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EFFECTS OF MODALITY AND SIMILARITY ON CONTEXT RECALL[1]

MICHELENE T. H. CHI[2] AND WILLIAM G. CHASE

Carnegie-Mellon University

In S. Sternberg's 1967 context-recall task, the search rate through short-term memory was a function of the sensory modality: If the memory set and test item were presented in the same mode (auditory–auditory or visual–visual), search rates were 48 msec. faster than for opposite-mode presentations.

In Sternberg's (1966) item-recognition task, Chase and Calfee (1969) found that when the memory set and test item were presented in different modalities (auditory vs. visual), search time was consistently slower than when the same mode was used. The slower search rates in the cross-modal case suggest that some of the original sensory information still remains in short-term memory even when verbal materials are encoded. Studies by Posner and his colleagues (e.g., Posner & Keele, 1967), using a same–different judgment, support this assumption. That is, responses to items presented in the same mode (within a few seconds of each other) are always faster than those in mixed modes.

Chase and Calfee (1969) further failed to find a consistent effect of acoustic confusability, although Conrad (1964) and many others have shown that acoustic similarity is a major source of interference in short-term memory tasks requiring recall of verbal materials. These effects of acoustic interference at recall occur regardless of whether the original material is presented visually or auditorily. Chase and Calfee, however, reported slower search rates through acoustically confusing material in only one of three item-recognition experiments.

The implication of Chase and Calfee's (1969) findings is that in the item-recognition task, the comparison does not always involve an acoustic-articulatory match but rather a sensory match is made if the modes are the same, and a higher level comparison is made if the modes are mixed. Chase and Calfee reconciled their findings with Conrad's (1964) by suggesting that perhaps the item-recognition paradigm does not involve the acoustic-articulatory process that produces interference due to acoustic similarity with recall.

The purpose of this experiment is to examine the effects of modality and similarity on Sternberg's (1967) context-recall paradigm. This task is very similar to the item-recognition task except that upon presentation of the test item, *S* must name the next item in the memory set that follows the test item. In the item-recognition task, *S* must say whether or not the test item is a member of the memory set. We expect a large effect of acoustic similarity and no effect of modality if, as Chase and Calfee (1969) suggest, a recall paradigm is the critical factor in Conrad's (1964) acoustic confusability effect.

Method.—Each trial of the context-recall paradigm consisted of a memorizing phase followed by a test phase. During the memorizing phase, *S* was presented with a list of three to six letters of the alphabet. When *S* indicated that he had memorized the list, the test phase followed with the presentation of a single test letter from the list. The *S*'s task was then to name, as quickly as possible and without errors, the letter following the test letter in the memorized list. If the test letter was the last letter of the list, then the response was the first letter of the list. The *S*'s latency was measured from the onset of the test letter to the vocal response.

Lists and test letters were presented either visually or aurally. During visual presentation, the memory set (typed in elite capitals) was seen on the top of a 5 × 8 card. Auditory presentations of the list consisted of *E* repeating the memory set, at approximately 2 letters/sec, with a 1-sec. pause at the end of the list.

The *S* took as much time as he wanted to memorize the lists. For auditory presentations, the number of repetitions of the memory set varied anywhere from 1 to as many as 10, depending upon *S*, size of the memory set, and the type of material. For visual presentations, *S*s used less time, but again the time depended upon *S*, the size of the memory set, and the type of material.

If a visual test followed, *S* pressed a button, looked into a Polymetric two-channel tachistoscope, and 1 sec. later the test letter appeared and the timer started. At a viewing distance of 39.6 cm., the test letter, as well as letters in the memory set, subtended a visual angle of about 24′ vertically. If an auditory test followed, *S* said "ready" and looked into the tachistoscope. The *E* then said "ready," paused about 1 sec., and then said the test letter, which started the timer and presented a blank field in the tachistoscope.

The three types of material were neutral letters (A, D, H, I, M, Q, Y, Z), visually confusable letters (B, C, D, G, O, Q, R, U), and acoustically confusable letters (B, C, D, E, P, T, V, Z). Visual similarity was defined by an a priori overlap measure and acoustic confusability was based on Conrad's (1964) confusion data. The sets were closely equated for naming time and frequency of occurrence in the English language.

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[2] Requests for reprints should be sent to Michelene T. H. Chi, Department of Psychology, Carnegie-Mellon University, Schenley Park, Pittsburgh, Pennsylvania 15213.

