Journal of Educational Psychology
1971, Vol. 62, No. 2, 123-131

INDIVIDUAL DIFFERENCES IN VISUAL AND AUDITORY MEMORY[1]†

ARTHUR R. JENSEN[2]
University of California, Berkeley

Two groups were given visual and auditory forms of a digit memory test in a counterbalanced order (auditory-visual group and visual-auditory group) under conditions of immediate and 10-second delayed recall. Two control groups were given exclusively either the visual or auditory test. Auditory memory was better than visual for immediate recall; the reverse was true for delayed recall, the interaction being significant beyond $p < .001$. The correlations between individual differences in auditory and visual memory, after correction for attenuation based on reliabilities obtained from the control groups, did not significantly differ from unity for either immediate or delayed recall. Thus there was no evidence for individual differences as a function of sensory modality of the input. On the other hand, there was a significant ($p < .001$) interaction between subjects and time of recall (immediate versus delayed).

Are there visual learners and auditory learners? Do some individuals learn and remember better in the one sensory modality than in the other? It is at least part of the general folklore of psychology that such auditory and visual types exist. Wechsler (1958), for example, in discussing the digit memory span test, states: "It is certainly true that a good auditory memory does not go with a good visual memory [p. 131]."

Interestingly enough, despite the fact that there is a venerable literature pertaining to this question, an effort to find any real empirical support in psychological research for Wechsler's statement has come to naught. Though the issue has been often discussed and even researched, it has apparently never been subjected to a proper experiment—one so designed as to be capable of answering the key question, at least for one type of memory. We know, of course, that no single experiment could answer the question for all types of learning and memory, since there are large task-specific sources of variance which interact with individual differences. Therefore, the present paper is concerned with this question only with respect to short-term memory, specifically memory for digits, a traditional part of standard psychometric tests such as the Stanford-Binet and the Wechsler intelligence scales.

The problem really comes down to two questions: (*a*) Do people in general learn or remember more effectively when the material is presented visually or aurally? (*b*) Do some individuals favor one sensory modality over another in learning and remembering?

Most studies have tried to answer the first question; few have tried to answer the second. The results are far from unanimous. Some investigators have found auditory memory superior to visual (Binet, 1894; Koch, 1930; Münsterberg & Bingham, 1894). Others have found visual superior to auditory (Hawkins, 1897; Henmon, 1912; Kirkpatrick, 1894; O'Brien, 1921; Worchester, 1925). Simultaneous presentation of the material visually and aurally always produced the best recall (Binet, 1894; Koch, 1930; Münsterberg & Bingham, 1894). Day and Beach (1950), who reviewed the entire literature up to 1950, concluded that, in terms of a box score, visual memory is generally better than auditory. But a box score of experimental outcomes is, of course, scientifically a confession of ignorance. It means the problem is complex and the conditions that produce one or another outcome must be precisely specified. Interactions of

[1] The research reported in this paper was performed under a contract (Project No. 1867) with the Cooperative Research Program of the Office of Education, United States Department of Health, Education, and Welfare.

[2] Requests for reprints should be sent to Arthur R. Jensen, School of Education, University of California, Berkeley, California 94720.

TABLE 1
STUDIES OF THE CORRELATION BETWEEN VISUAL AND AUDITORY MEMORY

Investigator	Material	N	Reliability		Correlation r_{AV}
			r_{AA}	r_{VV}	
Gates (1916c)	Digits	172			.57
Gates (1916b)	Digits	165			.62
Hao (1924)	Digits	83	.52	.83	.39
Wissler (1901)	Digits (written)	144			.29
	Digits (placed)	144			.39
Kitson (1917)	Various	40			.09–.54
Gates (1916a)	Various	197			.07–.41
Carey (1914)	Various (pooled)	150	.68	.64	.44

Note.—The author is indebted to John J. Geyer for compiling the information in this table.

the key variable (sensory modality) with other experimental variables could account for seemingly contradictory results in different studies, as could the interaction of the key variable with subject variables or individual differences. For example, although the majority of studies show that adults do better on visual than on auditory memory tasks, it appears that the reverse is true for children (Abbot, 1909; Hawkins, 1897; MacDougall, 1904). And visual short-term memory has been found to decline more rapidly with age (over 40) than auditory memory (McGhie, Chapman, & Lawson, 1965). In brief, the question of the superiority of visual or auditory memory cannot be given a general answer that covers all conditions and types of subjects. An experimental analysis of the specific conditions that make for the superiority of one or the other is needed.

