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The effects upon short-term memory of acoustic interference and the cognitive separation of a redundant element

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THE EFFECTS UPON SHORT-TERM MEMORY OF ACOUSTIC INTERFERENCE AND THE COGNITIVE SEPARATION OF A REDUNDANT ELEMENT

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TO MOM AND DAD

PREFACE

The author takes pleasure in acknowledging the advice and supervision given to him by Dr. James Tromater during the course of this investigation. The author would also like to acknowledge the assistance given by Dr. Kenneth Blick, Dr. William Leftwich, and a fellow colleague, James Overton.

PREFACE

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Chapter I

INTRODUCTION

Sperling (1963) noted that some subjects (Ss) stated they could "hear" material being held in short-term storage, and he suggested that short-term memory (STM) for verbal materials may be in the form of an auditory loop. The first major laboratory investigations of this topic were made by Conrad (1962;1964) who examined the errors made in immediate recall, and found that substitution errors tend to involve units that sound alike (acoustically-similar), even when the original stimuli were visual. He concluded that visual letters are recorded into auditory representations, which may subsequently be confused with one another. The auditory, or at least linguistic character of immediate memory has been impressively documented in a series of studies by Wickelgren, who demonstrated that phonetically similar letters impair recall in both a "retroactive (1965a) and a "proactive" (1966a) design. "Intralist" inhibition also appeared in a study (1965b) which found a high error rate in lists composed of letters that sound somewhat alike. Auditory similarity even affected STM when a method of recognition was employed, so that the subject need only say whether a particular test letter was or was not present in a preceding series (Wickelgren, 1965c; 1966b). These studies represent an explicit link between speech perception and immediate memory. The confusions among similar sounding letters cannot be ascribed to errors made in hearing them originally, since Wickelgren's Ss always began by copying the stimulus as it was presented.

Theories of Organization in STM

Having demonstrated that STM is essentially auditory, a more specific question to be answered is how the memory is organized. Several major competing theories about its organization exist; the slot theory, the association theory and the rhythm theory. Each of these interpretations will be briefly stated, so that the implications of the present thesis may be more easily related to current theoretical interpretations of immediate memory.

Slot Theory

Auditory memory may be thought of as the formation of a number of slots, bins, or "neuron pools" into which Ss put successive chunks of input. The span is limited to seven items because there are only that many slots (Miller, 1956a; 1956b). The slots exist before the stimuli appear, and by definition each holds exactly one chunk. When AZBDGKMQ is heard, A is put into slot #1, Z into slot #2, etc.. Forgetting then results from the gradual fading of each slot's contents and can be prevented by active rehearsal. The fact that Ss usually know the serial position of the items they can still remember, even when they have forgotten intervening material adds support to this interpretation. In addition, the curious "serial order intrusions" of Conrad (1960a), (instead of reporting the 6th item of a series just presented, Ss report the 6th item of the immediately preceding series) are explained by the slot theory as vestigal remains of previously tested arrays lingering in their slots, whence they are sometimes mistakenly retrieved.

Despite this and other arguments in favor of the slot theory, its adherents are in the minority. An alternative to the slot theory, which appeals to many experimental psychologists, is that STM and all other memory may simply depend on "associations".

Association Theory

The associative interpretation suggests that the successive items that are heard may be just bonded together so that each tends to elicit the next one in recall. On this view, when AZBDGKMQ is heard, new or strengthened associations are acquired between A and Z, Z and B, etc.. When the series is recalled, the Rs are determined by these bonds, analogous to the S-R and S-S models in learning theory. A principle advantage of the associative theory is the continuity between STM and LTM which it suggests. Wickelgren (1965a) argues for an associative theory over a slot theory on the basis of the interfering effects of auditory similarity.

A clear and concise account of the way "chunks" are organized in the memory span is apparent in neither the slot nor the associative theories. For this reason, Neisser (1967) has proposed a third interpretation based on rhythmic structuring.

Rhythm Theory

One of the most prevalent phenomena in auditory memory is subjective grouping. Ss recall a letter series as AZB-DGK-MQ, or in some other subjective sequence. Neisser suggests that rhythmic patterns must be represented by single unitary codes in the response system, and the way to think of the effect of rhythm is that it may provide a set of reference points, to which elements can be attached. Once a S has initiated the pattern, it runs automatically and he can learn that 'Q' occurs at the end of it, or that 'G' is the middle element of the second group. Such positions do not exist unless they form part of a subjectively created organization. In a sense, this is analagous to a slot theory in which the S makes up his slots as he goes along. A number of phenomena in auditory memory can be interpreted on a rhythmic basis, one of which is the "prefix effect". Conrad (1960b) found that simply saying the digit "nought" between an eight items series and its recall reduced scores in his Ss from 73% to 38%. This finding implies that any verbal response must be somehow incorporated in the rhythm structure. The rhythm pattern then, is a structural organization, which serves as a support, as an integrator, and as a series of cues for the words to be remembered.

Neisser has so aptly stated that the choice between such different theoretical interpretations of organization in STM can never be based on any crucial experiment, but rather special interest will inevitably be focused on phenomena which are easily understood within one framework but awkward or difficult for others. The "prefix effect" and, as will be seen, the "suffix effect", being key factors in this thesis, are such phenomena which have resisted explanation in S-R or associative terms.

<u>Response Prefix and Stimulus Suffix Effects in Immediate Memory</u>

Conrad (1958; 1960) was the first experimenter, as was noted previously, to require a response prefix: Ss had to say the digit '0' before recalling the memory series. This brief "interpolated" activity reduced recall substantially. Dallet (1964) confirmed this finding and made an even more striking discovery. A similar decrement appeared when E himself prefixed the stimulus string with a '0' that Ss did not have to repeat. Dallet symbolized this latter condition as 07:7, meaning that the stimulus was zero followed by seven digits, and the response was the seven digits. Conrad's response prefix condition becomes, under his notation, 7:07 while 07:07 stands for the case where S repeats the "redundant" zero also spoken by E. Dallet found that all three of these conditions were significantly worse than 7:7, while they did not differ significantly from each other, nor from 8:8.

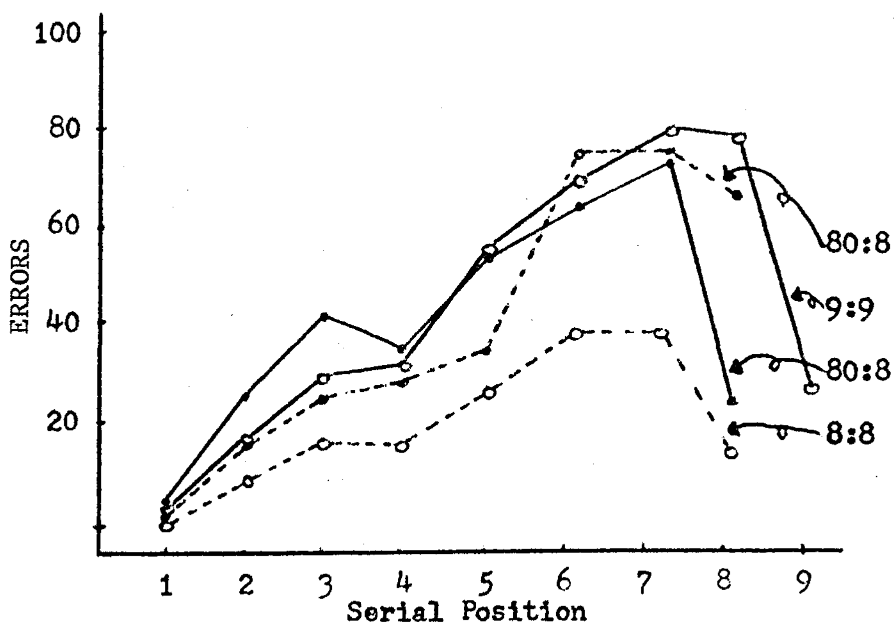
A number of workers have replicated and extended these findings (Crowder, 1967; Whimby and Leiblum, 1967; and Crowder and Hoenig, 1968). It has been established that the prefix effect is not due to the extra delay introduced by the spoken prefix, nor to the burden of remembering to emit or omit the prefix, nor to the interference from the greater similarity of series that all start with zero.

