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On an Associative Trace for Sentence Memory[1]

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An associationist model for sentence memory is described that assumes a configuration of independent associations underlies the memory trace for a simple sentence. This is contrasted with a gestalt hypothesis that postulates a unitary trace for the simple sentence. The associationist model, but not the gestalt model, leads to two predictions that were confirmed: (*a*) incomplete recall of simple sentences should be a frequent occurrence, and (*b*) repetition of the same verb in a number of sentences should decrease recall of the object to the cue of subject plus verb.

What is the nature of the mental trace that underlies our ability to remember a simple sentence like "The boy hit the girl."? Recently, Rumelhart, Lindsay, and Norman (in press) have suggested that this memory trace may be represented by a set of ordered triples. An ordered triple is a relationship between three elements, written $\langle A\ B\ R \rangle$, which expresses the fact "A has the relation R to B" (e.g., *canary* is a *subordinate* of *bird*). This may be thought of as an association from A to B that has been labelled with the relation R. (Anderson, in press, provides a discussion of labelled associations and their relation to the unlabelled associations which have been favored in the traditional S–R analyses of language.) Rumelhart *et al.* suggest that the sentence "The boy hit the girl" should be analyzed into two labelled associations, ⟨boy hit agent⟩ and ⟨girl hit object⟩. These two associations express the facts that "boy" is the agent of the verb "hit," and "girl" is the object of that verb. The concepts, agent and object, are taken from a recent version of case grammar proposed by Fillmore (1968).

The full memory trace could then be represented graphically by the associative structure in Fig. 1. The nodes correspond to the words and the arrows to the associations. In the figure, A stands for the relation "is agent of" and A^{-1} (read "agent inverse") for "has as agent"; similarly O stands for "is object of" and O^{-1} for "has as object". We assume that there are independent associations in both directions as Fig. 1 indicates. The Rumelhart *et al.* paper is not entirely explicit about backward associations. However, we understand (D. Norman, personal communication) that our formulation does justice to the spirit of their model.

One can question this claim of Rumelhart *et al.* that the simple sentence is analyzable psychologically into a number of distinct triples or labelled associations. For example, analysis of the sentence into independent parts conflicts sharply with the layman's intuitions about the conceptual unity of the proposition it asserts. At first blush, one is impressed that the simple sentence constitutes a "unitary gestalt". It is complete in itself; its "goodness" as a gestalt does not gain by elaborating it with further detail. On the other hand, remove one word from the simple sentence and its unity is destroyed. For instance, the sentence fragment, "The boy hit the ——", is an unstable structure that "begs" to be completed by an object. Also, if one word in

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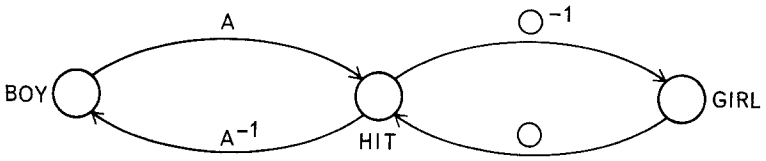

FIG. 1. Associative structure for the sentence "The boy hit the girl" according to Rumelhart *et al.* model.

the sentence is changed, the whole sentence–gestalt would appear to be changed. In contrast, in the associative analysis outlined above, a sentence like "The boy hit the dog" would share two associative links in common with the sentence of Fig. 1. But intuitively, the two sentences have entirely different characters. Such intuitions, if followed suggest that in Gestalt terms each distinct sentence constitutes a distinct, unitary and "good" figure.

If we accept this conclusion, that simple sentences constitute good figures, we are led to several predictions that discriminate between the gestalt and associationist conceptions of the memory trace. First, fragmentary recall of simple sentences (e.g., "Something about the boy and the girl.") should be very rare occurrences according to the Gestalt hypothesis. This prediction follows from two principles of gestalt psychology. First, to quote Köhler (1947), "the trace of a unitary experience is itself a unitary fact [p. 287]". That is, if an object is perceived as a unit there should be a simple all-or-none memory trace deposited. But as Köhler so cogently argues, unitary perception does not imply perfect recall of the units. The stimulus conditions at recall may not redintegrate the unitary trace, leading to complete failure of recall. However, a clear implication of the principle of a unitary trace is that, if part of a simple sentence is recalled, all must be recalled. To quote Koffka, "recall does not go from part to part, but from part to whole, [1935, p. 569]." Secondly, if for some reason, *S* did not perceive the sentence as a unit but formed only a fragmentary trace, then that fragmentary trace would have little chance of surviving until the time of recall. To quote Koffka (1935): "For if traces are exposed to forces which connect them with other traces, highly unstable trace structures will be destroyed. Chaotic patterns have neither a well-defined boundary, to keep them unified and segregated, nor interior stability. Therefore they can have but little power of resisting outside forces. This principle seems fundamental, [p. 507]."