What about the second question, that of individual differences? It should be answerable for a specified type of memory task. Kay (1958) used a paired-associate test consisting of familiar words and found that 45% of the subjects performed about equally in both modes of presentation, 12% did significantly better in the visual, and 4% did better in the auditory. If the same kind of material is presented to a group of subjects in each of two modalities independently, all aspects of the presentation being held constant except sensory modality, then the correlation between subjects' performance in the two modalities should be significantly less than 1.00 (after correction for attenuation), if the hypothesis of individual differences in the relative efficacy of the visual and auditory modalities in short-term memory is to be upheld. Several studies have been conducted in this vein. They are summarized in Table 1. The raw correlations (r_{AV}) between auditory and visual performance, being generally quite low, would give the impression that individual differences in auditory and visual memory are not highly correlated. But in most cases, we do not know the reliabilities (r_{AA} and r_{VV}) of the auditory and visual memory tests, and therefore cannot interpret the magnitude of the correlation r_{AV}. In the two instances where the reliabilities (r_{AA} and r_{VV}) are given, we do not know if they were obtained by a method that parallels the method for obtaining r_{AV}. Split-half reliability, for example, is different from test–retest reliability in theory and usually in fact, and so it would make little sense to correct r_{AV} for attenuation by using either type of reliability coefficient arbitrarily. The lack of any real answer to our question revealed by these data thus highlights the minimum requirements of any experiment addressed to the problem.

Essentials of Experimental Design

A proper test of the hypothesis must be designed to answer the question of whether the correlation (corrected for attentuation) between auditory and visual memory is significantly less than 1.00, that is,

$$\frac{r_{AV}}{\sqrt{r_{AA}r_{VV}}} < 1.00$$

This implies: (*a*) Reliability estimates (r_{AA} and r_{VV}) that are at least as dependable as the correlation between auditory and visual performance (r_{AV}) must be obtained. (*b*) Reliability coefficients must be in every way parallel to the r_{AV} correlation, that is, both the total amount of practice and the intervening time interval in the subjects' performance for obtaining the auditory-auditory and the visual-visual correlations (r_{AA} and r_{VV}) must be identical to the procedures for obtaining the auditory-visual correlation (r_{AV}). This can be achieved only by using independent groups of subjects randomly sampled from the same pool for determining the reliabilities of the visual and auditory tests, and still another group for determining the correlation between the visual and auditory tests. (*c*) The possibility of practice in one modality transferring differentially to the other must be counterbalanced by using two groups to obtain the correlation between modalities, one which practices auditory first and then visual, and one which does the reverse. The two correlations that result are designated r_{AV} and r_{VA}, respectively. (*d*) The testing procedure should be identical in all respects except for the sensory modality of the presentation.

The present experiment was designed to fulfill these requirements. In addition to sensory modality, one other experimental variable was introduced: immediate recall versus a 10-second delay in recall. Since time of recall cannot be precisely controlled in individual subjects, it is preferable to attempt to assess the effect of the variable by manipulating it and determining if it interacts with the subjects and with sensory modality.

METHOD

Subjects

The subjects were 150 undergraduate university students, 19 to 23 years of age, in an introductory educational psychology course. They were randomly assigned to four groups.

Group AA ($n = 50$). Subjects were given equivalent forms of the auditory digit memory test on each of 2 days.

Group VV ($n = 50$). Subjects were given equivalent forms of the visual digit memory test on each of 2 days.

Group AV ($n = 25$). Subjects were given the auditory digit memory test on the first day (Day 1) and the visual test on the second day (Day 2).

Group VA ($n = 25$). Subjects were given the visual test on Day 1 and the auditory test on Day 2.