These studies and others have come to be known as investigations of the effects of redundant elements in an immediate memory task. Immediate memory experiments contain redundant elements when, over a substantial block of trials, the series S receives, or his reproduction of it, contains some predictable element. By predictable is meant that the location and identity of the extra element is known in advance of the trial. In this thesis concern is only with conditions in which the redundant element occurs between presentation of the last non-redundant element (7o:7) and reproduction of the beginning of the series (7:07). By stimulus suffix is meant that the redundant element is presented by E himself, as if it were the n+1th element of a series of n elements (70:7). The response prefix occurs as S, following previous instructions, emits the redundant element just before initiating serial reproduction of the memory series (7:07). In both cases, the redundant element has been found to produce substantial decrements in recall (e.g., Crowder, 1967).

Serial Position Effects with Redundant Elements

Of significant importance is the fact that the prefix and suffix effects, although of comparable magnitude, react differentially upon the

the serial position function. Both Morton (1968b) and Crowder (1967, Exp.3) found that the stimulus suffix effect increased directly with serial position, the greatest effect occurring at the terminal element. The effect of the stimulus suffix is to reduce the availability of the last elements in the series. On the other hand, the prefix does not apparently change the form of the serial position function, only its elevation, relative to a non-redundant series. This relationship is graphically represented below as reproduced from a study by Crowder (1967).



Crowder and Morton (1969) very recently have proposed a conceptual system of information-flow in immediate memory tasks, which gives explanation for the various serial position data found in studies of redundant elements.

One central consequence of stimulus identification is postulated to be an articulatory event, preceded by an acoustic or other precategorical store.

Acoustic features, then are relevant only prior to categorization. Coupled with recent findings of modality effects in immediate memory (Corballis, 1966; Murdock, 1967) which conclude that auditory presentation provides an extra source of information about recent stimuli which is not available through the visual mode, Crowder is led to propose, with additional documented evidence, that the stimulus suffix effect is interpretable in terms of categorized information. Specifically, the suffix displaces a source of extra stimulus information deriving from auditory presentation. The mechanism for the response prefix effect, although not directly suggested by their data, is thought to result from articulatory interference. Since the Precategorical Acoustic Storage (PAS) is relevant only to the late serial positions, the redundant suffix has a selective effect; but since articulatory coding is a perceptual consequence for all elements in the list, the prefix has a non-selective overall effect on errors in recall, thereby producing, as was stated earlier, differential effects upon serial position, but not in overall errors made in recall.

<u>Acoustic Similarity and the Prefix Effect</u>

If the response prefix effect is caused by articulatory interference, then the similarity, in terms of articulation, of the prefix element to the members of the memory series should be directly related to the size of the prefix effect. A recent study (Crowder, 1969) has partially confirmed this prediction by showing that when the dominant phoneme in a memory list was "e" (BDGZPCE), a larger decrement was obtained when the prefix was the letter "V" than when it was "K", all data collected with visual presentation and written recall. Crowder warns however, that the extent to which phonetically based "retroactive inhibition" is responsible for the prefix effect must be assessed in further research, since the particular letters chosen (V and K) insufficiently represented the full range of phonic similarity. One of the purposes of this thesis was to represent by design, a more complete range of phonetically similar elements.

Modality Effects in Investigation of Redundant Elements

Earlier, this author reported that research supports the contention that auditory presentation provides an extra source of information about recent stimuli which is not available through the visual mode. It follows from Crowder and Morton's proposal (1969), (that is, that the stimulus suffix displaces a source of extra stimulus information (PAS) deriving from auditory presentation) that if Ss were required to vocalize a visually presented list, the vocal emmission of a response prefix should affect PAS and thereby, the serial position data more suggestive of a suffix effect. One complication to this interpretation of a response prefix effect is the finding by Crowder and Erdman (1968) that a vocalized prefix leads to a larger effect than a written prefix following vocal presentation. On the surface this would seem to indicate that the acoustic intensity of the prefix affects performance through PAS, but the increased effect of a vocalized prefix was not more pronounced in the terminal serial position than elsewhere in the list. In other words, making a written prefix more like a suffix by having S pronounce it led to an impirical result more suggestive of an increased prefix effect.

Speech Perception in Immediate Memory Tasks

Related investigation of organization in immediate memory has been recently conducted by Neisser (proponent of rhythm theory). Neisser (1969) has investigated perceptual organization in the prefix effect and attributed its effect to mechanisms of speech perception. The S's ability, according to Neisser, to repeat eight elements correctly depends on his capacity to plan a structured utterance with eight parts, whether one of the parts is known in advance or not. The redundant prefix element will take up as much space in the structure as any other element. Neisser, Hoenig, and Goldstein (1969) explored a change in the stimulus (e.g., the redundant prefix spoken by a female voice, and the memory series spoken by a male voice) which made it easier to separate the prefix cognitively from the rest of the string. The result was an absence of any significant prefix effect when experimental conditions allowed the S to deal with the prefix separately from the rest of the members of the string. These results lend considerable support to the rhythm interpretation of organization.

Thesis Intent

It seemed meaningful to this author to extend Neisser's conclusion by applying it to the stimulus suffix condition, that is, if experimental conditions permitted the S to cognitively separate the redundant suffix element from the rest of the members of the string, would the stimulus suffix effect still occur? And would the typical serial position findings pertaining to the suffix condition still be found? Would some form of cognitive separation negate the maximum impairment in performance provided by vocalization at presentation and recall? According to Crowder and Morton's interpretation, auditory traces would be set up, thereby maximizing errors late in the memory series, due to the acoustic properties of the input and output channels being identical.

To recapitulate, the rationale and intent of this thesis was as follows: Further evidence of the effects of redundant elements in immediate memory was needed regarding

a. a more complete range of phonetically similar and neutral items as redundant prefix and suffix elements in a memory series, so as to assess the extent of "retroactive inhibition" as being responsible for the impairment in performance.

b. the vocalization of a redundant prefix, so as to provide additional data and help clearify the puzzling finding (to Crowder and Morton's PAS) that, with vocal recall, the serial position data suggested a more increased prefix effect rather than increased similarity to a suffix effect.

c. the "cognitive separation" of redundant elements, and its effects particularly on the serial position data of a stimulus suffix condition.

The purpose of the present thesis was therefore to test the following hypotheses:

1. A thorough representation of phonetically similar prefix and suffix elements would, as a group, significantly impair the retention of a memory series.

2. The vocalization of a response prefix would yield a more increased prefix effect, that is, significantly more overall errors in the memory series with a pronounced effect at the terminal positions.

