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INPUT VARIABLES IN BISENSORY MEMORY

by

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INTRODUCTION

The present study is concerned with the effects of several variables on bisensory immediate memory and with a comparison of bisensory stimulation with unisensory stimulation (ordinary immediate memory) in the visual and auditory modalities. In the bisensory experimental situation different materials are simultaneously presented in two sensory modalities; S is then required to recall all of the material from one modality followed by the material from the other modality. In the single modality or ordinary immediate memory situation, a set of materials is presented to one sensory modality or channel; within several seconds of the presentation, depending on the nature of the study, S is to recall all of the material.

Some of the variables under consideration have been examined in the ordinary immediate memory situation (Brown, 1954; Conrad, 1957; Peterson & Peterson, 1959; Wickelgren, 1965), and in another condition of simultaneous stimulation -- the dichotic arrangement (Broadbent, 1954, 1956, 1957b, 1958). In this latter case, different materials are presented to the two ears simultaneously; S usually reports materials from both channels, all of one before any of the other.

In the study to be reported, the effects of a combination of variables previously studied in the two situations above were examined in bisensory memory. These variables were: (1) types of materials and combinations of materials in the two sensory modalities; (2) rate of presentation of material; (3) order of recall for a modality, either first or second; (4) locus of instructions about order of report, either before or after presentation of the material; and (5) overall differences in memory for the visual and auditory modalities.

In addition, measures of both visual and auditory immediate memory were taken at the rates used in the bisensory study. This provided comparisons both of the two kinds of ordinary immediate memory and of bisensory and ordinary immediate memory. These data were expected to be of aid in determining whether there was a general immediate memory function (relatively invariant across modalities) and in evaluating the nature of the decrement, if any, in the bisensory situation.

CHAPTER I

VARIABLES INVESTIGATED IN SHORT-TERM MEMORY

One of the problems suggested by the simultaneous stimulation (bisensory) situation is that of division of attention. Specifically, does the individual have the ability to perform two simultaneous perceptual and/or memory tasks? The data thus far collected indicate that division of attention is possible, though not necessarily equally between two input channels. One's ability to divide attention between different sets of materials arriving along two channels is optimal only under certain conditions, dependent on: order of report, instructions, rate of presentation, nature of materials, and channels involved. Since these are the variables of interest in the present study, each will be examined in turn.

Order of report. -- The manner in which the items exposed to S are reported by him is likely to vary; S may report these items in their order of arrival (i.e., pair-by-pair) or he may report all items from one channel first, followed by those from the other channel. Although order of report may be dictated by E, the manner of report without instructional control appears to be functionally related to the rate variable. Thus, Broadbent (1954, 1956) found that Ss were able to attend

to different sets of digits presented simultaneously to both ears, as in: Right, 723; Left, 516. Ss generally attempted recall of all of the material from one ear first and then from the other ear (e.g., 723516 or 516723). With a slow delivery rate (one pair of digits/2 sec.), however, recall was possible in the order of arrival of the digits or pair-by-pair (e.g., 752136). Broadbent reasoned that the slower rate allowed for switching from one ear to the other for each pair of digits; at the faster rates S was not able to switch from ear to ear fast enough. Thus he adopted the strategy of attending to all of the information from one channel first and then the other. Bryden (1962) has reported a similar relationship between rate and order of report. He found further that, as the number of pairs presented increased from three to four to five, the relationship between order of report and rate of presentation remained unchanged.

Similarly, Moray (1960) has shown that pair-by-pair or order of arrival recall for digits presented simultaneously to both ears is possible, though less efficient, then recall from one channel and then the other. At the fastest rate (2 signals/ear/sec.) however, when presentation of digits to the two sensory channels was staggered so that the signals did not overlap, pair-by-pair recall was as efficient as channel-by-channel recall for simultaneous presentation.

Moray argued that inferior recall in the simultaneous situation is obtained because S is switching between one signal and the trace of the other rather than the other signal itself. By delivering stimuli alternately to the two ears, it was shown that it was in fact possible to switch between channels in .5 sec. or less.

Further study of the order of report variable has suggested that ear-by-ear recall represents optimal strategy for the particular situation rather than the built-in mechanism implied in Broadbent's statement. Gray and Wedderburn (1960) demonstrated that, when Ss were provided with cues (meaningfulness) in conflict with a channel by channel order of recall, pair-by-pair recall could be obtained even at the rapid rate of one pair/.5 sec. This pair-by-pair recall was effected when words were broken up into syllables and these syllables were alternated between the two ears, as in: Right, ex, 2, pate; Left, 6 tir, 9.

The particular combination of materials has been another variable found to affect order of report in simultaneous dichotic recall studies. Broadbent and Gregory (1964, 1965) showed that it is just as difficult to alternate attention between two classes of materials (letters and numbers) when these classes are alternated as it is to alternate between ears at fast rates. Presenting mixed digit and letter lists

(as in: Right, A, 4, J; Left, 1, F, 9) to both ears, they found that scores for ear by ear recall were poorer than scores for either pair-by-pair recall or recall in terms of materials.

The effect of order of report has been studied for the bisensory as well as the dichotic situation. As in dichotic recall, digits simultaneously delivered to the eye and the ear are typically recalled by delaying all the information on one channel so that all the items from the other channel or modality may be recalled first. When material is recalled channel by channel, it is generally agreed that the material on the first-reported channel is better recalled than that of the channel reported second (Broadbent, 1958; Brown, 1954).

In the present study order of report is specified in instructions accompanying each bisensory stimulus.

Preparatory set. -- The experimental arrangement of providing instructions before or after presentation of materials has been employed in a number of studies of perception and the memory span (Broadbent, 1957b; Broadbent & Gregory, 1961; Brown, 1954; Lawrence & Coles, 1954; Lawrence & Laberge, 1956). This variable has been viewed as providing a basis for pinpointing the effects of differential sets.

In simultaneous stimulation studies, the instructional variable, introduced either before or after materials presen-

tation, informs S which channel or which type of material to report first. While the introduction of instructions prior to input has generally been found to increase overall efficiency, the items or channel reported first has typically yielded the higher score for both successive and simultaneous presentation. This has been true regardless of whether instructions about which channel to recall first are given before or after presentation of materials. Instructions given after presentation do, however, produce a different distribution of errors than those associated with instructions prior to presentation (Kay & Poulton, 1951). Broadbent (1957b) has found that well-practiced Ss, left in doubt as to recall order until after presentation, tend to report the two channels or two halves of a single list in ordinary immediate memory with equal efficiency.

In the present study, half the subjects are instructed regarding order of report before bisensory stimulation while the other half are instructed after stimulation.

Rate of presentation in ordinary immediate memory. -- Since there is evidence (Broadbent, 1958) that the short-term store is capable of holding items for seconds only, rate of presentation of materials is a variable highly relevant to the amount of material recalled. It would seem that, with such rapid decay, the more rapid presentation rates (and

hence shorter total time in store) should be the most favorable conditions for recall. Several experimenters (Brown, 1958; Conrad, 1957; Fraser, 1958; Mackworth, 1962; Posner, 1964) have found that, in simple auditory memory span experiments, fast presentation of material is in fact superior to slow presentation.

Conrad (1957) found that not only did presentation rate affect recall of eight-digit numbers but that pacing the recall also affected the total amount reported. Comparing a slow-paced recall (30 digits per minute), a fast-paced recall (90 digits per minute) and unpaced or free-recall, the proportions of wrong recalls were greatest for the slow-paced and least for the free-recall. Fraser (1958) corroborated Conrad's findings and found further that rapidity of decay increased with S's age. Posner (1964) varied the time that the item must stay in store prior to recall and replicated Conrad's and Fraser's findings. Thus, for the auditory modality, the longer the item must stay in store without rehearsal, the greater is the probability that the item will not be recalled.

With visual presentation, on the other hand, Mackworth (1962) found that increased delivery times led to increases in recall. For eight- and nine-digit messages, recall improved steadily as presentation rates decreased from 1/4 sec.

to 2 sec. per item. This suggests that in short-term memory, different mechanisms or processes may be optimal for the visual and auditory modalities or that the rate and/or manner of processing information differs in these two modalities.