Procedure

Apparatus. The subjects were tested alone in a sound-protected room which was barren except for the simple apparatus essential for the testing. The experimenter could observe the subject from an adjoining room through a one-way window. On the visual test, digits (2 inches high) were presented on an in-line display unit placed approximately 2 feet from the seated subject, at eye level. Rate of digit presentation, stimulus selection, and all time intervals were preprogrammed on a punched tape and were automatically controlled by an apparatus described in detail elsewhere (Jensen, Collins, & Vreeland, 1962). For the auditory test, the in-line display unit was replaced by a speaker which presented the digits (and other signals involved in the procedure) in a normal, clear female voice. The tape recording was made to precisely the same pacing rate and time intervals as the visual presentation by having the speaker read aloud the entire automatically presented visual test into a tape recorder. In front of the subject, who was seated at a table, there was a response console tilted at a 30° angle. Directly in the center of it was a clipboard holding the specially prepared forms on which the subject would write his response after each series of digits had been presented. Three inches away from each side of the clipboard were two pushbuttons (¾-inch in diameter) protruding from the console; the right-hand button was labeled with a red plus (+) sign and the left-hand button was labeled with a red minus (−) sign. To prevent the subjects' writing during the presentation of the digit series and during the delay interval prior to recall, the subject was required to keep his index fingers poised on the pushbuttons. (Failures to do so at the prescribed times were automatically recorded by the apparatus.)

Materials

The digit series, comprised of numerals 1 through 9 (zero was never used), were originally produced by a computer; the sequence was always random, with two exceptions: (*a*) no digit was ever repeated in the series, and (*b*) no two digits ever occurred in the normal numerical order in the forward direction, such as 3–4 or 7–8.

There were two conditions of recall, immediate and delayed; in the delayed condition the subject received the signal to write his response 10 seconds after the last digit of the series had been presented. The delay interval was filled by a random sequence of red plus and minus signs, at a 1-second rate, on the screen (in the visual presentation) or spoken (in the audio presentation); the subject was required to press the corresponding plus and minus pushbuttons as these symbols appeared on the screen or issued from the speaker. The subject's errors and omissions of pushbutton responses were automatically tabulated on counters in the control unit, so it was possible to tell if the subjects were obeying instructions.)

Each digit series was preceded by the sound of a "bong" as a signal to pay attention, and after the digit presentation a "bong" signaled for the subject to write his response. (The same "bong" was common to both the visual and auditory presentations.)

Instructions

The task was explained to the subject with the aid of a wall chart which showed the two conditions (immediate and delayed) and the design of the whole procedure, as follows:

Immediate Recall

Events	*Time*
bong (ready signal)	1 second
blank	1 second
digits (2 to 9)	2–9 seconds
bong (signal to write)	1 second
blank (for writing response)	13 seconds
bong (ready signal)	1 second
etc.	

Delayed Recall

Events	*Time*
bong (ready signal)	1 second
blank	1 second
digits (2 to 9)	2–9 seconds
blank	1 second
+ and − (random order)	8 seconds
bong (signal to write)	1 second
blank (for writing response)	13 seconds
bong (ready signal)	1 second
etc.	

There were five replications of the test in each day's session. Thus there were 8 (series lengths) × 2 (immediate or delayed recall) × 5 (replications) = 80 digit series presented in each test.

To insure that all subjects understood the instructions and procedure, the test proper was preceded by a practice test consisting of eight series (four of each condition, immediate and delayed); the digit series was never larger than five in the practice test.

The equivalent forms (1 and 2) of the test were identical in all respects except that different digit series were used in each. The visual and auditory tests also were identical (for both Forms 1 and 2) except in mode of stimulus presentation.

The subjects were tested on Forms 1 and 2 on each of 2 days, Day 1 and Day 2, 1 week apart, at the same hour.

Measures

The subjects were instructed to write down in correct sequence as many of the digits as they could recall. The answer sheet contained 80 series of 9 boxes for the subject to write his responses. The subject's score is the total number of digits recalled in the correct positions.

The possible total number of correct responses for 1 day's test session (of approximately 50 minutes) was thus the sum of series lengths $2 + 3 + \cdots + 9 = 44 \times 2$ (delayed or immediate) $\times 5$ (replications) $= 440$. The subjects' answer sheets were directly punched on IBM cards and scoring was done by computer.

RESULTS

Effects of Sensory Modality

Table 2 presents the means and standard deviations of digit recall scores for the four groups in the study. All mean differences between the main effects of auditory and visual, between immediate and delayed recall, and between Day 1 and Day 2 (i.e., the general practice effect) are revealed by analysis of variance to be significant beyond the .001 level. Day 2 performance is significantly superior to Day 1, indicating a practice effect. Immediate recall is nearly always superior to delayed recall; only 2 of the 150 subjects showed either no overall difference or a difference in favor of delayed recall. Overall, visual was superior to auditory, but this fact must be viewed in relation to