3. The cognitive separation of the redundant element would negate the maximum impairment in performance produced by vocalization at presentation and recall.

Chapter II

METHOD

Subjects

Each of 36 Ss were drawn from the introductory psychology classes at the University of Richmond, who participated in the experiment as part of their course requirements. It was necessary to drop 4 Ss due to the malfunction of the interval timer.

Materials

A Kodak Carousel Model 800 slide projector was used in conjunction with a Hunter Interval Timer to govern slide changes. The slides were typed in upper case letters on Radio-Mat transparencies mounted in Kodak Ready Mounts. A 12 x 12" projection screen was mounted 10" above the surface of a table such that the central point of the screen was at S eye level. Directly below the screen was a grid of eight 2 x 2" blocks mounted to the surface of the table.

Design

Each of 32 Ss recalled 160 series of eight consonant letters. Each S served in four experimental conditions (Factor B) over successive blocks of 40 trials. The conditions were: Control (8:8), Response Prefix (8:08), Stimulus Suffix (80:8), and a modified Stimulus Suffix condition (80':8). The order of the four conditions were counterbalanced by means of a systematic method of randomization (Underwood, 1949). The modified Stimulus Suffix condition was designed such that a 3-space break between the main string and the suffix existed, in addition to a different typographical case (lower case as opposed to upper case).

Each of the eight-letter memory stimuli were composed of randomly-selected letters from the subset BCDGPTVZ (S1) and HJINRXQY (S2). An equal number of letters from each subset appeared in the serial positions 1,2,3,...,7,8 (Factor C) an equal number of times over forty series.

Each of the letters in the high (H) similarity subset (S1) and the low (L) similarity subset (S2) were used as redundant elements five times in the response prefix, stimulus suffix, and modified stimulus suffix conditions, that is, one group of Ss (a1) received forty series or trials of H redundant elements, and the other group (a2) received forty trials of L redundant elements within each of the three conditions. A more complete range of phonetic similarity was therefore evident by this design. The control condition was composed of forty trials of an equal number of letters from each subset (S1 and S2). The same ordered list of 160 memory stimuli were used for all Ss so as to unconfound both order effects and individual stimuli with conditions (Appendix A, Table I).

The location of the H and L elements within the eight-letter stimuli did not conform to any specific alternating pattern (The stimuli used by Crowder (1969) conformed to patterns of single, double and quadruple alternation which resulted in not only significant main effects of H and L pattern, but also significant interaction between pattern and serial position, indicating that the locations of phonetically homogeneous letters affected the form of the serial position function). Because of the interest in the effects upon serial position of the Modified Stimulus Suffix condition, it was necessary to control this interacting variable of pattern alternation by randomizing the position of H and L elements.

Although the number of letters from S1 (and likewise S2) were not found to exactly equal one half that of the forty elements in each of the eight serial positions over forty trials, the slight inequalities were corrected by E without hindering the random representation of letters across trials. A table of random permutations of sixteen numbers (Winer, pg.659) was used to assign each letter to one of the eight serial positions, with the exception of several changes by E in order to equate the number of letters from S1 and S2 within each series.

Procedure

The memory series were presented visually, all eight (nine within suffix conditions) letters at once, for a period of 3.2 seconds. After disappearance of the stimulus slide, a period of 8.8 seconds was allowed for ordered verbal recall. Ss were provided with a grid of eight 2 x 2" blocks and asked to point to the corresponding blocks as they recited each letter. A similar procedure was employed by Neisser, Hoenig, and Goldstein (1969). This device was employed in order to indicate to E the positions of unknown letters. The Ss were instructed to vocalize the series during both the presentation and the recall phases (Appendix A, Table II). Five practice trials were given to each S prior to the beginning of the experiment in order that Ss completely understood their task and were able to pronounce the memory series within the 3.2 seconds. Clarifying instructions were also given prior to each of the experimental conditions along with three practice trials. Instructions generally included: emphasis on the ordered recall of elements, a demonstration as to the pointing to the blocks as they recited letters, and the pronouncement of the word "blank" as they touched a block, the corresponding letter to which they could not recall.

All statistical tests were performed at the .01 level of significance. An IBM 360 (Model 40) was employed for the main analysis of variance.

Chapter III

RESULTS

Performance was scored in terms of total errors in recall as a function of serial position. Results were analyzed in a 2 (redundant letters) by 4 (experimental conditions) by 8 (serial position) factorial design with repeated observations on experimental conditions and serial positions.

Figure 1 graphically represents the relation between serial position and error frequency for the four experimental conditions as a function of acoustically similar and neutral redundant elements. Table I shows that the main effects for redundant letters did not reach statistical significance, indicating a lack of differential effects upon error frequency of redundant elements composed of acoustically similar and neutral letters.

Table I, however, does show significant main effects for experimental conditions, $F(3, 186) = 35.79$, $p < .01$; and serial position, $F(7, 434) = 36.83$, $p < .01$. The only significant interaction was that between experimental conditions and serial position, $F(21, 1302) = 7.73$, $p < .01$, indicating that the experimental conditions affected the form of the serial position functions.

A profile of this interaction is graphically represented in Figure 2. An analysis of variance for simple interaction effects was computed and is summarized in Table II. These confirm differences in the effects of experimental conditions at all levels of serial position. A Newman-Keuls procedure for testing differences between ordered scores was then calculated for the purpose of illustrating where differences in experimental conditions affected serial position. These results are presented in Table III. Upon examination, it can be seen that the control condition (b1) significant-