In the present study three rates of presentation, most often employed in ordinary immediate memory and dichotic studies (Broadbent, 1954, 1956; Mackworth, 1962; Moray, 1960) are utilized in visual and auditory ordinary immediate memory.

Rate of presentation in simultaneous studies. -- In situations where two channels are involved and input arrives simultaneously or alternately along both channels, the rate variable does not seem to operate as it does in ordinary immediate memory of the auditory type. In experiments with two different inputs (dichotic), more efficient recall is usually found with slow rather than fast presentation rates. As previously mentioned, Broadbent (1954) found scores for pair-by-pair recall of digits with 1.5 sec. and 2-sec. interstimulus intervals to be superior to scores obtained with .5 sec. or 1-sec. intervals. Moray (1960), also using digits, found that slow presentation rates (one pair/2 sec. and one pair/sec.) normally result in better performance than did the fast rate (2 pairs/sec.); this was true with any order of recall.

> It is only when digits are arriving by two separate sensory channels that slow presentation is superior to fast. In simple memory spans the exact opposite is true. . . . Thus the better performance at slow presentation rates. . . . must be connected with the use of two channels. The obvious explanation is that time is used in switching between two channels, and no other explanation has yet been produced (Broadbent & Gregory, 1961, p. 107).

The studies that have so far explored the rate variable in simultaneous stimulation have been restricted to the dichotic technique. Whether the same generalizations about the effect of rate will apply to bisensory memory is one of the interests of the present study.

In this study, the same rates employed in auditory and visual ordinary immediate memory are also used bisensorily.

Combinations of materials.--Few studies have presented two different kinds of materials to coincide with two sensory channels in bisensory memory. Both Gray and Wedderburn (1960) and Broadbent and Gregory (1964) have varied their materials, but in both instances materials were varied across channels; that is, both types of materials were represented in both channels on a given trial. The materials variable is one that has been studied in retroactive interference experiments and forms the basis for the Skaggs-Robinson hypothesis about this phenomenon. This hypothesis predicts maximal interference in recall following learning of two lists of materials composed of similar items (e.g., list I, nonsense syllables; list II, a

second set of nonsense syllables). Much less interference is predicted where the two learned lists have been composed of different kinds of items (e.g., list I contains nonsense syllables; list II, numbers). The variables shown to influence recall in the retroactive interference situation have not yet been studied in bisensory memory, though they have been studied extensively in ordinary immediate memory (Brown, 1958; Melton, 1963; Pillsbury & Sylvester, 1940). It seems likely, in a bisensory situation, with channel by channel recall, that dissimilar materials would aid in the differentiation of channels and in subsequent storage and retrieval of materials. On the other hand, it is expected that similar items would result in impaired recall beyond that associated with the use of two channels.

In the present study both similar and dissimilar materials are presented to the auditory and visual channels concurrently.

Modality comparisons. -- In reviewing the literature, it was found that a distinction between the visual and auditory modalities in terms of effects of the foregoing variables did not exist. Rather, the general trend has been to assume that effects observed an auditory presentation would also obtain for visual presentation. More precisely, there has been a lack of concern for specific visual effects. Experiments

employing the visual modality have not considered modality to be a pertinent condition of the experiment. Mackworth's study (1962) of visual rate effects is among the very first to suggest that the auditory and visual channels may function differently in respect of the foregoing variables.

In the present experiment data are collected in each modality separately for comparisons not only between ordinary immediate memory and bisensory memory but also between modalities.

Interactions of variables. -- Each of the preceding variables has been shown to effect ordinary immediate memory and dichotic memory. No study, however, has considered all of them concurrently so as to evaluate their interactive roles. The present study examines each of these variables in a factorial design permitting an assessment of their effects on the visual and auditory modalities under conditions of separate and simultaneous stimulation.

CHAPTER II

METHOD

Apparatus

For bisensory simultaneous stimulation materials were presented on 16 mm. film (24 frames/sec.) with synchronous sound track by means of an RCA model 400 projector. The exact auditory sequences intended for pairing with the appropriate visual sequences were recorded in a sound studio by E. At the recording session an attempt was made to approximate the rates actually employed; however, more precise control of synchrony was accomplished by splicing the auditory tape. That is, speech recordings were spliced into the film so that each utterance of a stimulus item commenced within the first half frame of its associated visual stimulus (± 21 msec.).

Visual stimuli were made by "Letraset" instant black letters exposed singly on white 8-1/2" x 11" cards which were then filmed and appropriately edited. These materials, when projected, resulted in an image of 28 in. in height by a minimal five in. in width (the total width depending on the actual item displayed). The contrast ratio as displayed was approximately 80 per cent. The interstimulus and interlist inter-

vals for visually presented materials consisted of clear leader which was slightly less bright than the stimulus sequence thus minimizing the negative after-image.

Previous attempts at synchrony, particularly earlier attempts, have been rather crude. For example, Broadbent (1956) had the visual stimuli written on the back of the auditory tape and as the tape moved to the take-up reel the stimulus item became visible. Similarly, Mowbray (1952, 1953), used a visual tape which was pulled past a viewing window cut in a screen. Synchronization of auditory and visual items was maintained by timing of the auditory tape and the visual pacer. A more recent attempt at synchrony was made by Buschke (1962). Visual materials were presented on Burroughs Corporation standard "NIXIE" tubes; whereas auditory presentation involved recorded tapes played on a Wollensak tape recorder. In other words, manual timing was necessary. Thus, the use of sound motion pictures represents a more precise control of stimulus durations, intervals, and auditory-visual synchrony than has been used in the past.

In the present study, provision was also made for presenting materials to either channel independently of the other channel. In the case of visual stimuli this entailed the display of film without the audio portions. In the case of unisensory auditory stimulation, for the sake of economy,

a Wollensak T-1400 tape recorder was employed. The same tape recordings which provided the input to the sound track of the film were cut and spliced to form an auditory tape, marked timing tape serving to achieve appropriate stimulus spacing; the tape was run at 7-1/2 inches per second.

An attempt was made to balance the intensity of the materials in the two channels on reproduction. E and five additional individuals gave judgments as to the subjective equality of the materials. This was achieved by varying the loudness dimension and keeping brightness constant. The playback level of the tape recorder was so adjusted as to sound equal in loudness to the level of the sound track emanating from the projector's twin speakers. It seemed reasonable to assume that the intensities might not be the crucial variable so long as the material was clearly and easily discriminable.

Figure 1 represents a scale drawing of the room in which the experiment was performed; the floor of the room rises slightly from the front to the back.

Procedure

List preparation and presentation. -- The first ten letters of the alphabet, A through J, were employed as were the digits 0 through 9. These letters were chosen as pilot