In contrast to this Gestalt hypothesis of a unitary memory trace, the associationist hypothesis of Rumelhart *et al.* dictates that a simple sentence be represented by a configuration of several independent associations. We would expect that only some of these associations will be durably established during a single learning trial. To that extent, *S* should frequently give partial sentence recall. So the frequency of complete versus fragmentary recall to sentence probes will be one observation of interest in the following experiment.

The second and major point of interest in this experiment concerns sentence recall accuracy when a given verb occurs in several different sentences. An experiment by Rohwer and Lynch (1967) yielded results that one might interpret as discriminating against an associationist hypothesis. In their recall experiment, the same verb was used in either two, four, or eight different sentences among a set of 16 which *S* studied. Consider how an associative theory might reconstruct the situation when *S* has studied two sentences with the same verb, such as the pair of sentences, "The boy hit the dog" and "The girl hit the ball". The Rumelhart *et al.* model, as described above, implies the associative memory structure diagrammed in Fig. 2a.

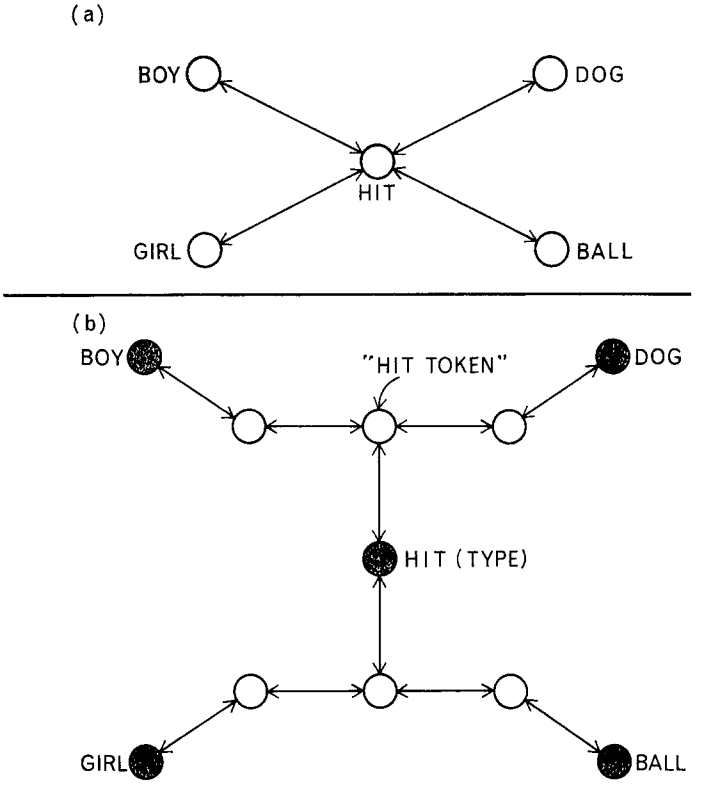

FIG. 2. Associative structure for the two sentences "The boy hit the dog" and "The girl hit the ball"—(*a*) without type-token distinction; (*b*) with type-token distinction.

In this figure, to help simplify matters, we have replaced the two unidirectional arrows used between nodes in Fig. 1 by a single bidirectional arrow. This bidirectional arrow is to be interpreted as indicating two separate associative links just as the two unidirectional arrows had. If this were the memory representation, the *S* would not be able to remember who hit what. Moreover, as the same verb is used in more and more sentences, the confusion should increase.

Rohwer and Lynch had their *S*s attempt to recall the object when probed with the subject of each sentence. Because of this confusion factor, the theory represented in Fig. 2a expects probability of object recall to decrease as the same verb is used in more and more sentences. In fact, this result was *not* obtained by Rohwer and Lynch; recall remained constant independent of the number of different sentences in which a given verb occurred. This result would be predicted by the Gestalt hypothesis of a distinct, unitary trace for every distinct sentence. Since each sentence had a unique subject and object, the hypothesis would suppose that each sentence had a unique gestalt pattern, independent of verb repetition; consequently, there would be no interference or confusion of the memory traces for different sentences.