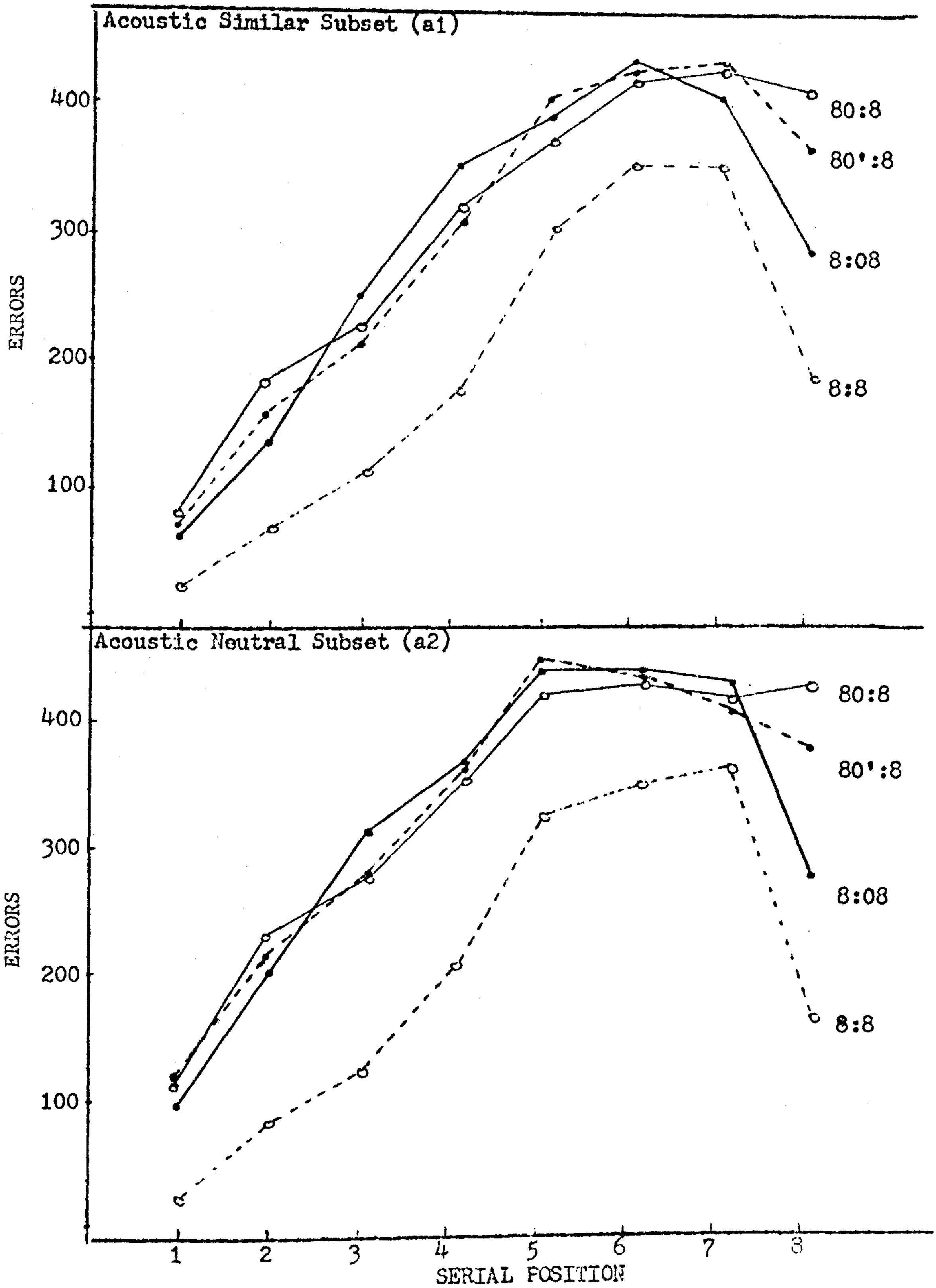


Figure 1. Error frequency of experimental conditions as a function of serial position.

Table I

ANALYSIS OF VARIANCE: TOTAL ERRORS

Source of variation	df	MS	F
Between subjects	63		
A (Redundant letters)	1	373.85	.11
subject w. groups (errer (a))	62	3169.94	
Within subjects	1984		
B (Expm. conditions)	3	1518.43	35.79*
AB	3	19.20	.45
Bx subj. w. groups (error (b))	186	42.42	
C (Serial position)	7	3689.66	36.83*
AC	7	29.86	
Cx subj. w. groups (error (c))	434	100.18	.29
BC	21	65.04	7.73*
ABC	21	3.56	.42
BC x subj. w. groups (error (bc))	1302	8.41	

* p <.01

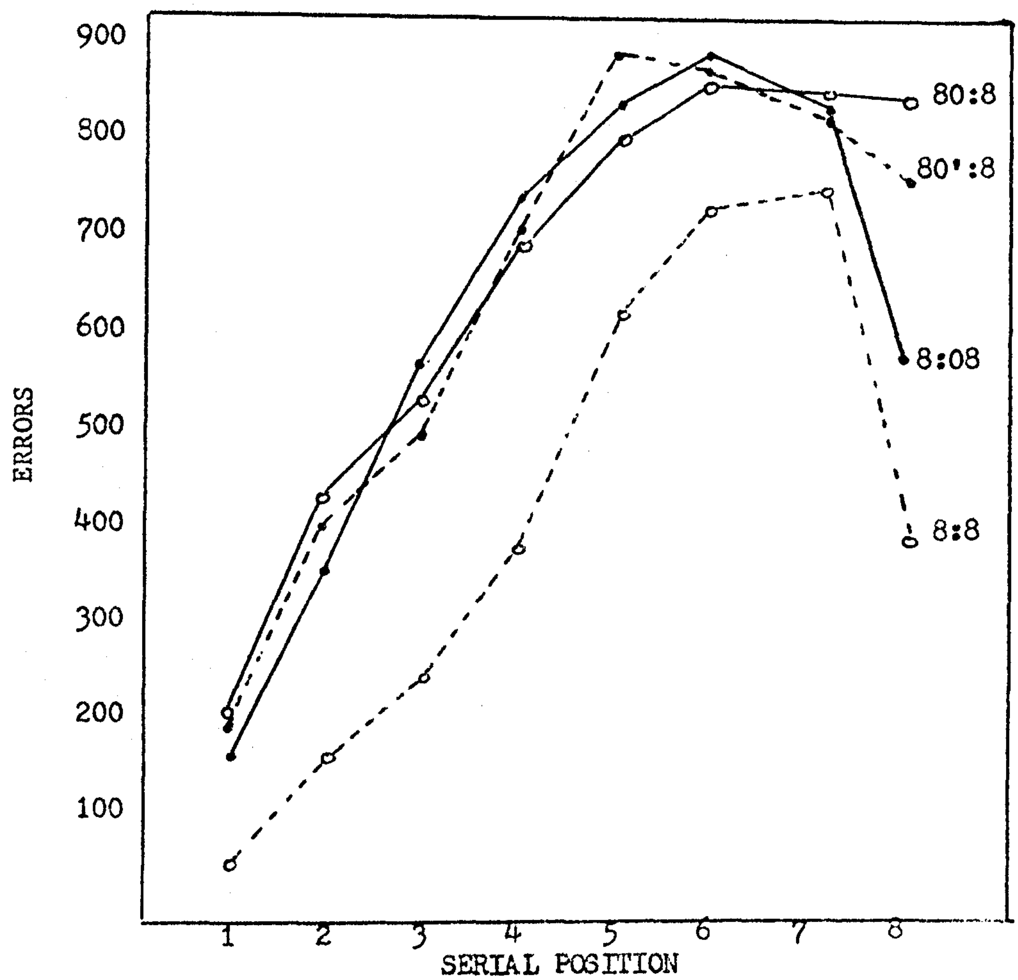


Figure 2. Profile of experimental conditions X serial position.

Table II

ANALYSIS OF VARIANCE: SIMPLE INTERACTION EFFECTS BETWEEN EXPERIMENTAL CONDITIONS AND SERIAL POSITION

Source of variation	df	MS	F
Conditions at level c1	3	71.0	8.44*
Conditions at level c2	3	199.0	23.66 *
Conditions at level c3	3	322.0	38.28*
Conditions at level c4	3	390.3	46.39*
Conditions at level c5	3	170.6	20.28*
Conditions at level c6	3	96.0	10.23*
Conditions at level c7	3	59.6	7.07*
Conditions at level c8	3	665.0	79.07*
Error	1302	8.41	

* $p < .01$ $(3,1302)=3.78$

Table III

NEWMAN-KEULS TEST OF DIFFERENCES

MS error=8.41 n=32 $sx=\sqrt{nMS\ error}=\sqrt{32x8.41}=16.41$

K		(2)	(3)	(4)
q .99(K,1302)		3.64	4.12	4.40
sx q .99(K,1302)		59.73	67.61	72.21

B at c1				
Ordered scores:	b1=56	b2=162	b4=195	b3=202
Ordered differences:		(2)	(3)	(4)
(1)		106*	139*	146*
(2)				40

b2, b3, b4 > b1

B at c2				
Ordered scores:	b1=172	b2=347	b4=381	b3=432
Ordered differences:		(2)	(3)	(4)
(1)		175*	209*	260*
(2)			34	85*
(3)				51

b2, b3, b4, > b1
b3 > b2

B at c3				
Ordered scores:	b1=252	b4=486	b3=517	b2=581
Ordered differences:		(2)	(3)	(4)
(1)		234*	265*	329*
(2)			31	95*
(3)				64

b2, b3, b4, > b1
b2 > b4

B at c4				
Ordered scores:	b1=389	b3=684	b4=689	b2=733
Ordered differences:		(2)	(3)	(4)
(1)		295*	300*	344*
(2)			5	49
(3)				44

b2, b3, b4 > b1

Table III (cont.)