Approximate scale: 1:133

X indicates seat where each S sat

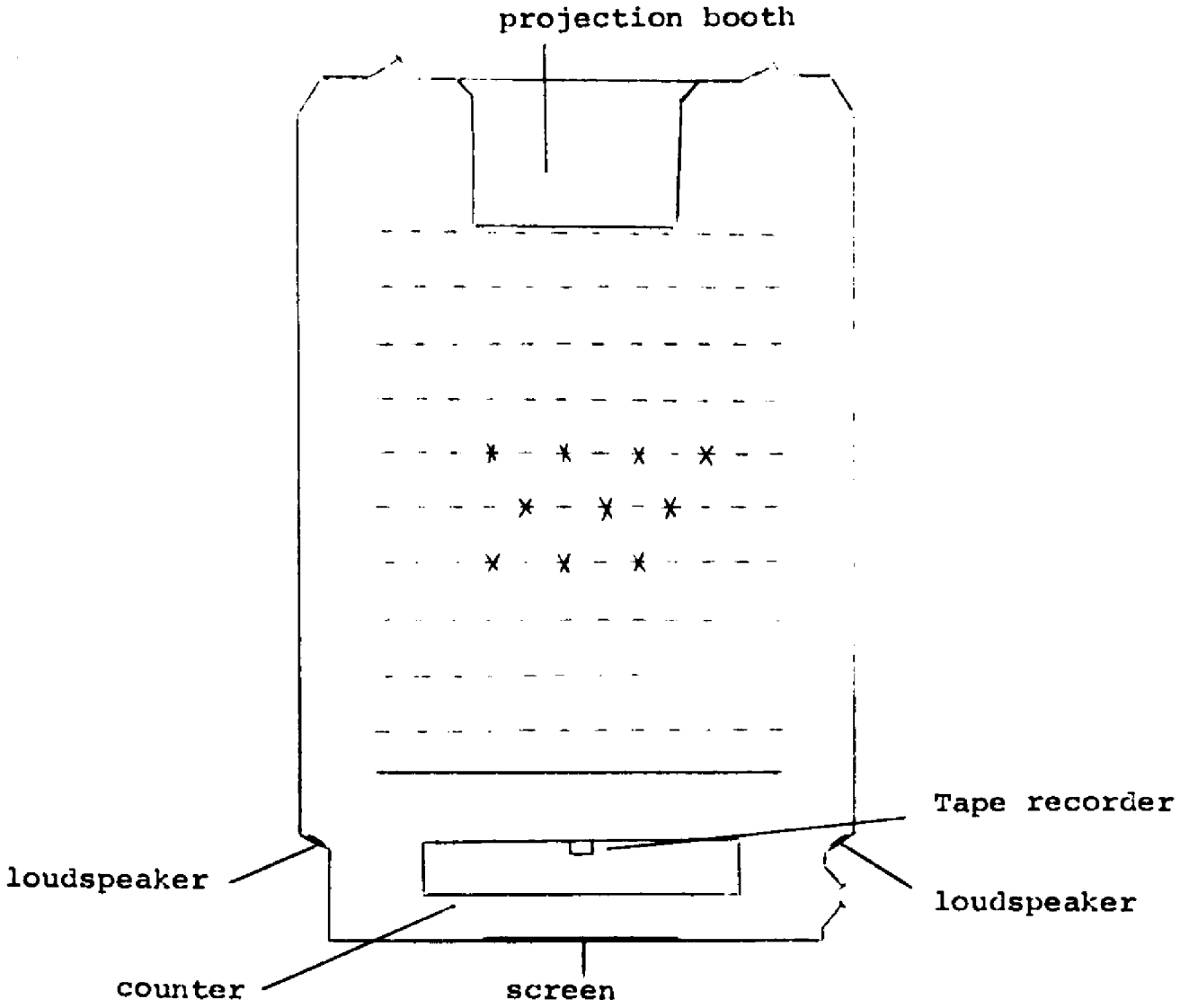

Figure 1. Drawing of room in which main experiment was performed.

studies measuring tachistoscopic thresholds[1] of the 26 letters of the alphabet indicated that each item was recognized with equal facility.

In the bisensory situation each list contained six items; this number was determined by pilot studies (see Tables A_1 and A_2). Altogether 48 lists were required in order to produce 24 pairs of lists sampling all possible combinations of 3 rates of presentations, 2 orders of report, and 4 combinations of materials. The materials combinations were: (1) auditory-numbers, visual-numbers, (2) auditory-numbers, visual-letters, (3) auditory-letters, visual-letters, and (4) auditory-letters, visual-numbers. To avoid duplication in the combinations where similar materials are in each channel, 12 different items are necessary. As indicated, however, each stimulus category was comprised of ten items. Therefore, where items had to be employed twice, this was done within rather than across modalities. The actual stimuli were presented in the exact order in which they are displayed in Table 1, where the various combinations mentioned are apparent.

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[1]A Gerbrands tachistoscope was used to expose single letters (made from "letraset" instant lettering) centered on stimulus cards. The stimulus cards were presented to each of six Ss in a pre-arranged random order. All Ss identified each letter at the lowest duration available, .01 sec.

Table 1

Bisensory Stimuli in Presentation Order

Stimulus	Report First	Channel	Rate of Presentation		
			F (1 pr/.5 sec)	M (1 pr/sec)	S (1 pr/2 sec)
NALV	A	a	4 1 8 5 3 7	7 2 5 4 1 0	9 7 0 4 9 6
		v	F A E H G D	D G I A B H	C I J H F A
NANV	A	a	1 6 3 2 3 9	1 9 1 2 6 3	9 6 2 9 7 8
		v	4 8 4 5 7 0	8 4 5 7 0 7	5 4 3 0 5 1
LVNA	V	a	2 9 6 1 3 0	3 1 2 7 9 8	0 6 2 7 1 9
		v	B A I E F H	D E A J I F	I B D H E J
LANV	A	a	D H E B I C	H G F I J D	J B A E D H
		v	2 1 5 7 3 9	3 4 9 6 7 2	6 7 1 0 8 2
NVLA	V	a	F J G A C I	C A G I J D	G A F C H B
		v	9 5 7 3 1 6	1 9 3 8 6 4	7 0 1 5 9 8
LVLA	V	a	B D A G A I	A F I G B G	B I D A C I
		v	C E H F J H	D C J E H E	E F J F H G
NVNA	V	a	7 1 0 4 0 8	4 3 0 1 9 3	7 2 5 4 6 4
		v	2 5 9 5 3 6	2 7 8 7 6 5	1 3 1 9 8 2
LALV	A	a	E J A J I D	F A I E G F	H B G A F H
		v	B C F B C H	B H D J D C	E C E I J D

Visual items were presented for .5 sec. (12 frames); the durations of the auditory items averaged 10 frames or .42 sec. Materials were presented at three rates; (1) 1 pr/.5 sec., no interstimulus interval (fast); (2) 1 pr/sec., .5 sec. interstimulus interval (medium); (3) 1 pr/2 sec., 1.5 sec interstimulus interval (slow). There was a 20 sec. interlist interval, with 15 sec. for recall and a ready signal given .5 sec. before the start of each list.

In addition, for comparison with and to obtain base line data for bisensory studies, four lists of 12 similar items (i.e., two lists of digits and two lists of letters) at each of three rates were constructed for stimulation of each modality separately. These lists are presented in Table 2.

Subjects. -- Sixty volunteer undergraduate introductory psychology students served as Ss and were tested in groups of ten.

Administration. -- The experiment was conducted in two parts. In Part I Ss were presented the unisensory materials in the exact orders in which they are displayed in Table 2. Half of the Ss were given the visual materials first and half the auditory materials first. S's task was to reconstruct each list serially, on answer sheets with spaces provided for each item. The following instructions were given:

Table 2

Unisensory Stimuli in Presentation Order

Visual	Auditory
F (1 item/.5 sec)	
5 8 5 0 3 1 8 9 4 7 2 6	4 7 9 1 0 5 1 8 7 2 6 3
E D A B D J C H G F I A	G H A G B J C A I F D E
4 3 0 1 3 9 2 7 6 5 8 0	6 7 0 6 1 9 2 0 8 5 3 4
F I F A D B I J E H C G	E H J D A F B I H C G D
M (1 item/sec)	
1 4 0 9 5 1 6 7 2 8 3 6	5 0 9 6 2 8 5 1 4 3 2 7
F H J I E A C E D B G C	A B E C G J E I H D F J
5 7 9 8 4 0 2 4 3 1 6 2	0 1 4 2 6 9 4 8 7 3 5 9
B E A J F B G H C I D G	F A J G C I F B E D C H
S (1 item/2 sec)	
9 1 3 0 1 7 4 5 8 6 9 2	1 7 2 6 4 3 9 7 8 1 0 5
C G J A B H E J H F D I	H C F D G I D I A J E B
2 6 9 0 1 7 4 9 7 5 3 8	7 2 5 3 6 8 3 8 9 0 4 1
J B D A B H E F I G J C	B H C G E D J H I B A F

> This is a memory task. You will be presented with a silent film (tape) made up of series of letters and numbers. Each series will consist of 12 letters or numbers. Immediately after each series you are to write down on your answer sheet the items you saw (heard) in their proper serial order. For example, if you see (hear) the numbers 1,2,3,4,5,6,7,8,9,10,11, 12 and you can only remember, say, four of them, you will be scored as correct only if they are in their proper serial position, i.e, 1,2,3,_,_,_,7,_,_,_,_,_. You will have approximately 15. sec. after each presentation to write down what you recall. You will be given a ready signal before the start of each series at which time you are to stop writing the previous series and attend to the screen (tape). Ten digits, 0 through 9 and ten letters, A through J will be used. A number or letter can occur twice within a series. The series of items will be presented very rapidly, in a matter of seconds, so be prepared. Are there any questions?