TABLE 2

SUMMARY STATISTICS ON THE FOUR GROUPS IN THE EXPERIMENT

Measure	Visual (Group VV)				Auditory (Group AA)				Visual-auditory (Group VA)				Auditory-visual (Group AV)			
	Day 1		Day 2		Day 1		Day 2		Day 1		Day 2		Day 1		Day 2	
	M	*SD*	*M*	*SD*	*M*	*SD*	*M*	*SD*	*M*	*SD*	*M*	*SD*	*M*	*SD*	*M*	*SD*
Immediate (I)	172.22	22.25	182.94	20.69	180.37	20.05	184.39	20.02	182.84	21.60	181.88	22.33	169.28	23.46	177.96	26.38
Delayed (D)	152.66	30.16	171.26	25.41	136.00	25.68	146.29	28.32	163.00	29.61	137.60	31.48	129.48	27.84	156.60	34.59
Difference (I − D)	19.56	17.32	11.68	17.64	44.37	19.44	38.10	21.48	19.84	16.62	44.28	13.60	39.80	19.02	21.36	18.64
Relative difference[a]	11.38	10.78	6.10	9.29	24.20	10.52	20.31	11.44	11.00	9.90	24.72	9.91	23.24	11.81	12.40	12.55

Note.—$n = 50$ for Group VV and for Group AA, $n = 25$ for Group VA and for Group AV.

[a] The formula for the relative difference is $[(I - D)/I] \times 100$.

the marked interaction between sensory modality and time of recall.

The interaction between sensory modality (auditory versus visual) and time of recall (immediate versus 10-second delay) is significant beyond the .001 level. The form of this interaction is shown in Figure 1. For immediate recall, auditory was superior to visual ($p < .05$) and for delayed recall, visual was markedly superior to auditory ($p < .001$).

Transfer or practice effects from visual to auditory and from auditory to visual practice unfortunately cannot be properly assessed from these data. Differences in difficulty level of the auditory and visual conditions on Day 1 are confounded with Day 2 performance, such that comparisons of Day 2 scores between Groups VA and AA and between Groups AV and VV cannot be rigorously interpreted with respect to the relative amounts of transfer from one sensory modality to the other. This transfer or practice effect could be properly assessed only if the auditory and visual tasks were somehow experimentally equated in difficulty. (Statistical equating, as by analysis of covariance, would be an incorrect procedure in this case.)

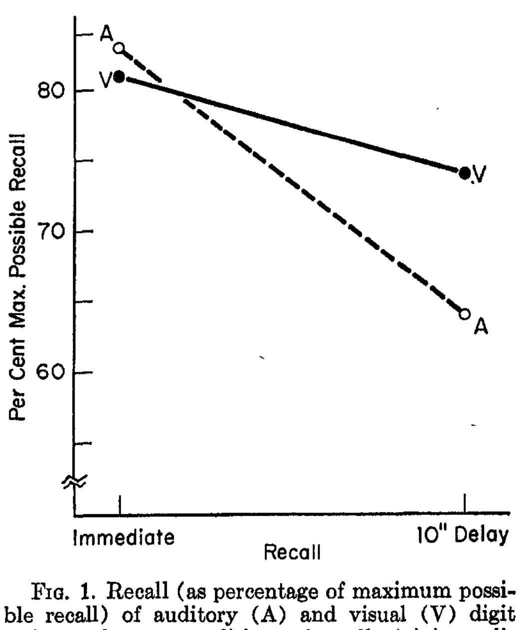

FIG. 1. Recall (as percentage of maximum possible recall) of auditory (A) and visual (V) digit series, under two conditions of recall: (*a*) immediately following presentation of the digit series, and (*b*) following a 10-second delay after the presentation of the series. (Series varied in length from two to nine digits presented at a rate of 1 digit per second.)

Serial Position Effects

Since serial position effects (i.e., probability of correct recall of a digit as a function of its position in the series) have some bearing on the theoretical interpretation (see Discussion section) of the interaction shown in Figure 1, the serial position data are given in Tables 3 and 4 as probability of correct recall of each digit at each position in the series.

Individual Differences

The principal question this study was designed to answer is, Do some persons have better short-term memory in one modality than in another? If the true-score correlation between modalities is significantly less than unity, the answer to this question is yes. If the true-score correlation does not differ significantly from unity, it cannot be concluded that individual differences in recall interact with sensory modality of the presentation.