NEWMAN-KEULS TEST OF DIFFERENCES

B at c5

Ordered scores:	b1=630	b3=789	b2=839	b4=862
Ordered differences:		(2)	(3)	(4)
(1)		159*	209*	232*
(2)			50	73*
(3)				23

b2, b3, b4 > b1
b4 > b3

B at c6

Ordered scores:	b1=706	b3=848	b4=856	b2=878
Ordered differences:		(2)	(3)	(4)
(1)		142*	150*	172*
(2)			8	30
(3)				22

b2, b3, b4 > b1

B at c7

Ordered scores:	b1=716	b4=836	b2=839	b3=843
Ordered differences:		(2)	(3)	(4)
(1)		120*	123*	127*
(2)			3	7
(3)				4

b2, b3, b4 > b1

B at c8

Ordered scores:	b1=380	b2=569	b4=756	b3=844
Ordered differences:		(2)	(3)	(4)
(1)		189*	376*	464*
(2)			187*	275*
(3)				88*

b3 > b4 > b2 > b1

ly differs from the response prefix (b2), stimulus suffix (b3), and modified stimulus suffix (b4) conditions at all levels of serial position. In addition, significantly more errors occurred in the stimulus suffix condition than in the response prefix condition at the second serial position; and significantly more errors in the response prefix condition than the modified stimulus suffix condition at the third serial position; and significantly more errors in the modified stimulus suffix condition than the stimulus suffix condition at the fifth serial position. Of most importance is the finding at the terminal position that error frequency significantly differs between each of the experimental conditions.

Of greater relevance to the original hypothesis were comparisons represented in a second analysis of variance including as factors phonetic similarity of the redundant elements (high vs. neutral), experimental conditions (control, response prefix, stimulus suffix, modified stimulus suffix)and acoustic similarity of the letters used as stimuli (high vs.neutral). The summary table of the analysis of variance for these data is presented in Table IV, where it is seen that main effects were significant for the experimental conditions, $F(3,186)=35.7$, $p<.01$, and the phonetic similarity of the stimuli, $F(1,62)= 41.2$, $p<.01$. Significant interaction occurred between experimental conditions and the similarity of the letters used as stimuli, $F(3,186)= 4.35$, $p<.01$. A profile of this interaction is graphically represented in Figure 3, and an analysis of variance for simple interaction effects is summarized in Table V. These data confirm differences in the effects of experimental conditions at both levels of the phonetic similarity of the stimuli. A Newman-Keuls procedure for testing differences between ordered scores, represented in Table VI, shows that signifi-

Table IV

ANALYSIS OF VARIANCE: SIMILARITY OF REDUNDANT ELEMENTS
X EXPERIMENTAL CONDITIONS X PHONIC SIMILARITY OF STIMULI

Source of variation	df	MS	F
Between subjects	63		
A	1	1513.0	.12
subject w. groups (error (a))	63	12458.6	
Within subjects	448	164	
B	3	6004	35.7*
AB	3	73	
Bx subj. w. groups (error (b))	186	167.8	.43
C	1	7954	41.21*
AC	1	47	.24
Cx subj. w. groups (error (c))	62	193.25	
BC	3	87.34	4.35*
ABC	3	12.0	.6
BC x subj. w. groups (error (bc))	186	20.6	

* $p < .01$

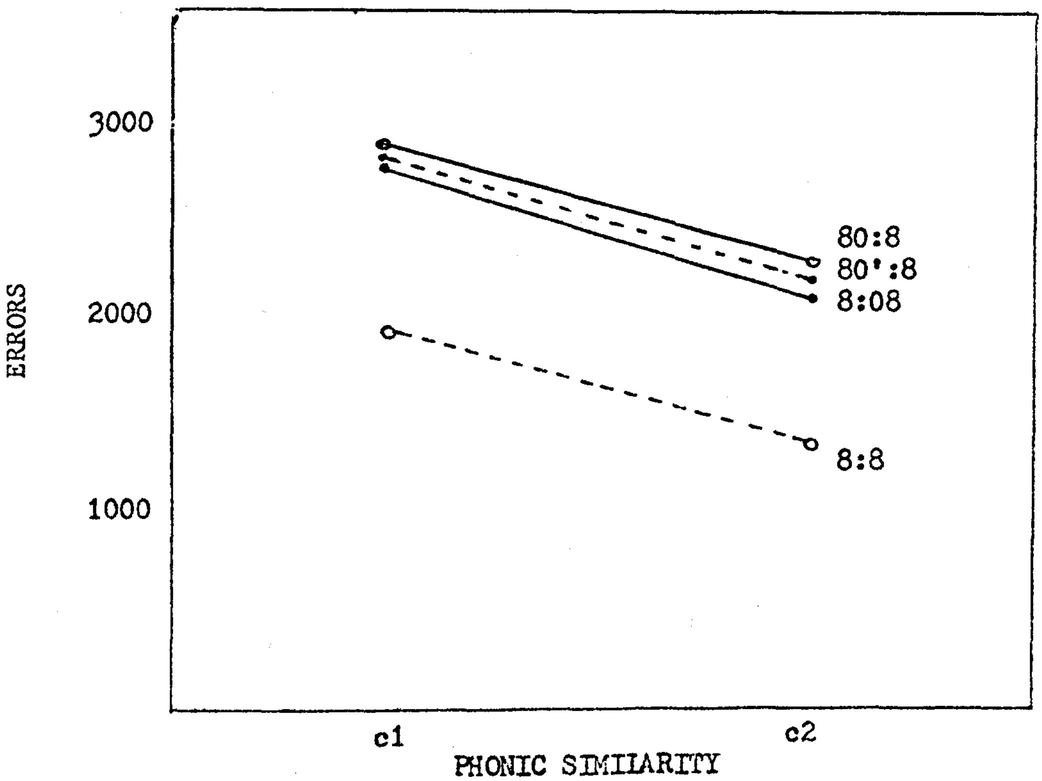


Figure 3. Profile of experimental conditions X phonic similarity of the stimuli.