After the presentation of the film (tape) S was instructed:

> You will now hear a tape (film) of the same type as the film (tape) -- series of letters and numbers. The same instructions apply. Any questions?

During the film presentation, the lights were switched on for the recall interval so that S could record his responses. They were switched off again concurrent with the ready signal for the next trial.

Part II of the experiment, consisting of bisensory stimulation with the material from Table 1, commenced immediately upon the conclusion of Part I. For this part the Ss were divided into two instructional groups: half of them pre-instructed regarding order of report and half of them post-

instructed. These two instructional groups did not differ on their Part I scores. Each group of 10 Ss were assigned to one of these groups. Within these two instructional groups, rate of presentation, materials interaction, and order of report were varied in the exact manner shown in Table 1. The same lists were used for both instructional groups. The order of presentation of the rate variable was partially counterbalanced, in Latin-square manner. That is, ten Ss in each instructional group received the F, M, S order; ten in each instructional group received the M, S, F order; and the remaining ten in each group received the S, F, M order. Separate films, each duplicated from the original, were used for each order of rate presentation. On the films presented to the pre-instructed group the word "auditory" or "visual", indicating the prescribed order of report, was spoken immediately after the ready signal and before the presentation of the list. For the post-instructed group these terms were given immediately after the presentation of the last item in the list. As indicated in Table 1, half of the lists were preceded by or followed by "auditory" and half by "visual" in a prearranged random order.

Each S was given answer sheets in booklet form - each page represented one rate - with space provided for each response; auditory items were on one half of the page, visual

items on the other half. (Pilot studies indicated a written response was superior to an oral response in this situation - see Table A_3). Half of the Ss received answer sheets with visual on the right side, auditory on the left; the other half, the reverse order.

The following instructions were given:

> You will now see a film of letters and numbers and hear a tape of different letters and numbers at the same time. Thus, different items will be presented to your eyes and to your ears simultaneously. For example, sometimes you will hear numbers and see different numbers, hear letters and see different letters, hear letters and see numbers, hear numbers and see letters. This time there will be a series of six items -- six to the eyes and six different items to the ears. After each presentation you will have 15 sec. to write down both what was seen and what was heard. If you look at your answer sheets you will see a column marked auditory and a column visual. What you hear goes in the auditory column and what you see in the visual column. In order for you to be scored correct the material must be reported in the serial order in which it is presented. Before (after) each series of items you will be told whether the visual materials or the auditory materials are to be reported first. For example, before (after) each series you will hear the word "auditory" or the word "visual" -- if you hear "auditory" this means report the auditory items first and then the visual items; if you hear "visual", you report visual items first and then the auditory items -- in each case, however, you must report both sets of materials. A ready signal will be given before each presentation. The digits 0 through 9 and the letters A through J will be used. Items sometimes will appear twice within a list. Again, the materials will be presented in a matter of seconds, so be prepared. When you come to the end of one sheet of paper turn to the next. Most importantly, try to give equal attention to both sets of material. Do not memorize one set of material at the expense of the other. Any questions?

To detect gross hearing defects which might have interfered with the reception of auditory materials each S, at the end of the experimental session, was given a hearing test through ear phones which consisted of his reporting the presence of a continuous 1000 cps tone at 20 decibels above threshold. All Ss succeeded in this test.

CHAPTER III

RESULTS

The test sheets for both parts of the experiment were scored according to the accuracy of responses both in nature and location. Thus for each list in Part I the maximum possible score was 12 whereas for each list in Part II the maximum score was 6. In the succeeding analyses the two parts are considered separately and thereafter are compared.

String Analysis of Bisensory Data

The data from Part II on bisensory stimulation were first examined to determine whether each of the experimental variables had played a significant role in the results. For this purpose the 24 pairs of lists shown in Table 1 were construed as pairs of six-item strings, each to be retained on an all-or-none basis. The scores for any S were recoded as a pattern of zeroes and ones: 0-0 for success on neither string, 1-0 and 0-1 for success on one part but not the other (the former referring to success on list reported first and the latter to success on list reported second), and 1-1 for success on both strings. The responses of each sort for all 60 Ss summed as follows:

String Type	0-0	1-0	0-1	1-1	Total
Number	1038	293	98	11	1440
Per Cent	72.0%	20.4%	6.8%	0.8%	100.0%

The most salient outcome is the high probability, under this stringent criterion, of attaining neither part correctly and the vanishingly small probability of attaining both parts correctly. If, however, one part was correct, considering the data as a whole, that part was the channel reported first 75 per cent of the time.

An examination of the 1-1 occurrences of both parts correct revealed that they were contributed by six subjects and were associated with 7 of the 24 stimuli in no particular pattern. For the remainder of this analysis, therefore, the 1-1 scores were combined with the appropriate 1-0 and 0-1 distributions for each task. Table 3 shows these distributions for each of the 24 tasks for both the pre- and post-instructed groups.

The scores in Table 3 were summed in all possible ways to determine the relative importance of each stimulus dimension. These sums are presented in Table 4, in descending order of magnitude of chi-squares taken between the sums.

It is observed that differences within each dimension had a significant effect on the number of strings correctly reported, and that the dimensional differences varied considerably in their capacity to divide the 413 correct strings.

Table 3

Scores for String Analysis

	Rate of Presentation					
	Fast		Medium		Slow	
Order Instructions	1-0	0-1	1-0	0-1	1-0	0-1
LVLA (pre)	0	1	1	4	2	2
(Post)	0	1	0	2	0	1
NVLA (Pre)	2	1	13	1	6	3
(Post)	1	0	2	0	4	1
LALV (Pre)	10	0	9	2	4	2
(Post)	4	0	3	0	0	0
LANV (Pre)	14	1	6	2	6	1
(Post)	2	0	1	0	0	3
LVNA (Pre)	7	10	8	10	4	4
(Post)	2	6	10	4	3	2
NVNA (Pre)	1	9	5	5	10	1
(Post)	2	6	3	9	4	4
NALV (Pre)	21	1	10	1	14	0
(Post)	12	0	14	0	7	1
NANV (Pre)	16	2	22	3	16	1
(Post)	5	0	10	0	8	2
Totals	137		160		116	
Frst:Sec.	99	38	117	43	88	28
Aud:Vis.	118	19	110	50	73	43

Table 4

Sums of Strings Associated with Each Stimulus Dimension

					DF	χ^2	P
Order	First:	304	Second:	109	1	90.2	.001
Modality	Auditory:	301	Visual:	112	1	82.4	.001
Materials	Numbers:	293	Letters:	120	1	72.2	.001
Instructions	Pre:	274	Post:	139	1	42.1	.001
Rate	Fast:	137	Medium: 160	Slow: 116	2	7.0	.05

The five dimensions were next intercompared by means of contingency tables to determine if any interactions obtained among them. Only two of ten possible interactions proved significant and are displayed in Tables 5 and 6.

Table 5

Modality by Materials Interaction

	Letters	Numbers		
Auditory	76	225	301	$\chi^2 = 7.56$
Visual	44	68	112	DF = 1
				P < .01
	120	293	413	

Table 6

Modality vs. Rate Interaction

	F	M	S		
Auditory	118	110	73	301	$\chi^2 = 19.48$
Visual	19	50	43	112	DF = 2
					P < .001
	137	160	116	413	

Table 5 reveals a significant interaction between modality and materials: although letters are retrieved more poorly than numbers, the disparity is much greater in the auditory channel than it is in the visual channel.

Table 6 demonstrates a highly significant interaction between modality and rate. Auditory strings are retrieved pro-

gressively more poorly with decreasing rate of presentation. Visual strings, conversely, are poorest at the fastest rate. The nature of this interaction accounts for the somewhat weak discrimination attributed to rate alone in Table 4.