The appropriate reliability coefficients for the visual and auditory tasks are obtained from the correlations (r_{AA} and r_{VV}) between Day 1 and Day 2 for Group AA and Group VV, for immediate recall and delayed recall separately. These reliability coefficients are then used to correct the correlations (r_{AV} and r_{VA}) between auditory and visual tasks for attenuation to obtain the true-score correlation between modalities. The true-score (i.e., corrected) correlations (r') are $r'_{AV} = r_{AV}/\sqrt{r_{AA}r_{VV}}$ and $r'_{VA} = r_{VA}/\sqrt{r_{AA}r_{VV}}$. The results are shown in Table 5. Since none of the corrected correlations is significantly less than unity, these data do not support the hypothesis that individual differences in memory for digits are a function of the sensory mode (visual versus auditory) of presentation. This is true for both immediate and delayed recall. Even though the mean difficulty level of auditory and visual tasks is reversed in immediate and delayed recall, the rank order of individuals' recall scores remains the same in both modalities. Another way of stating this, in terms of the

TABLE 3

PROBABILITY OF CORRECT RECALL IN VISUAL DIGIT SERIES AS A FUNCTION OF LENGTH OF SERIES, SERIAL POSITION OF DIGIT, AND TIME OF RECALL (IMMEDIATE VERSUS DELAYED)

Series length	Time of recall	Serial position									*M*
		1	2	3	4	5	6	7	8	9	
2	Immediate	982	987								985
	Delayed	975	962								968
3	Immediate	983	981	985							983
	Delayed	981	965	951							966
4	Immediate	982	979	977	975						978
	Delayed	954	937	919	833						911
5	Immediate	976	956	940	949	961					956
	Delayed	932	850	830	794	826					846
6	Immediate	982	936	907	890	906	921				924
	Delayed	971	899	843	800	772	794				847
7	Immediate	942	907	861	795	779	749	786			831
	Delayed	916	775	691	644	627	558	519			676
8	Immediate	896	778	724	662	594	599	550	557		670
	Delayed	872	764	683	604	536	499	428	444		604
9	Immediate	914	728	623	605	552	505	494	418	458	589
	Delayed	856	733	597	523	464	396	359	311	340	508

Note.—Decimals are omitted. Differences greater than .040 are significant beyond the .01 level.

analysis of variance, is that there is no significant Subjects × Modality interaction.

Interaction of Subjects × Recall Condition

Time of recall (immediate versus delayed), on the other hand, interacts significantly with subjects, both for visual (Group VV: $F = 4.09$, $df = 49/196$, $p < .001$) and for auditory (Group AA: $F = 5.62$, $df = 49/196$, $p < .001$) presentation. Individual differences in immediate and delayed recall have between 60% and 70% of their true-score variance in common. While virtually all subjects show poorer delayed than immediate recall, some subjects show a considerably greater memory decrement after delayed recall than do others. Thus, subjects do not maintain the same rank order of ability in immediate and delayed recall, while they do maintain the same rank order in the aural and visual tests.

DISCUSSION

Mean Differences

The present findings are consistent with earlier studies that generally reported superior recall for auditory than for visual presentation. All these studies used immediate recall, which favors the auditory. The important question, however, is why does sensory modality interact with time of recall? Clues to the answer are provided by recent theory and research on short-term memory.

Sperling (1963) has hypothesized that a primary function of verbal rehearsal in visual memory tasks is to convert information from visual to auditory storage. That is to say, the memory traces are transformed and encoded in an auditory form, regardless of the sensory channel of reception. Rehearsal, therefore, should be less necessary

TABLE 4

PROBABILITY OF CORRECT RECALL IN AUDITORY DIGIT SERIES AS A FUNCTION OF LENGTH OF SERIES, SERIAL POSITION OF DIGIT, AND TIME OF RECALL (IMMEDIATE VERSUS DELAYED)

Series length	Time of recall	Serial position									*M*
		1	2	3	4	5	6	7	8	9	
2	Immediate	997	997								997
	Delayed	984	973								979
3	Immediate	998	997	998							998
	Delayed	981	954	957							964
4	Immediate	996	982	918	929						956
	Delayed	976	926	878	818						900
5	Immediate	997	978	962	969	983					978
	Delayed	917	796	744	672	689					764
6	Immediate	986	932	876	844	896	950				914
	Delayed	940	805	698	628	568	636				712
7	Immediate	980	922	870	805	761	750	858			849
	Delayed	893	700	594	466	428	340	373			542
8	Immediate	921	794	708	639	592	588	615	700		695
	Delayed	817	631	517	459	376	320	255	272		456
9	Immediate	900	733	588	589	469	465	473	508	670	599
	Delayed	830	710	509	409	361	284	247	227	257	426