Table V

ANALYSIS OF VARIANCE: SIMPLE INTERACTION EFFECTS BETWEEN EXPERIMENTAL CONDITIONS AND ACOUSTIC SIMILARITY

Source of variation	df	MS	F
Conditions at level c1	3	2404.6	116.7*
Conditions at level c2	3	3686.3	178.9*
Error	186	20.6	

* =<.01 (3,186)=3.88

Table VI

NEWMAN-KEULS TEST OF DIFFERENCES

MS error=20.6 n=32 $sx=\sqrt{nMS\ error}=25.68$

		(2)	(3)	(4)
K		(2)	(3)	(4)
q .99(K,186)		3.64	4.12	4.40
sx q .99(K,186)		93.47	105.80	112.99

B at c1

Ordered scores:	b1=1971	b2=2740	b4=2748	b3=2777
Ordered differences:		(2)	(3)	(4)
(1)		769*	777*	806*
(2)				37

b2, b3, b4 > b1

B at c2

Ordered scores:	b1=1334	b2=2200	b4=2309	b3=2375
Ordered differences:		(2)	(3)	(4)
(1)		866*	975*	1041*
(2)			109*	175*
(3)				66

b3, b4, b2 > b1
b4, b3 > b2

cantly more phonetically similar letters (c1=BCDGPTVZ) were in err in the response prefix, stimulus suffix and modified stimulus suffix conditions than in the control condition. With phonetically neutral letters (c2=HJLNRXQY) the same relation existed, but, in addition, there were significantly more neutral letters in err in the stimulus suffix and modified stimulus suffix conditions than in the response prefix condition.

Types of Errors

An additional performance measure was recorded involving the types of errors which occurred during the immediate memory task. The character of these errors permitted a breakdown into nine sepatate classifications. These included: (1) slot errors--instead of reporting the nth item of a series just presented, Ss reported the nth item of the immediately preceding series; (2) redundant letter error--the letter in err was the same as the redundant element letter; (3) reversal errors--a correct pair of letters if positions were reversed (i.e., VD instead of DV); (4) dual position errors--a correct pair in the wrong positions (i.e., DV appears in position #2 and #3 instead of position #5 and #6); (5) single position errors--the letter appears in the memory series but is reported in the wrong position; (6) repetitious errors--the letter appears in the memory series but was reported a second time; (7) a subset error--the letter does not appear in the memory series but is one of the sixteen possible letters used in the experiment; (8) alien errors--some letter is reported other than the sixteen possible letters; (9)omissions--no letter was reported.

Figure 4. presents, in the form of bar graphs, the mean frequency of occurence of each of these types of errors within the four experimental conditions. Neither a legitimate parametric nor non-parametric test of dif-

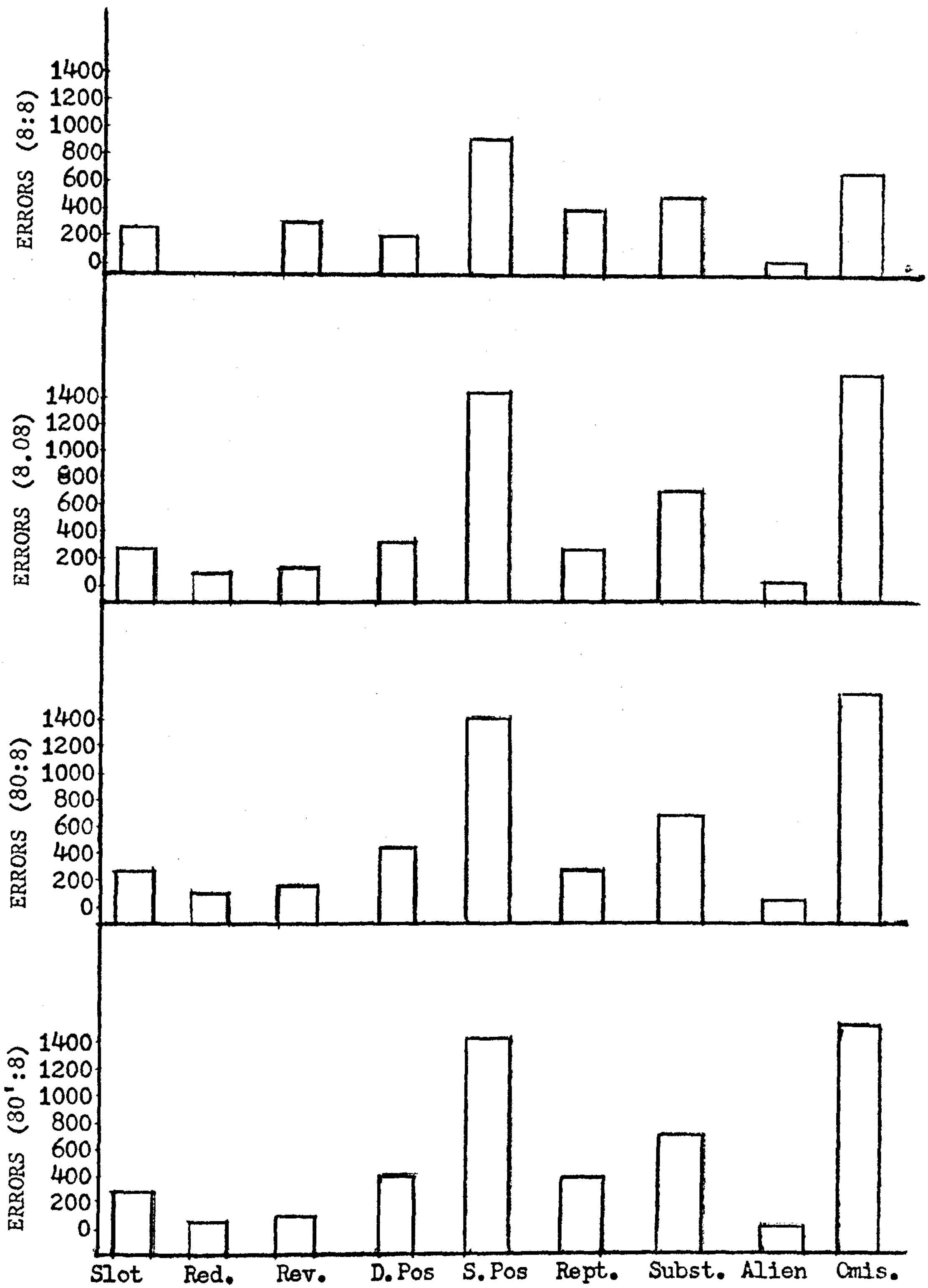


Figure 4. Bar graphs of error types (mean frequency)

ferences was feasible with these data due to the violation of their underlying statistical assumptions. The various kinds of errors were not independent classifications, that is, a particular error could be categorized in more than one classification. In addition, an order restraint existed in these data, that is, the order in which these errors were recorded affected categorical placement. It is apparent, however, upon examination of Figure 3 that differences exist in the frequency of occurrence of these various errors as recorded. Of note also, is that error frequency remained proportionally constant throughout the four experimental conditions.

Chapter IV

DISCUSSION

Neisser (1967) has based his approach to the study of verbal short-term memory on the mechanisms which are continuous with those of speech perception. Speech perception, in turn, is thought of as a constructive process closely related to the production of speech itself. Strings of digits then, have to be organized very much like speaking. If the digit strings are random, and if S has no mathematical system or mnemonic device which can integrate them, he is forced to rely in a more primitive organization, that of rhythm or grouping. Accordingly, the length of the memory span is determined by Ss ability to plan and execute an articulate rhythmic structure. From this point of view, it is easy to see why a response prefix should represent virtually the same load on memory as a nonredundant digit. This postulated relationship with active speech perception was substantiated by the findings of Neisser (1969) that a redundant prefix can not be ignored when it is included in the active construction of the digit string by the listener, and becomes ineffective when the experimental conditions allow him to deal with it separately from the other members of the string.