Finally, the distributions of correct strings were examined in terms of the contexts in which they occurred. Posed as a question, did the nature of the material occurring simultaneously in the other channel affect the success with which a string was reported? Since a significant interaction was observed in Table 5 between modality and materials, the question was examined separately for each modality-material combination. The results are shown in Table 7. It is apparent that for three of the combinations, recall for a stimulus sequence is independent of the nature of the material in the other channel. For the fourth combination, visual letters, there is an enormous disparity, suggesting that concurrent letters in the auditory channel suppress retrieval of visual letters.

Table 7

Context Responses from the String Analysis

	Accompaniment			
Material-Modality	like	Unlike	χ^2	P
Number-Auditory	111	114	.04	--
Letter-Auditory	41	35	.47	--
Number-Visual	33	35	.06	--
Letter-Visual	7	37	20.45	.001

When the same all-or-none method of scoring was applied to Part I, it was found that Ss almost never retrieved all 12 items correctly. Indeed, of 1440 12-item strings, only 29 or 2% were correct. To compare Part I and Part II data, therefore, a less stringent scoring scheme was required.

For that analysis the data of Parts I and II were scored on an item-by-item basis as described in succeeding sections.

Item Analysis of Bisensory Data

The data for each subject on each string in Part II were now scored on an item-by-item basis, permitting individual scores to take on values between 0 and 6. The average scores for each of the 48 tasks are shown in Figure 2. They are expressed as percentages to facilitate later comparisons with Part I data which are also shown in the figure.

The relations among the variables observed in the string analysis may also be discerned in this figure: more items are retained from the channel reported first than from the channel reported second; numbers are generally retained better than letters; auditory retrieval is best at the fastest rate while visual retrieval is best at the slowest rate. Also, as before, the nature of the material in the opposing channel appears to be relevant only for visual letters.

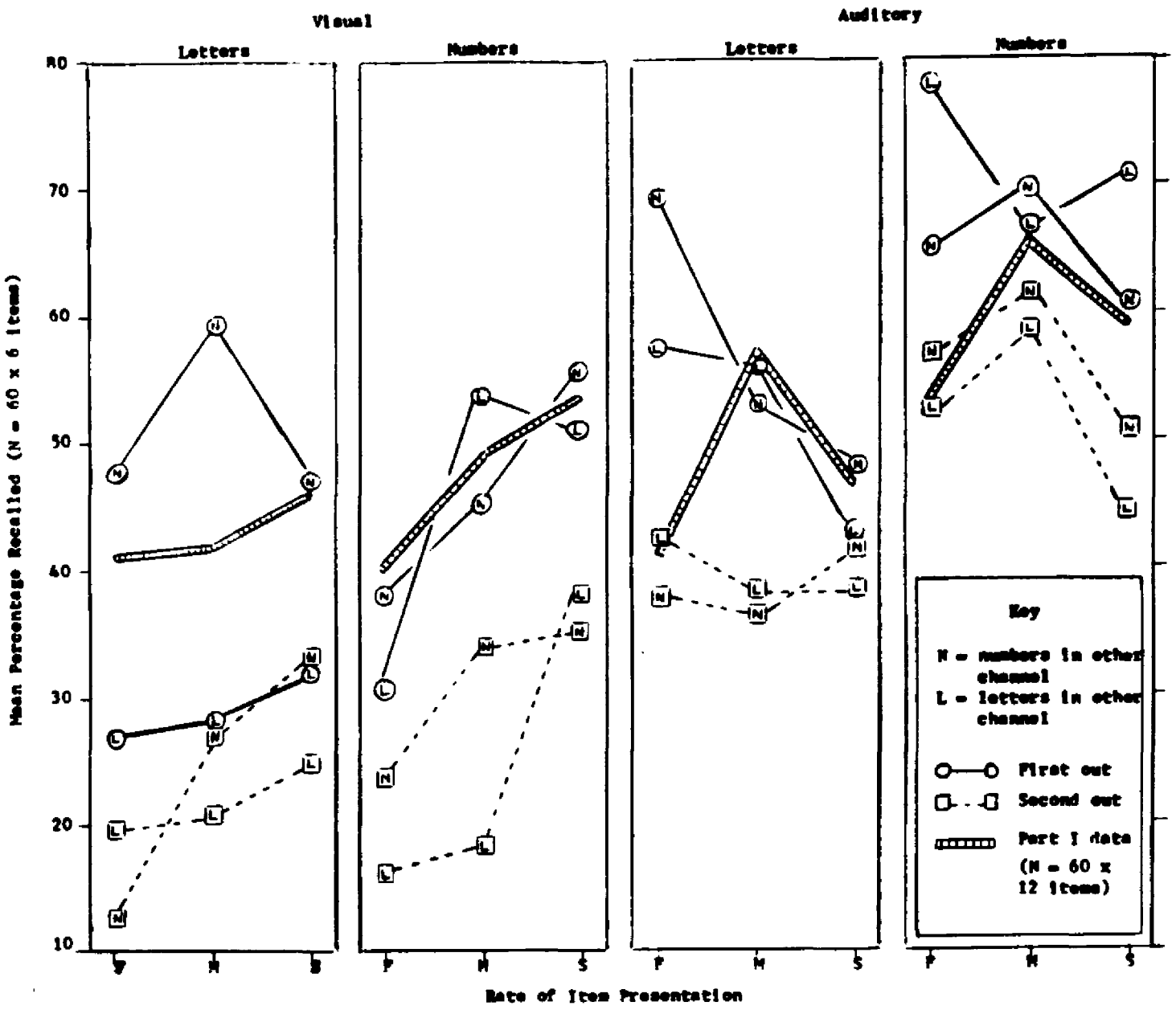

Figure 2. Intercomparison of Item Analysis of Unisensory and Bisensory Data

To render these observations more precisely, the performances of each S were summed in all possible ways as had been done in the string analysis. The mean performances associated with each stimulus dimension are shown in Table 8, where the significance tests appropriate to each dimension are indicated. These were related sample t-tests for the dimensions of order, modality, and materials, a one-way analysis-of-variance for the rate variable, and an independent-sample t-test for instructions, where it should be recalled, the two means are based on the performance of separate groups of subjects. It is observed that differences in each dimension had a significant effect on the number of items reported, but that the magnitudes of the differences are less dramatic than had been observed in the string analysis. For example, the differences in order and modality are no longer in the ratio of 3:1, but closer to 3:2.

The data were next examined for the purpose of determining interactions among the stimulus dimensions. To this end, the possibility was considered of performing a five-dimensional analysis-of-variance but the idea was dismissed for two reasons. In the first place, it was certain that high-order interactions would emerge from any idiosyncratic features of any of the 48 strings, since each of them represented a unique combination of the materials, rate, modality, and order dimensions. In the

Table 8*

Means and (Standard Deviations) Associated with each Dimension of Bisensory Stimulation (Maximum score = 6)

					DF	test	P
Overall:	2.65 (.61)						
Order:	First:	3.14 (.90)	Second:	2.16 (.65)	59	t = 8.11	.001
Modality:	Auditory:	3.24 (.88)	Visual:	2.06 (.64)	59	t = 10.57	.001
Materials:	Numbers:	2.97 (.68)	Letters:	2.33 (.61)	59	t = 11.59	.001
Instructions:	Pre:	2.89 (.60)	Post:	2.41 (.51)	58	t = 4.68	.001
Rate:	Fast 2.52 (.68	Medium 2.74 (.66)	Slow 2.69 (.76)		2.118	F = 4.06	.05

*A fixed effects model is assumed for this analysis and succeeding analyses in which the individual stimulus items are presumed to have equal difficulty. In partial corroboration, the variances associated with each of the 24 stimulus strings reported out first were intercompared and an F-ratio between the largest and smallest variance failed to achieve significance. It remains possible, however, that some of the variance associated with experimental treatments ought properly to be assigned to the stimulus strings themselves. In this case all error terms would be inflated and the present high significance levels would be somewhat diminished.

second place, it was already apparent that the nature of the material in the other channel on any task interacted with performance in an assymetric fashion.

For these reasons it was decided that interactions would be sought in a manner paralleling the method employed for the string analysis. Instead of contingency tables, each dimension was intercompared with each other dimension by means of two-way analyses of variance. Three interactions proved to be significant, two of them already established in the string analysis. Their summaries are presented in Tables 9, 10, and 11.