Note.—Decimals are omitted. Differences larger than .040 are significant beyond the .01 level.

for auditory than for visual presentation, since no effort is needed on the subject's part to transform the auditory input to get it into auditory storage. (Yet, strangely enough, unilateral temporal lobe damage or lobectomy seriously impairs auditory but not visual memory—Meyer, 1961, p. 545.) Rehearsal serves not only to convert the visual to auditory storage, but also to strengthen the memory trace, whether presentation is visual or auditory. If subjects transform the visual input into an auditory form, then it should be less susceptible to visual retroactive interference (the series of red pluses and minuses projected on the screen) than to auditory forms of retroactive interference (a spoken series of "plus" and "minus"). The subjects often report assuming a more passive attitude in the auditory than in the visual presentation; they experience an "echo chamber" effect for immediate recall of auditory digits, and simply read back the "echo" in writing down their answer. But the echo fades rapidly and also is highly susceptible to interference by any other intervening auditory input, and thus there is a greater decrement in the delayed recall of auditory as compared with visual digits.

This interpretation is consistent with Gates' (1916b) finding that subjects tested with lists that exceeded their immediate memory span remembered 25.9% less than

TABLE 5

RAW CORRELATIONS BETWEEN DAY 1 AND DAY 2 FOR THE FOUR GROUPS AND CORRELATIONS CORRECTED FOR ATTENUATION FOR THE CHANGED-MODALITY GROUPS (AUDITORY-VISUAL AND VISUAL-AUDITORY)

Recall condition	Raw correlations				Corrected correlations	
	r_{AA}	r_{VV}	r_{AV}	r_{VA}	r'_{AV}	r'_{VA}
Immediate	.82	.70	.86	.78	1.13	1.03
Delayed	.80	.79	.79	.79	.99	1.00

their span on visual and 36.6% less on auditory tasks. If we assume that the amount recalled is less than the subject's span when the series presented exceeds the span because the subsequent items in the series retroactively inhibit the earlier items, it appears from Gates' results that auditory presentation is more retroactively inhibiting than visual presentation. In the present experiment it is interesting that the digit position with the lowest probability of correct recall (in series of three to nine digits) is, on the average, 2.14 positions from the end of the series for visual, and 2.71 for auditory (see Tables 4 and 5). This is consistent with Gates' (1916b) finding.

Waugh (1960) has suggested that subjects rehearse a digit series (or any other kind of serial list) "cumulatively"—that is, during presentation, subjects repeat to themselves the items from the beginning of the series up to the item being presented. The earlier items are therefore more thoroughly rehearsed, and this would account for the pronounced primacy effect (i.e., superior recall of the first items as compared with the last) typically found in short-term serial memory. Corballis (1966) tested this hypothesis for immediate recall of digits separately under visual and auditory presentation. The experiment also included two conditions of presentation—one favored cumulative rehearsal, the other did not. It turned out there was cumulative rehearsal for visual digits but little, if any, for auditory. Corballis concluded that rehearsal, particularly cumulative rehearsal, is more restricted by auditory than by visual presentation.

The Waugh and Corballis hypotheses should predict a greater primacy effect for the visual than for the auditory digit series, due to greater cumulative rehearsal from the beginning of the list for the visual than for the auditory series. And we should expect this to show up even more for delayed than for immediate recall, since rehearsal should lessen decay of the memory trace. This prediction is not entirely borne out by the present data. An index of the primacy effect was derived for every length of list; it consisted simply of the ratio of first-position correct responses to last-position correct responses. In immediate recall, the mean index was 1.24 and 1.12 for visual and auditory tasks, respectively; but delayed recall showed the opposite: 1.47 for visual versus 1.83 for auditory. Since delay of recall increases the primacy effect for both visual and auditory tasks, it is puzzling, and also contrary to the Waugh-Corballis hypothesis, that the strongest primacy is found for auditory delayed recall.