This principle of cognitive separation was extended in these data. Letters, as opposed to digits, were used as stimulus elements. In addition, the principle was applied to a redundant suffix as opposed to a prefix. But with these extensions, the predicted results failed. The modified stimulus suffix condition produced significantly more errors than that of the control condition at all serial positions. If this principle of cognitive separation held, no differential effects in total errors would have resulted. It can therefore be concluded that the method of cognitive separation used within this design ineffectively separated the redundant suffix from the rest of the members of the stimulus. The eight nonredundant elements did not form a structure separate from the redundant suffix. Whether this principle of cognitive separation is confined to redundant prefix effects, whether this principle applies only with digit stimuli, or whether it is operative only with an auditory modality and not a visual method of presentation remains for further research to test.

Modality Effects

According to the conceptual model of information flow in immediate memory proposed by Crowder and Morton (1969), information about vocal stimuli is held in PAS for some brief time and subject to displacement by subsequent items. Normally, without a stimulus suffix, this means that the terminal position (s), by virtue of having few or no subsequent elements, are represented in PAS longer than early elements in the list, and therefore can be more readily perceived or categorized. The effect of the stimulus suffix is then to reduce the availability of these last elements in PAS and limit the normally generous readout time they enjoy.

This experiment sought to test the deduction that if S vocalizes a visually-presented list, vocal emission of a response prefix should affect PAS and result in more errors late in the memory series. A loss of information in PAS would result just as when a stimulus suffix is employed thereby producing with the response prefix a serial position function similar to that of the stimulus suffix. Figure 1 depicts the failure of this deduction, since the form of the response prefix condition follows the traditional form of a drop in errors at the terminal position. Further evidence for this failure is seen in the results presented in Table III which shows that at the last serial position (c8), there were significantly more errors in the stimulus suffix than the response prefix condition. These data therefore complicated Crowder and Morton's suggestion of the effects of a response prefix. The absence of a selective effect at the terminal position suggests that the vocalized response prefix did not reduce the availability of the last elements in PAS.

Acoustic Similarity of Redundant Elements

The mechanisms for the response prefix effect was not directly proposed by Crowder and Morton (1969), nor was it critical for the arguments they made for PAS, but they suggested that it resulted from articulatory interference at a categorical and not pre-categorical level. "Since articulatory coding is a perceptual consequence for all elements in the list, the prefix has a nonselective, overall effect on errors."

If the response prefix effect is a function of articulatory interference, then the similarity of the prefix element to the members of the memory series should be directly related to the size of the prefix effect. Crowder (1967, Expm.3) has previously shown that in terms of formal similarity (letters vs. digits) the prefix effect does not vary accordingly to the laws of retroactive interference. In a more recent study Crowder (1969) provided support for the prediction by showing that when the dominant phoneme in a memory series was "e", a larger decrement was obtained than when the prefix element was acoustically similar.

These data do not support the supposition that the prefix element will be larger the more similar the redundant element is to the nonredundant elements of the memory series. This is reflected in the lack of significant main effects of acoustic similarity of the redundant elements (Factor A) presented in Table IV. Coupled with Crowder's earlier investigation (1967, Expm. 3) these data concluded that retroactive inhibition (RI) does not participate in the prefix effect, with these particular dimensions of similarity varied. It is suspected, as hypothesized, that the particular letters (V vs. K) chosen by Crowder (1969) insufficiently represented the full range of phonic similarity and therefore was not a thorough test of the effects of RI with the response prefix condition.

Types of Errors

Conrad (1959) remarked that one of the greatest advances in our understanding of long-term memory processes came from the study of the character of imperfect recall, and not from the correlation of the quantity recalled which has dominated immediate memory studies.

Types of errors were categorized in this study according to a ninefold classification scheme. Related classifications were not combined for purposes of statistical analysis because it is believed that meaningful information would be lost. In justification of this position, consider the following memory series: A B C D E F G H. If the S sequentially misplaces one element in the recall of this series, it is possible that all elements would be in err (i.e.,BCDEFGHA). The E would record eight errors of the single position type. Likewise, if S misplaces two elements of the series, it is possible that all elements would be in err(i.e.,CDEFGHAB). The question which follows then is: are these errors comparable to an equal number of subset errors where the letters reported were not even letters that appeared in the stimulus series? The criterion score in this study, as is the case in most studies in immediate memory, involves the quantity of errors, not the quality of such. Information regarding the nature of these errors is lost.

The qualitative nature of errors reported in this study is of most import and relevance due some observations made while scoring these data. It becomes evident that, while these nine classifications sufficiently represented all posibilities, many of these categories could be combined. Expressing this finding in another fashion, a particular letter in err classified in one category could also be classified in another. In particular, slot errors could be classified as single position, repetitious, or subset errors. Of the 963 slot errors recorded in this study, 454 could be classified as single position errors (47%), 413 could be classified as subset errors (43%) and 96 could be classified as repetitious errors (10%).

Even though Conrad (1965) has put forward an explanation of these single position (transposition) errors which at least partially account for them within the framework of a slot theory, it appears that the strength of serial order intrusions (slot errors) as underlying support for a theory of organization in immediate memory is impaired.

Additional information relative to major theoretical interpretations of organization in STM is provided in these data. Applications of subordinate principles were examined, and more specifically, this experimental design questioned: a) the applicability of the rhythmic-theory principle of cognitive separation in the stimulus suffix condition; b) the system for precategorical storage of acoustic information with regard to the differential effects of a redundant prefix and suffix; c) the participation of the principle of retroactive inhibition in the prefix effect; d) the lack of information concerning the qualitative nature of errors in investigations of STM. In addition, new areas of research were suggested for the purpose of strengthening many of the principles which underlie the theoretical interpretations.

One particular area of research which seems most appropriate yet is only beginning to be investigated is the relevance of frequency and association values of single letters to studies of STM employing alphanumeric materials. Underwood and Schultz (1960) have reported an analysis of the relationship between frequency of occurence of letters in the language and the frequency of single letter responses to single letter stimuli. More recently, Anderson (1965) obtained word associations to each of the 26 letters of the alphabet under procedures of single association and continued association. The results showed a significant correlation between association value and measures of the frequency of letters (.30), letter preference (.56) and vocal reaction time (.63). Applying her scale of association value to the letters used in this experiment results in a mean value of 11.3 for those letters which constitute the high similarity subset, and 10.8 for those letters which constitute the neutral subset. Even if there were no significant differences between the association value of the two groups of letters, there are certainly differences within each group which suggests that research is needed to evaluate the effects of these differing association values within studies of acoustic similarity effects. In addition vocal reaction time of each of the letters ought to be related to modality effects in STM.

Association value of single letters, pairs of letters and triads within a memory series may also be relevant to the phenomena of subjective grouping. Pairs of letters with high association value may interact with the patterns that evolve in subjective grouping. Possible support for this hypothesis is seen in Crowder's (1969) study of perceptual organization where pattern alternation within the memory series significantly affects total errors.

The relation between the perception of language and memory investigations serves to advance a whole class of variables, such as articulatory representation. The consequences of such a stratified and diversified account of linguistic perception, as reflected by the three major interpretations presented here, suggests that there is great variety in what Ss learn about nominal stimuli. Such diversity in the product of learning is bound to have important behavioral consequences.

Chapter V

SUMMARY

The acoustic similarity and neutrality of letters in an immediate memory task were studied as a function of redundant elements and serial position. Several underlying principles of theoretical interpretations of organization in STM were extended and tested: the effect upon serial position of the cognitive separation of a stimulus suffix; the effects of vocalizing a visually-presented memory series upon a system for precategorical storage of acoustic information; the effects of representing a complete range of phonetically similar and neutral items as redundant elements so as to assess the extent of RI participation in performance decrements.