Table 9

Modality by Materials Analysis of Variance from the Item Analysis

	SS	DF	MS	F	P
Between Ss	13009.65	59			
Within Ss	26416.75	180			
A (Materials)	3412.60	1	3412.60	129.46	.001
AC	1555.65	59	26.36		
B (Modality)	11746.01	1	11746.01	111.77	.001
BC	6200.24	59	105.09		
AB	1020.94	1	1020.94	24.27	.001
ABC	2481.31	59	42.05		

Table 10

Modality by Rate Analysis of Variance
from the Item Analysis

	SS	DF	MS	F	P
Between Ss	8673.09	59			
Within Ss	20660.17	300			
A (Rate)	202.95	2	101.47	4.06	.05
AC	2944.72	118	24.95		
B (Modality)	7830.67	1	7830.67	111.77	.001
BC	4133.50	59	70.06		
AB	1529.95	2	764.97	22.46	.001
ABC	4018.38	118	34.05		

Table 11

Instruction by Order Analysis of Variance
from the Item Analysis

	SS	DF	MS	F	P
Between Ss	26019.32	59			
A (Instructions)	3933.00	1	3933.00	10.32	.005
Ss within groups	22086.32	58	380.79		
Within Ss	33652.57	60			
B (Order)	17064.63	1	17064.63	65.62	.001
AB	1505.32	1	1505.32	5.79	.001
B x within Ss	15082.62	58	260.04		

Table 9 parallels Table 5 in demonstrating a highly significant relation between modality and materials. A Scheffé test for multiple comparisons established that each of the four combinations of modality-materials differed significantly from one another ($p < .001$).

Table 10 parallels Table 6 in demonstrating a highly significant relation between modality and rate. As rate decreases, auditory performance lessens and visual performance improves. Indeed the progressions of means are quite regular: for audition they are 4.6-4.4-4.0, and for vision they are 2.1-2.9-3.2, in fast-medium-slow order. Scheffé tests for these data established that auditory retrieval at the slow rate and visual retrieval at the fast rate were significantly poorer than at their other rates ($p < .001$).

Table 11 describes a significant interaction between instructions and order of report, which had not been observed in the string analysis. The nature of the interaction is that pre-instruction emphasizes the disparity between the channel reported first and the channel reported second. The means for the pre-instructed group are 3.5-2.2, and for the post-instructed group are 2.8-2.1, in first out-second out order. T-tests established that the difference between the pre- and post-instructed groups remained highly significant for the channel reported first, but failed of significance for the channel reported second.

Finally, the data for each modality-materials combination were examined in terms of the context in which they occurred. Table 12, paralleling Table 7, indicates mean recall scores for like and unlike accompaniments. As before, for three of the combinations, related-sample t-tests indicate that performance is independent of the nature of the material in the other channel. For visual letters, however, a highly significant disparity obtains. Once again, retrieval of visual letters appears to be suppressed by the concurrent presentation of letters in the auditory channel.

Table 12

Mean Context Responses and (Standard Deviations) for the Item Analysis (DF = 59)

	Accompaniment			
Modality-Material	Like	Unlike	t	p
Numbers-Auditory	3.69 (1.09)	3.74 (.96)	.013	--
Letters-Auditory	2.73 (.99)	2.76 (1.00)	.009	--
Numbers-Visual	2.32 (.96)	2.09 (.74)	1.920	--
Letters-Visual	1.56 (.71)	2.29 (.91)	5.330	.001

Item Analysis of Unisensory Data

For purposes of comparison with the bisensory results, the unisensory data of Part I were now examined. For this analysis, the data for each subject on each of the 24 strings in Table 2 were scored on an item-by-item basis, permitting individual scores to take on values between 0 and 12.

In contrast to the design for Part II, each unisensory task was represented by two 12-item strings. Since an initial

comparison of all twelve pairs of similar strings revealed no significant differences, the paired scored for each S were averaged prior to further analysis.

Table 13 presents the results for each of the twelve task conditions and provides averages across each of the stimulus dimensions.

Table 13

Means and (Standard Deviations) Associated with Each Dimension of Unisensory Stimulation (Maximum score = 12)

	Visual	Auditory	Average
	Fast		
Letter	4.90 (1.47)	4.89 (1.62)	4.89 (1.55)
Number	4.75 (1.87)	6.35 (1.43)	5.55 (1.65)
Average	4.82 (1.67)	5.62 (1.52)	5.22 (1.60)
	Medium		
Letter	4.93 (1.77)	6.72 (1.76)	5.82 (1.76)
Number	5.86 (1.60)	7.91 (1.78)	6.88 (1.69)
Average	5.40 (1.68)	7.31 (1.77)	6.35 (1.72)
	Slow		
Letter	5.50 (2.21)	5.33 (2.32)	5.41 (2.26)
Number	6.40 (2.28)	7.09 (2.20)	6.76 (2.24)
Average	5.95 (2.24)	6.21 (2.26)	6.08 (2.25)
	Overall		
Letter	5.11 (1.81)	5.64 (1.90)	5.37 (1.85)
Number	5.67 (1.92)	7.11 (1.80)	6.39 (1.86)
Average	5.39 (1.86)	6.38 (1.85)	5.88 (1.85)

Table 14 presents an analysis-of-variance for these data. It is observed that each of the three main variables are highly significant ($p < .005$) and that the interactions are also highly significant ($p < .005$). These interactions are precisely those which had been observed in the bisensory condition under both methods of data analysis!

Table 14

Part I Analysis of Variance

Source	SS	DF	MS	F	P
Between Ss	2675.8	59			
Within Ss	9584.1	660			
A (Rate)	694.9	2	347.4	31.9	.005
A x Wss	1287.9	118	10.9		
B (Modality)	746.2	1	746.2	36.6	.005
B x Wss	1201.7	59	20.4		
C (Material)	682.5	1	682.5	67.6	.005
C x Wss	596.1	59	10.1		
AB	318.6	2	159.3	19.6	.005
AB x Wss	956.3	118	8.1		
AC	39.1	2	19.6	1.9	--
AC x Wss	1195.1	118	10.1		
BC	134.3	1	134.3	16.4	.005
BC x Wss	485.9	59	8.2		
ABC	58.3	2	29.1	2.9	--
ABC x Wss	1187.2	118	10.1		

The twelve task combinations of Part I are graphed in Figure 2 for purposes of direct comparison with the bisensory data. Examination of the figure permits the conclusion that

to the extent a bisensory variable is able to operate in the unisensory condition, its behavior is essentially the same. For both conditions of stimulation: auditory retrieval is generally better than visual retrieval; numbers are better than letters. Indeed, the descending hierarchy of NA > LA > NV > LV is maintained under both conditions. Except for the NA combination, however, differences between adjacent combinations in the hierarchy did not achieve significance in the unisensory condition.

The nature of the interaction between modality and rate is not precisely identical for the unisensory and bisensory conditions owing to a discrepancy at a single point. Whereas visual retrieval improves steadily with decreasing rate, and auditory retrieval lessens between the medium and slow rates of presentation, the unisensory and bisensory results for auditory retrieval at the fast rate yield divergent outcomes. Bisensory retrieval is best at the fast rate while unisensory retrieval is worst at the fast rate. This one departure from an otherwise orderly pattern, is the only obstacle to a conclusion that the rate-modality function is stable whether tested under unisensory or bisensory conditions.

CHAPTER IV

DISCUSSION

General Effects

Several of the variables studied produced effects in bisensory memory similar to those recorded for them in the existing literature on unisensory memory.

Indeed, it was not unexpected that the channel reported first should be the channel recalled best, simply because it is first out, and therefore not subject to lengthy storage demands. That instructions facilitated overall bisensory recall is also in keeping with the bulk of data collected on the effect of preparatory set.

There were also material differences which are not without a precedent. Thus, while the letters variable was defined by ten items, these ten items were part of a potentially larger response set consisting of all 26 letters of the alphabet. There is no assurance that instructions restricting the stimulus set served to adequately restrict Ss response set (Garner, 1962). By contrast, the ten digits defined both the stimulus and response set. Therefore it is not surprising that numbers prove considerably easier to recall than letters under any condition of short-term memory.