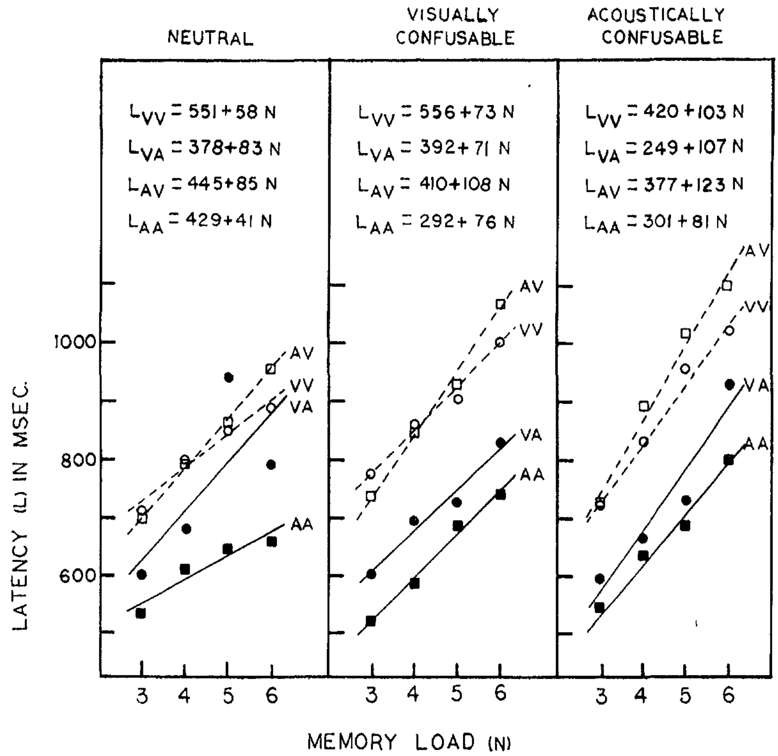

FIG. 1. Mean latency as a function of memory load for each similarity condition and each modality condition: Auditory list–auditory test (AA), auditory list–visual test (AV), visual list–auditory test (VA), and visual list–visual test (VV).

Eight *S*s served in all four combinations of auditory and visual memory set and test letter presentations: Visual list–visual test (VV), visual list–auditory test (VA), auditory list–visual test (AV), and auditory list–auditory test (AA). The order of these four conditions was counterbalanced across *S*s with a 4 × 4 Latin square.

For each of the four sessions, there were 192 trials plus 12 lead-in trials. The 192 trials consisted of 64 trials for each memory set size (3, 4, 5, 6) within each type of material. Each serial position of the test item was tested approximately equally often. The order of the 192 trials was randomized for each *S* and each session. Each session lasted about 1½ hr., there was a short break after 96 trials, and only one session was run per day.

Results.—Reaction time was a linear function of memory load under all modality and similarity conditions, the linearity accounted for 99.5% of the variance due to memory load, and there was no significant lack of fit, $F\ (2, 21) < 1$. Finally, there were strong serial position effects (all $p\text{s} < .001$) with the latency generally increasing linearly from Serial Position 1 onward, suggesting a serial self-terminating search process. All of these results are in accord with the original findings of Sternberg (1967). Hence, we use the slope of the line as a measure of the memory search rate. With a self-terminating search, the memory search rate is twice the slope of the regression line since *S*s search half of the list on the average before finding the test item. The average slope of 84 msec. in this experiment is interpreted as a memory search rate of 168 msec/item. The intercept and slope parameters are shown in Fig. 1 for the modality and similarity conditions.

The most important result of the present experiment was that the search rates were faster by 48 msec/item when the memory set and test item were presented in the same mode (AA, VV) than in opposite modes (AV, VA); this contrast accounted for 96% of the variance due to the Memory Set Modality × Test Item Modality interaction on the search rates, $F\ (1, 7) = 86$, $p < .001$. This result is very similar to that reported by Chase and Calfee (1969) for recognition latencies.

The basic finding involving similarity was that search rates were slower through acoustically confusable letters than through visually confusable or neutral letters (58 msec/item average). This contrast accounted for 83% of the variance in search rates due to similarity, $F\ (1, 14) = 20.2$, $p < .001$. The 30-msec. difference between neutral and visually confusable search rates was not statistically significant, $F\ (1, 14) = 4.1$. Again, this result is similar to that reported by Chase and Calfee (1969) for recognition latencies.

There were no interactions involving modalities and similarities, which is again consistent with Chase and Calfee (1969).

In the present experiment, the intercept for auditory test items was 120 msec. lower than for visual test items, a result almost identical to Chase and Calfee's (1969) results for recognition latencies (118 msec.). This contrast accounted for 45% of the variance in the intercepts. Although the variance in the intercepts was too large to establish the reliability of this effect, the main effect of test-item modality was highly significant ($p < .001$).

There were also some artifacts in the intercepts that should be pointed out. For example, the intercept for acoustically confusable materials was 75 msec. lower than for the other two conditions. And for the modality conditions, equating for the modality of the test item, it can be seen in Fig. 1 that steeper slopes were generally associated with lower intercepts (e.g., AV vs. VV). This is due to the fact that the cross-modality effect and acoustic similarity had their effects at larger memory loads, and latencies are about the same for all conditions for a memory load of three items (with the exception of the test-item modality, which is a real effect), and extrapolating back to zero distorts the intercepts. Although we are mainly concerned with the slopes in this study, two points should be made. First, no psychological significance should be attached to the intercept effects in this case. And second, it is important to exercise caution in interpreting the intercept in the serial search model; the model in fact needs to be extended to get a clear estimate of the intercept.