Each of 32 Ss recalled in a counterbalanced order 160 memory series of eight consonant letters, 40 series each in a control, response prefix, stimulus suffix, and modified stimulus suffix condition. Three-fourths of these trials involved redundant elements which were acoustically similar for one group and acoustically neutral for the other.

While the results supported traditional significant differences between redundant response prefix and stimulus suffix elements, the two extensions of underlying principles in major theories of STM organization failed to produce significant effects. The experimental conditions did not permit the cognitive separation of the redundant suffix as reflected by the performance impairment at the terminal serial position. The vocalization of a visually-presented memory series did not affect the form of the serial position function of the experimental conditions. The lack of differential effects, with thorough representation of phonetically similar and neutral redundant elements, presents a problem to associative theory and

to a system of information flow based on acoustic dimensions.

These results were indicative of the complex interaction between perception of language and memory investigation, in addition to providing data which are difficult to account for by several theoretical interpretetions of organization in STM.

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APPENDIX A

Table I Lists of Memory Stimuli

(8:8)	(8:08)	(80:8)	(80':8)
N T J V C L H Z	L D J H T C N R	N V H G D Y Z C	N P R Y C J Z D
Y R G P Q D B X	X C L Y V G P Q	V T L J B X N R	C Q T G V X L R
R B X V Y D L Q	J D Z X Y N H T	N Q H C G J P T	Z H Q G C N X Y
P J N H T G C Z	P Q R H X G V L	C R Z D V Q Y L	G Y N J Z R P V
Y R L G J T B D	D P L G H J Q Z	J Z L Y D Q H G	Y H C P R J Q D
X V N Z H P Q Y	D C Y T N R X V	R H B N X T P V	Z N B G V T X L
T C P J Z G D Y	Q D L V J H N T	B D T G X Z V Y	L D Q Y B V X T
X V P C R Q L B	Y X Z J V C B R	L H R N J P B D	H Z J G Q N C R
N V G J D Q T X	Y T V B Z N Q R	X J C Z N D V H	V B T H L P N Y
Z H Y D P R B T	G H J X D P C L	T B P Q G R Y L	T D R Q J P G Z
J N Q T X B C Y	J R Y D N X T Z	Q G H Z C J X P	G C Z H L Q V T
P D H R L V Z G	R B Q P N Z C H	C L B V R X T N	Y J R D P C X B
P Y R B G N Q X	R V N Q Z H G P	V Y Z Q P X L C	R P C Y N X B Z
V D L Z C T J H	J Q C T P X Y R	N T B R G J H V	J L H Q D G T V
N J Y H D G X C	G H Q J C P N B	P N B R T C X Y	V T L G R J B H
Q R T Z L H B V	R J B T Y D L V	D Q P Z Y X V H	X Z P C H B Q J
B L H P Z T V C	T P H X Z R G J	H T Q G X V Y C	Y D T Q P N V H
J N D X R G Q Y	Q D C V N B Y L	T L N D Y P H Z	X C Q B L G J R
J R D H Q B G V	B N D L J P X V	C X G Z J D R L	Y P J Q D G B L
N T Y L P X Z C	P R Y Q Z B C J	V P H Y Q B T L	C X B N V H Z Q
G Z V Q X Y H J	X J N D C G H L	Z X T L H Q Y V	X L R Z N D V G
D C L R T B N V	V Z P Y Q T R B	C V P N J G B Q	J Q T B H N Y C
T C Y P H X J N	N X T D H R P Q	H Z D R N T J X	Q V C P Z N J Y
R G V B Z L D Q	Z B L G J V C Y	L X Y Q G V C B	B G R H D X L T
T Q L N C D Y G	H Q G N Z V X T	N B Y G J T D C	V R H N X P T C
X R Z H G V J B	D R J P Q L G C	Q P V X Z R B H	Q L Y Z J D B G
B V Z P Y Q C N	Z B P X Y V L N	R X N B V D Z J	G Y Q D V T H N
G D X J H L T R	R T J P L H C D	Y L G H Q P C Z	P Z N R G J C L
G H D V B L J P	V C D Q N H J P	J C X T R H V Y	R V T H D N L P
C Y T N Z R X Q	L D N R T X B Z	Z Q G N P L D B	D Y Q Z G B J C
P Z D Y N L C X	P L Z R T N B G	D J B V Z R H X	J V C R Q X H B
B H G J Q T V R	Z D T G Y J C X	G T P L R N X Y	N Z G X Y T P L
X Y N P T D J R	R G B T P X D L	Y T N Q C D B X	T X Z G R C V N
X H G L Z B C Q	T Q V H C Z N B	J H R Z G P V L	C H L Y J P B D
R B C L X H V Y	D P N G Q Z R B	Z L Y V B H R P	B R G D L C T J
B D G J T Q N P	V H P Y T L C J	C T Q V J Y N D	N X Z P H T Q V
C X D Z G N J P	R Q Y B V Z C X	H T L X Z B V P	V C P J L H Y T
T V Q H L R Y B	N H P C L G J T	J D N P R C Y G	D X N R B Z V L
J D G B R P Y T	D H T Y Z L P G	G T C L H R N D	J X Z G V Q L H
N X L Z H Q V C	V N C T B R X J	G Q Y P V B X J	C B T P D N R X

Table 2. Instructions

The experiment in which you are participating is designed to study a form of human learning involving short-term retention. A series of letters will appear on the screen similar to this one...(ABCDEFGH).... Your task is to pronounce each of these letters, out loud, within the three seconds alloted, and then, (advance to blank slide) when the blank slide appears on the screen, try to recall those letters. In addition, I want you to point to these blocks which correspond to the position of each of the letters in the memory series, that is, the first block corresponds to the first letter of the series (A), the second block to the second letter of the series (B) etc. Any questions?

We will now have five practice trials, at which time I want you to try to get a feel for how quickly you must pronounce each letter in order to pronounce all of them within the three seconds, and also get the idea of pointing to the blocks as you recall the letters.

(Five Practice Trials)

SPECIAL INSTRUCTIONS FOR THE EXPERIMENTAL CONDITIONS

Response Prefix condition

During this phase of the experiment, you will again be shown an eight letter memory series, but this time I want you to prefix the recall with a particular letter which I am going to give you in advance. For example, suppose I gave you the letter'X'...... after having pronounced each of the letters of the memory series, when the blank slide appeared on the screen, before you recalled the series, you would pronounce the letter 'X'. Is this clear? (Three practice trials)

Stimulus Suffix condition

During this phase of the experiment, you will see projected on the screen nine letters instead of eight, but you will know in advance what the last letter of the series is. When the blank slide appears on the screen, I want you to recall just the first eight letters. I want you to omit the extra letter which I have given you in advance. Clear?
Remember to pronounce the extra letter during presentation and omit it during recall. (Three practice trials)

Modified Stimulus Suffix condition

During this phase of the experiment, you will see projected on the screen nine letters instead of eight. The nineth letter will be separated from the memory series by three spaces and typed in lower case. Again, you will know in advance what this extra letter will be. I want you to pronounce the extra letter during presentation and omit it during recall. OK? (Three practice trials)

In addition to the above instructions, the Ss are told that the extra letter involved in the three experimental conditions will change every five trials.

VITA

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