Thus the variables of instruction, order of report, and nature of materials yielded effects in the bisensory situation similar to those reported for the dichotic and ordinary immediate memory situations.

On the other hand, there were variables that yielded results which were unexpected on the basis of the existing literature. More precisely, it was not clear in advance how these variables would influence bisensory memory.

It was demonstrated that the material in one channel generally did not influence recall in the other channel; material combinations were irrelevant in determining recall. This, of course, is not in keeping with retroactive and proactive interference data. Presumably, if dichotic data were analyzed in the manner in which the present bisensory data were, that is, recall scores for a given condition when accompanied by another condition, reports of recall differences attributable to materials would disappear.

A second outcome, previously unspecifiable bisensorily, was the modality effect which cannot be considered independent of rate of presentation. Bisensorily, both modalities displayed curves predictable from data obtained for each modality when it was explored independently of the other modality. Thus the integrity of the modality-rate results was maintained even when both modalities were stimulated simultaneously. Auditory re-

sults yielded a decay function with decreasing rate, whereas visual results yielded an increasing function with decreasing rate. That this independence of modality was maintained was most surprising particularly in view of results obtained for the only other condition of simultaneous stimulation given previous attention, the dichotic situation. Briefly, in the latter case, recall was better at slower rather than faster rates, presumably because of the use of two channels.

This modality-rate interaction, i.e., differences in amount recalled in each modality at each rate in the bisensory condition and the ordinary immediate memory condition provides the most intriguing effect and as such will be discussed in some detail as will the materials variable which also, as mentioned, provided somewhat unexpected results.

Bisensory Memory

Recall of auditory materials. -- Bisensorily, six items were presented to the auditory modality and the typically reported decay function was obtained: most was recalled at the fastest rate, least at the slowest rate.

Recall of visual materials. -- In the visual modality, the finding that slower rates yield better recall requires an explanation, since decay theory in its present form cannot predict this outcome.

The nature of the rehearsal process provides a plausible basis for explaining the visual data and also the contrasts between visual and auditory recall. Broadbent (1963), Sperling (1960), and Wickelgren (1965) have all expressed the view that both auditory and visual stimuli are transformed into auditory subvocalizations. Wickelgren has further suggested that short-term storage, even when materials are presented visually is auditory (speech-motor). Broadbent, speaking of acoustic similarity, has stated:

> If one has seen the letter V, for instance, one may recall the letter B . . . It is likely that all of us will agree in this case that what is happening is that the subject tended to make a verbal response to the visually presented letters, and that subsequently in recall they responded to their own previous response . . . (1963, pp. 34-35).

Finally, Sperling (1963) proposes, as a model for visual recall, that a visual stimulus is first stored in VIS, visual information storage, in the form of a visual image. It is then scanned and rehearsed. The rehearsal component produces a verbal response "audible" in AIS, auditory information storage, or a vocal response audible to another person and indirectly also in AIS.

This alleged necessity to transpose incoming information from visual input to an aurally-based storage may serve to retard visual recall, particularly at the fastest rates. Required for this alternation may be an interval of time long

enough to affect the processing of materials arriving at a very rapid rate. By contrast, material on the auditory channel may be "shadowed" subvocally almost in simultaneity with its arrival.

In addition to differences in preferred rate of presentation, the total percentages recalled in unisensory and bisensory conditions differed for each modality. Auditory recall showed no change between the conditions while the visual underwent a decline between the unisensory and bisensory condition. Again the rehearsal process may be invoked to provide explanation for this auditory-visual difference. Acknowledging that both sets of stimuli, auditory and visual, are rehearsed subvocally, it is highly likely that for auditory materials this will occur almost instantaneously upon reception while there may be a delay involved in the subvocalizing of visually presented items. If this is the case, at the fastest rate S may rehearse all of the items in auditory input first, since switching from one modality to the other at this rate might not be the most economical method of rehearsal. This is what was suggested by Broadbent (1956), who found, in a dichotic situation, that Ss recall all of the material from one ear first and then from the other. With a slow delivery rate (one pair/2 sec.), he found recall to be possible in the order of arrival or pair-by-pair. Broadbent reasoned that at the faster rates S was

not able to switch from ear to ear fast enough to make possible order of arrival reports. In the present situation, if all of the auditory material is processed first, as suggested, S has the difficult task of recognizing and rehearsing items from the fading trace of visual input. This seems likely to be the case for fast rates. At medium and slow rates, items might be rehearsed alternately. However, also applicable to the medium and slow rates is Sperling's suggestion that ". . . the interval between the rehearsal of successive items is longer if they are not taken from the same sense modality (Sperling, 1963, p. 29)." The implication in this statement is that there should be a recall decrement for both modalities at these rates -- and in fact there is. At these two rates auditory as well as visual recall is poorer in Part II than in Part I.

Material Interactions. -- It was demonstrated that it does not matter whether the accompaniment to a given stimulus is composed of similar or dissimilar materials except in the case of visual letters. That is, how successfully auditory materials are recalled is irrelevant of what is going on in the visual modality. The same is true for the visual modality when numbers are on this channel; a similar number of lists are recalled when either type of material opposes numbers on the visual channel. However, when letters are on the visual

channel, this channel is inexplicably jammed when letters are also on the auditory channel. That acoustic similarity is not necessarily responsible for this jamming is suggested by the fact that no decrement occurs for the reverse combination, i.e., LA-LV. Further, the relevant factor in determining recall is the particular sequence to be recalled rather than the accompaniment to that stimulus except again for the LV-LA combination. That is, for example, NA when accompanied by either LV or NV is superior to the reverse combinations. Perhaps, following Sperling's model, already described, AIS might be closer to an overloaded condition when auditory letters are in store than when auditory numbers are in store. This would be plausible if numbers had an additional storage locus such as might be implied by the dual meanings of the word "digit" in our language. If auditory numbers were a lesser load on AIS more of AIS would be available to receipt of visual letters, in which case the aberrancy in the results requiring explanation would not be the jamming of visual letters by auditory letters but rather the lack of jamming resulting from the storage of auditory numbers.

Ordinary Immediate Memory

Auditory recall. -- Auditory effects are considerably less clear than visual effects. Part I indicates a strong in-

teraction between rate and amount of material presented. That is, how much is to be recalled is a subtle interplay of the rate at which material is presented. Mackworth (1965) also found an interaction between rate of presentation and message length. Specifically, she found, with eight items per message, the characteristic greater recall at a fast rate (2 items/sec.) than at a slow rate (one item/sec.); with ten items there was little difference in amount recalled at the two rates. However, when each message contained 12 items, recall at the fast rate was inferior to that at the slower rate.

Thus, in the light of Mackworth's rate-amount interaction, it is probable that the amount of material (12 items) at this fast rate (one item/.5 sec) exceeded the time capacity of the store (Broadbent, 1958) and effected a decline in the amount recalled, particularly since rehearsal was limited by the absense of an interstimulus interval at the fast rate. This view fits Brown's conception of immediate memory, described by Broadbent (1958) as a process by which:

> The presented material forms a trace which decays rapidly, but can be restored by rehearsal. Since all the items cannot be rehearsed simultaneously, there is a limit to the number of items which can be kept in existence as traces by rehearsing each in turn and returning to the first when the last has been rehearsed. Beyond a number fixed by the rate of decay, and the rate of rehearsal, the first trace will have disappeared completely before the last has been rehearsed. If this number of items has been reached, any other activity which interferes with rehearsal will cause a failure of recall (p. 226).

Thus, the effect of rate on auditory recall should not be considered independently of the amount of material involved.