Individual Differences

The fact that there are no significant individual differences as a function of sensory modality would seem consistent with the hypothesis that the stimuli, regardless of sensory channel, are encoded in a single auditory short-term memory system. Under this condition, and assuming the subjects had no primary visual or auditory defects, the only source of individual differences in visual and auditory memory would be in the effectiveness with which subjects transformed visual input into an auditory memory trace. This can be thought of as a kind of mediation process. It might well be that young children, the mentally retarded, the senile, and certain types of brain-damaged subjects would show marked individual differences in auditory and visual memory span. A college population, on the other hand, by its very nature has been thoroughly, though indirectly, screened for these conditions. Also, one would expect a more or less uniformly high level of development of the rudimentary transformational or mediational skills involved in digit memory among a young, intellectually superior segment of the population. (The present subjects were at least in the upper 10% of all high school graduates.) The present results, therefore, cannot safely be generalized to a population that includes all ages, all levels of intelligence, or organic brain abnormalities.

REFERENCES

ABBOT, E. E. Memory consciousness in orthography. *Psychological Monographs,* 1909, **11,** 127–158.

BINET, A. *Introduction à la psychologie experimentale.* Paris: Baillière, 1894.

CAREY, N. Factors in the mental processes of school children. *British Journal of Psychology,* 1914, **7,** 453–490.

CORBALLIS, M. C. Rehearsal and decay in immediate recall of visually and aurally presented items. *Canadian Journal of Psychology,* 1966, **20,** 43–51.

DAY, W. F., & BEACH, B. R. *A survey of the research literature comparing the visual and auditory presentation of information.* (AF Technical Report No. 5921) Dayton, Ohio: Wright-Patterson Air Force Base, 1950.

GATES, A. I. Correlations and sex differences in memory and substitution. *University of California Publications in Psychology,* 1916, **1,** 343–350. (a)

GATES, A. I. The mnemonic span for visual and auditory digits. *Journal of Experimental Psychology,* 1916, **1,** 393–404. (b)

GATES, A. I. Variations in efficiency during the day, together with practice effects, sex differences, and correlations. *University of California Publications in Psychology,* 1916, **2,** 1–56. (c)

HAO, Y. T. The memory span of 600 Chinese school children in San Francisco. *School and Society,* 1924, **20,** 507–510.

HAWKINS, C. J. Experiments on memory types. *Psychological Review,* 1897, **4,** 289–294.

HENMON, V. A. C. The relation between mode of presentation and retention. *Psychological Review,* 1912, **19,** 79–96.

JENSEN, A. R., COLLINS, C. C., & VREELAND, R. W. A multiple S-R apparatus for human learning. *American Journal of Psychology,* 1962, **75,** 470–476.

KAY, B. R. Intra-individual differences in sensory channel preference. *Journal of Applied Psychology,* 1958, **42,** 166–167.

KIRKPATRICK, E. A. An experimental study of memory. *Psychological Review,* 1894, **1,** 602–609.

KITSON, H. D. The scientific study of the college student. *Psychological Monographs,* 1917, **23**(1, Whole No. 98).

KOCH, H. L. Some factors affecting the relative efficiency of certain modes of presenting material for memorization. *American Journal of Psychology,* 1930, **42,** 370–388.

MACDOUGALL, R. Recognition and recall. *Journal of Philosophy, Psychology, and Scientific Method,* 1904, **1,** 229–233.

MCGHIE, A., CHAPMAN, J., & LAWSON, J. S. Changes in immediate memory with age. *British Journal of Psychology,* 1965, **56,** 69–75.

MEYER, V. Psychological effects of brain damage. In H. J. Eysenck (Ed.), *Handbook of abnormal psychology.* New York: Basic Books, 1961.

MÜNSTERBERG, H., & BINGHAM, J. Memory. *Psychological Review,* 1894, **1,** 34–38.

O'BRIEN, A. A quantitative investigation of the effect of mode of presentation upon the process of learning. *American Journal of Psychology,* 1921, **32,** 249–283.

SPERLING, G. A model for visual memory tasks. *Human Factors,* 1963, **5,** 19–31.

WAUGH, N. C. Serial position and the memory span. *American Journal of Psychology,* 1960, **73,** 68–79.

WECHSLER, D. *The measurement and appraisal of adult intelligence.* (4th ed.) Baltimore, Md.: Williams & Wilkins, 1958.

WISSLER, C. The correlation of mental and physical tests. *Psychological Review Monograph Supplement,* 1901, **3**(6, Whole No. 16).

WORCHESTER, D. A. Memory by visual and auditory presentation. *Journal of Educational Psychology,* 1925, **16,** 18–27.

(Received January 11, 1970)