0.695	0.869	0.869
2	51	47	36	40	0.921	0.705	0.784
3	17	17	17	12	1.000	1.000	0.705
4	22	21	16	18	0.954	0.727	0.818
5	16	10	15	16	0.625	0.937	1.000
6	53	18	49	45	0.339	0.924	0.849
7	24	7	10	24	0.291	0.416	1.000
8	33	30	32	33	0.909	0.969	1.000
9	107	102	107	105	0.953	1.000	0.981
10	26	19	19	26	0.730	0.730	1.000
MEAN	37.20	28.70	32.10	33.90	0.74211	0.82818	0.9008
SD	26.30	26.63	27.38	25.73	0.24437	0.17492	0.1038

GROUP 31

S	TLT	NUMBER SER.S TO CRIT. CVC& COLOR	&C-C SHAPE	&-V- SIZE2	MORPH/TLT CVC& COLOR	&C-C SHAPE	&-V- SIZE2
1	51	18	24	51	0.352	0.470	1.000
2	44	23	28	42	0.522	0.636	0.954
3	64	13	15	61	0.203	0.234	0.953
4	51	29	31	51	0.568	0.607	1.000
5	21	12	15	21	0.571	0.714	1.000
6	39	16	13	39	0.410	0.333	1.000
7	50	13	19	50	0.260	0.380	1.000
8	19	9	14	19	0.473	0.736	1.000
9	29	16	15	28	0.551	0.517	0.965
10	16	15	14	14	0.937	0.875	0.875
MEAN	38.40	16.40	18.80	37.60	0.48520	0.55058	0.9748
SD	15.51	5.51	6.19	15.33	0.19450	0.19004	0.0383

GROUP 32

		NUMBER SER.S TO CRIT.			MORPH/TLT		
	TLT	CVC& SIZE2	&C-C SHAPE	&-V- COLOR	CVC& SIZE2	&C-C SHAPE	&-V- COLOR
1	16	15	15	15	0.937	0.937	0.937
2	44	28	38	43	0.636	0.863	0.977
3	23	10	16	11	0.434	0.695	0.478
4	20	20	18	19	1.000	0.900	0.950
5	41	24	20	41	0.585	0.487	1.000
6	47	29	27	47	0.617	0.574	1.000
7	28	26	24	19	0.928	0.857	0.678
8	43	32	22	43	0.744	0.511	1.000
9	55	33	28	49	0.600	0.509	0.890
10	53	39	29	53	0.735	0.547	1.000
MEAN	37.00	25.60	23.70	34.00	0.72196	0.68840	0.89125
SD	13.37	8.26	6.67	15.18	0.17363	0.17396	0.16616

GROUP 33

		NUMBER SER.S TO CRIT.			MORPH/TLT		
S	TLT	CVC& SIZE2	&C-C SHAPE	&-V- COLOR	CVC& SIZE2	&C-C SHAPE	&-V- COL
1	20	20	16	18	1.000	0.800	0.90
2	17	15	16	16	0.882	0.941	0.94
3	19	14	18	16	0.736	0.9[illegible]7	0.84
4	44	42	18	43	0.954	0.409	0.97
5	27	22	25	27	0.814	0.925	1.00
6	35	33	15	30	0.942	0.428	0.85
7	32	27	17	31	0.843	0.531	0.96
8	25	24	22	22	0.960	0.880	0.88
9	21	19	20	20	0.904	0.952	0.95
10	48	39	39	48	0.812	0.812	1.00
MEAN	28.80	25.50	20.60	27.10	0.88524	0.76282	0.931
SD	10.19	9.17	6.78	10.57	0.07827	0.20891	0.055

GROUP 34

		NUMBER SER.S TO CRIT.			MORPH/TLT		
	TLT	CVC& SHAPE	&C-C SIZE2	&-V- COLOR	CVC& SHAPE	&C-C SIZE2	&-V- COLOR
S							
1	45	10	45	26	0.222	1.000	0.577
2	39	14	26	39	0.358	0.666	1.000
3	43	36	41	43	0.837	0.953	1.000
4	30	9	30	19	0.300	1.000	0.633
5	49	13	48	49	0.265	0.979	1.000
6	49	10	29	49	0.204	0.591	1.000
7	30	11	29	28	0.366	0.966	0.933
8	27	14	25	27	0.518	0.925	1.000
9	25	8	21	25	0.320	0.840	1.000
10	32	19	31	31	0.593	0.968	0.968
MEAN	36.90	14.40	32.50	33.60	0.39867	0.88929	0.91131
SD	8.71	7.81	8.55	10.09	0.18709	0.13816	0.15475

GROUP 35

S	TLT	NUMBER SER.S TO CRIT. CVC& COLOR	&C-C SIZE2	&-V- SHAPE	MORPH/TLT CVC& COLOR	&C-C SIZE2	&-V- SHAPE
1	50	20	45	50	0.400	0.900	1.000
2	31	9	27	28	0.290	0.870	0.903
3	32	32	21	30	1.000	0.656	0.937
4	16	16	16	16	1.000	1.000	1.000
5	30	11	30	29	0.366	1.000	0.966
6	44	41	34	41	0.931	0.772	0.931
7	26	11	26	25	0.423	1.000	0.961
8	47	22	42	46	0.468	0.893	0.978
9	20	10	18	15	0.500	0.900	0.750
10	34	15	31	32	0.470	0.911	0.941
MEAN	33.00	18.80	29.00	31.20	0.58505	0.89053	0.9370
SD	10.62	9.94	9.06	11.03	0.26337	0.10282	0.0687

GROUP 36

		NUMBER SER.S TO CRIT.			MORPH/TLT		
	TLT	CVC& SIZE2	&C-C COLOR	&-V- SHAPE	CVC& SIZE2	&C-C COLOR	&-V- SHAPE
S							
1	79	54	54	79	0.683	0.683	1.000
2	70	55	60	70	0.785	0.857	1.000
3	74	72	30	66	0.972	0.405	0.891
4	28	24	25	24	0.857	0.892	0.857
5	22	22	22	21	1.000	1.000	0.954
6	26	15	21	25	0.576	0.807	0.961
7	24	18	19	20	0.750	0.791	0.833
8	71	68	60	64	0.957	0.845	0.901
9	44	33	28	43	0.750	0.636	0.977
10	58	49	47	55	0.844	0.810	0.948
MEAN	49.60	41.00	36.60	46.70	0.81788	0.77300	0.93254
SD	22.08	20.09	15.88	21.67	0.12861	0.15585	0.05552

GROUP 37

	TLT	NUMBER SER.S TO CRIT. CVC& SHAPE	&C-C COLOR	&-V- SIZE2	MORPH/TLT CVC& SHAPE	&C-C COLOR	&-V- SIZE2
S							
1	43	12	12	41	0.279	0.279	0.953
2	31	15	21	28	0.483	0.677	0.903
3	31	12	12	31	0.387	0.387	1.000
4	31	13	24	31	0.419	0.774	1.000
5	22	15	13	22	0.681	0.590	1.000
6	21	11	10	14	0.523	0.476	0.666
7	35	13	15	34	0.371	0.428	0.971
8	21	12	21	21	0.571	1.000	1.000
9	26	11	18	26	0.423	0.692	1.000
10	15	12	15	15	0.800	1.000	1.000
MEAN	27.60	12.60	16.10	26.30	0.49409	0.63057	0.94948
SD	7.78	1.35	4.43	8.05	0.14803	0.23422	0.09896