Table 1 illustrates several important results concerning errors: (*a*) Errors increased with memory load ($p < .001$). (*b*) For memory loads of five and six items, there was a serial position effect ($p < .001$, in both cases). This serial position effect resembled the classical serial position curve, except that the last item in the list showed more errors than normal, probably because the item was associated with the first item of the list. (*c*) There were more errors for acoustically similar material, but only for memory loads of five and six items ($p < .001$), and then only for items in the middle of the list ($p < .001$).

It is interesting to note that with a list of six acoustically confusable letters, *S*s averaged as much as 33% errors in the middle of the list even when they were given as much time as they needed to memorize the lists (*S*s generally did take longer on the larger acoustically confusable lists). The error data, then, are in agreement with Conrad (1964) that acoustic similarity is a powerful cause of forgetting in short-term memory.

Discussion.—The most interesting result of the present experiment is the faster search rates when the memory set and test item are presented in the same modality, a result quite similar to that found by Chase and Calfee (1969) for recognition memory. This finding agrees with the hypothesis that specific sensory information is also stored in short-term memory, making possible a faster physical match when the memory set and test item are presented in the same mode. When different modes are used, the comparison process presumably must involve a higher level of representation in which the auditory and visual exemplars are identical. Thus, in both the recognition and recall paradigms, the search process can apparently be based on a direct comparison of sensory features.

The findings on similarity, however, pose some problems for the sensory coding hypothesis since there were no Modality × Similarity interactions in either the present experiment using a recall paradigm or in the earlier experiments (Chase & Calfee, 1969) using a recognition paradigm. According to the sensory coding hypothesis, visual confusability should influence the visual code and acoustic confusability should influence the auditory code. The only significant effect of similarity, however, was a slower search rate through acoustically confusable material regardless of list or test modality. These results provide some support for Conrad's (1964) acoustic coding hypothesis. An alternative hypothesis, however, is that acoustic confusability has its effect on the retention process prior to the search, as evidenced by the greater error rates. That is, acoustic similarity may weaken the memory of the list, and search through these weaker memory traces is slower.

Another result of interest is the 120-msec. advantage of auditory over visual test items. At least part of this difference can be attributed to sensory processes in the sense that auditory latencies are faster than visual latencies by about 50 msec. for simple stimuli such as lights and tones. Although we don't know why this modality effect is larger for more complex stimuli, we can surmise

TABLE 1

ERROR PERCENTAGES FOR EACH LEVEL OF MEMORY LOAD, TYPE OF SIMILARITY, AND SERIAL POSITION

Memory load	Serial position	Similarity			
		Neutral	Visual	Acoustic	Average
3	1	2.6	2.1	2.1	2.3
	2	3.1	5.6	2.5	3.8
	3	3.1	10.6	3.8	5.8
	Average	2.9	6.1	2.8	4.0
4	1	7.0	4.7	2.3	4.7
	2	6.2	11.7	3.1	7.0
	3	3.9	1.6	6.2	3.9
	4	3.1	10.2	7.8	7.0
	Average	5.1	7.0	4.9	5.7
5	1	2.3	5.5	7.0	4.9
	2	12.5	5.2	29.2	15.6
	3	9.4	7.3	11.5	9.4
	4	11.5	9.4	8.3	9.7
	5	4.2	15.6	5.2	8.3
	Average	8.0	8.6	12.2	9.6
6	1	9.4	10.9	9.4	9.8
	2	15.6	17.2	29.2	21.1
	3	8.3	13.5	33.3	18.4
	4	7.3	6.2	24.0	12.5
	5	6.2	12.5	6.2	8.9
	6	4.7	8.3	17.2	9.8
	Average	8.6	11.4	19.9	13.4

that modality of the test item has its effect on a stage of processing that is independent of the comparison process, perhaps at an earlier stage, since this modality effect does not interact with variables affecting the comparison process.

Another question of concern is how well Sternberg's (1967) serial self-terminating model accounts for the data in the present experiment vis-à-vis some kind of parallel search model. At first glance, the increasing latencies with serial position seem to be strong evidence for such a serial self-terminating model. However, there is a parallel self-terminating model which also makes these same predictions. Suppose it is assumed that only a primacy effect occurs in these data so that the associative strengths decrease across serial positions. If it is further assumed that (*a*) the time to compare the test item against a member of the memory set is proportional to the serial position, (*b*) all comparisons are carried out independently in parallel, and (*c*) the search is terminated as soon as the test item is located in the list, then this model makes exactly the same predictions as Sternberg's model and, in addition, the serial position effect is explicitly predicted. However, we must reject this model in favor of Sternberg's because the error data of Table 1 disconfirm the assumption that associative strengths decrease over serial positions. Rather, associative strengths resemble the classic serial position curve. We conclude, therefore, that context recall involves a serial self-terminating search process.

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