Visual recall. -- Although the rate effect differed in Part I and II for recall of materials in the auditory modality, this was not the case for visually presented materials. In both Part I and Part II, while visual recall was less efficient than auditory recall, the former evidenced an increase in amount recalled as rate decreased. Explanation for these findings have been interpreted in terms of the rehearsal process. Perceptual factors acting as limitations on visual recall were considered as plausible explanations of visual findings but in view of the conditions of stimulus presentation in the present situation were thought less desirable than rehearsal factors. For example, Averbach and Coriell (1961) have posited an erasure process that is exerted upon the visual image by a succeeding one. Erasure will occur if, from the actual stimulus or its image, the item presented has not been recognized, named or read into a more permanent store before the next item appears. Mackworth (1963, 1964) has similarly suggested that one visual image may wipe out or mix with a previous one. The time relations controlling erasure appear to be such that the longer the interval between stimulus presentation, the greater is the probability that any given item will be recognized and recalled.

Bearing some resemblance to the erasure process is the masking theory developed by Eriksen and Steffy (1964) and Kolers and Rosner (1960). Backward masking, when a second stimulus interferes with the perception of the first stimulus, depends on the delay interval of the second stimulus and the luminance of the two. Kolers and Rosner have extended these masking effects so that they are bidirectional. In other words, not only does a second stimulus interfere with a first, but a first stimulus may itself interfere with a second.

Although the above explanations may apply with very close temporal contiguity (exposure durations on the order of milliseconds), and low luminance levels, such conditions did not obtain in the present study. Therefore it seems reasonable that in the present situation any limitations on visual recall are not perceptual in nature. To be specific, the visual stimuli in the present experiment were of .5 sec. duration. Furthermore, contrast was sufficiently great to preclude the occurrence of the erasure or masking effects described.

Comparisons between auditory and visual immediate memory. -- In both the ordinary immediate memory and the bisensory situation more auditory material was recalled than visual. While the result has been found by another investigator (Buschke, 1962) it is difficult to account for. One explanation of the differences in amounts recalled in the two modal-

ities might be an attentional factor. Auditory materials seem to have the advantage over visual in that attention to auditory material is more compelling. For the visual items, turning one's head from the screen or blinking can cause several items to be missed. On the other hand, one cannot "escape" the auditory material so easily. The superiority of auditory over visual presentation was noted by Elliot (1936) in an investigation of the effectiveness of visual, auditory, and visual-auditory material in advertising. Noting that sound makes use of more reflex simple central connections than are available for reaction to light, Elliot suggested, however, that a stronger explanation of auditory superiority would be the nondirectional character of sound.

> In vision an object must be fixated directly to enable a full and detailed reception. Any deviation toward peripheral or indirect vision brings an indistinct picture . . . . In audition, however, turning the head . . . . from the direction of the sound makes little difference in reception. Sound is largely nondirectional (p. 48).

Another possibility that might be of potential use in accounting for the differences in amount recalled is that the present task is sequential. That is, the stimulus materials are presented in successive fashion and are, of course, recalled successively. Auditory stimuli are by nature sequential or successive whereas sets of visual stimuli can and do occur simultaneously. Thus the auditory modality may be the more practical one for this sequential mode of presentation.

CHAPTER V

SUMMARY AND CONCLUSIONS

Some of the variables studied in the bisensory situation had the traditional effect on recall. The channel reported first was the channel that was recalled best, and prior instructions as to recall order served to facilitate the channel recalled first, leaving the second channel relatively unaffected. This order of report and instruction interaction occurs also in dichotic immediate memory and in ordinary immediate memory where the two halves of any given list are comparable to the sensory channels.

In the auditory modality rate of presentation produced a decay function whereas in the visual modality increasing amounts were recalled as the rate slowed. It seems desirable in view of this interaction, to consider modality and rate together, as the modality effects are meaningless without specifying the rate of presentation. Further, the amount presented also seems to interact with modality and rate and should also be included in specifying the effect of any given condition.

One result that would not have been predicted from retroaction concepts is that successful recall of a channel was

independent of the stimuli on the other channel except in one instance which is unaccounted for.

While there has been little call for explanation of auditory decay functions in the literature, concern has centered on visual short-term memory effects especially in relation to auditory functions and decay theory. In the present situation there are apparently limitations on the amount recalled in the visual modality. Considering the clarity of the current task these limitations are not thought to be perceptual but rather seem to be associated with events occurring after stimulation -- toward memory, as opposed to stimulus reception. In the light of present knowledge this seems to be a most parsimonious explanation. As an alternative, however, which should not be dismissed too lightly, is the possibility that there are different memory models for the two modalities, the characteristics of which have as yet to be pinpointed.

It is concluded that an individual cannot successfuly do two things at once -- i.e., S cannot attend to both channels equally. Or, if he can attend to both channels equally he cannot retain them equally well. Of relevance, then, are the variables that determine how successfully each channel will be recalled. The first concern of successful recall is order of report. That is, whether a given channel is first out or second out. This is the variable of greatest influence. For

example, the usually inferior visual modality can evidence equal recall with the auditory modality when it is the channel reported first. Of concern next should be the modality, and at the same time the rate of presentation; since these two variables are not independent of each other. And finally, the last concern, should be the materials.

APPENDIX

RESULTS OF PILOT STUDIES

The following four tables describe the results of pilot studies carried out in advance of the main experiment reported in the body of the thesis. Auditory and visual stimuli were of the same nature as used in the main experiment. Auditory material was presented on a Wollensak T-1400 tape recorder; visual material was presented on a Bell and Howell projector. In addition, the same three rates of presentation used in the main experiment were used in the pilot studies. An attempt was made to equate loudness and brightness of the materials by obtaining subjective equality judgments from each S. Ss were sometimes run in small groups, sometimes individually, a total of 17 Ss were employed in these preliminary investigations.

Table A_1

Results for Pilot Study 1[a]

(N = 8, individually tested)

Rate	Auditory		Visual	
	Mean[b] Amt.	Mean Per.	Mean Amt.	Mean Per.
1 pr/.5 sec.	34.8	48.0	23.4	32.0
1 pr/sec.	34.1	47.3	31.5	43.7
1 pr/2 sec.	29.5	40.9	36.2	50.3
Mean Total	32.8	45.4	30.3	42.0

a This study investigated appropriate list length. The table indicates recall scores at three rates of presentation with six items per list. Six pairs constituted a task of sufficient difficulty to allow for differential results in each modality at each rate. There were 12 lists in each modality; overall length of the task was reduced from 12 to eight lists/modality for the remaining studies and for the experiment proper.

b Maximum score possible: 72

Table A_2

Results for Pilot Study 2[a]

(N = 3, group tested)

Rate	Auditory		Visual	
	Mean[b] Amt.	Mean Per.	Mean Amt.	Mean Per.
1 pr/sec.	24.3	76.0	23.0	72.0
1 pr/2 sec.	26.0	81.0	26.0	81.0

a This study was concerned with list length. The table indicates recall scores at two rates of presentation with four items/list. (Due to experimental error data for the fastest rate were invalidated). Four items/list did not allow for sufficiently differential recall scores across rates and modalities.

b Maximum score: 32

Table A_3

Results for Pilot Study 3[a]

(N = 3, individually tested)

	Auditory		Visual	
Rate	Mean[b] Amt.	Mean Per.	Mean Amt.	Mean Per.
1 pr/.5 sec.	22.6	47.2	17.3	36.1
1 pr/sec.	24.3	50.6	16.0	33.3
1 pr/2 sec.	22.3	46.5	16.3	34.0
Mean Total	23.1	48.0	16.5	34.4

a Ss were required to give responses orally and E recorded them. While there were decreases in amount retained in both modalities compared to data with written response (Table A_1) the visual modality was consistently more disadvantaged than the auditory modality. It was determined that S would record his own responses.

b Maximum score: 48.

Table A_4

Results for Pilot Study 4^2

(N = 3, group tested)

	Auditory		Visual	
Rate	Mean[b] Amt.	Mean Per.	Mean Amt.	Mean Per.
1 pr/.5 sec.	36.0	75.0	31.0	65.0
1 pr/sec.	40.0	88.0	36.0	75.0
1 pr/2 sec.	43.0	89.0	42.0	87.5
Mean Total	39.6	84.3	36.3	75.8

a Distractive effects were compared in the two modalities. Ss were presented with materials to both modalities but had to recall materials in only one modality. The amount recalled when attention was given to one modality only was greater for that modality than was retention when S must attend to both sets of incoming stimuli.

b Maximum score: 48.

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