However, a slightly more sophisticated version of the associationist model can accommodate the Rohwer and Lynch result. This version requires a distinction between word types and word tokens. This distinction was made by Rumelhart *et al.* for reasons independent of the Rohwer and Lynch result. In this version, the nodes entering into the

associative relationships encoding a particular sentence would be denoted as token nodes; these token nodes in turn are assumed to be connected to type nodes by further associations. In this way the system can keep track of the several linguistic contexts in which a given word occurs. This elaborated memory structure is illustrated in Fig. 2b which is Fig. 2a elaborated to include the type-token distinction. The unlabelled nodes are tokens connected to a labelled type node. Information about the concept referenced by the word, its acoustical parameters, its orthographic representation, etc. is stored at the type node. Since the articulatory and orthographic representations of each word are stored at the type node, recall of the object word when the person is cued with the subject word would require that the type-to-token association for the subject word be established. Recall of the object to the subject-cue also requires that the token-to-type association for the object be intact. The type node may point to as many tokens as is needed for representing the different sentences in which that word-type occurs. In the memory structure of Fig. 2b, there is a unique token node for the verb in each unique sentence. For this reason, occurrence of the same verb in several different sentences should not occasion confusions in object recall to the subject cue. In other words, the amended theory in Fig. 2b expects the "null result" of verb repetition as reported by Rohwer and Lynch.

A simple extension of the Rohwer and Lynch experiment, however, will yield evidence discriminating between the gestalt idea and this revised associationist hypothesis. The evidence concerns the pattern of recall for particular parts of the sentence given one or another type of probe or cue for recall. Consider the memory testing circumstance in which *S* is cued with the subject "boy" for recall of both the verb "hit" and the object "dog", but he does not recall either word to this cue. The issue is what the associationist model implies about *S*'s ability to recall the object if he is *now* cued with a "subject plus verb" compound. From Fig. 2b and *S*'s failure to recall the verb to the cue of "boy", we may infer that his memory structure for that sentence does not contain an intact associative path from the type node for "boy" to the type node for "hit". At least one of the three associative links in that path must have failed to be established. Similarily there cannot be an intact path from "boy" to "dog". Therefore, when cued with the subject plus verb, *S* should be unable to recall the object via an associative path from the subject. (If there had been an intact path from subject to object, *S* would have recalled the object to the subject-only cue.) The only possibility for recall in this set of circumstances is if an associative path exists from the verb type to the correct object. However, it is precisely at this point that the multiple contexts of a verb's occurrence lead to its ambiguity as a recall probe. If the verb has occurred in several sentences, the type node for that verb will lead to many tokens connected in turn to many objects. Since there is no association from the subject to the correct verb token, the *S* will probably not be able to select with certainty the correct path from the verb type to the appropriate object. The *S* in this predicament would have to guess among several equally likely paths from the verb type. Hence, conditional upon non-recall of both verb and object to the subject-only cue, the model predicts confusion in object recall to the cue of subject-plus-verb if that verb occurred in several sentences. Moreover, this confusion or object-competition will increase and correct recall decrease as the verb occurs in progressively more sentences.

To summarize, then, this elaborated associative model for sentence memory makes two predictions:

1. The probability of correct object recall when *S* is cued with the subject alone should be independent of verb repetition.

2. The probability of object recall to the cue of subject plus verb, conditional upon

recall of nothing to the subject-only cue, will decrease monotonically as the verb is repeated.

The gestalt hypothesis agrees in the first but not in the second prediction. It would suppose that the subject-plus-verb patterns are quite distinct even if the verbs are repeated. The uniqueness of the subject is sufficient to make each cue totally different (e.g., "The boy hit" is a very different thing than "The girl hit"). Therefore, the gestalt hypothesis predicts no confusion as a consequence of verb repetition.

METHOD

The sentences used were all of the simple subject-verb-object variety. In most, a Fillmore case grammar would describe the subject as being in the agentive case and the object as being in the objective case. However, a few of the sentences had the subject in the dative case (e.g., "The lawyer hated the model"). This minor variation does not alter the predictions of the model and only extends the generality of the results.

Each *S* studied two sets of 32 sentences. In each set, 8 sentences used 8 different verbs once each, 8 sentences used 4 verbs twice each, 8 sentences used 2 verbs 4 times each, and the remaining 8 sentences used 1 verb 8 times. There were thus 4 values of the *verb-repetition* variable, all of which were represented within each set of 32 sentences. By counterbalancing across *S*s, an attempt was made to equate the particular sentences used in each of the repetition conditions.

Either one or two *S*s were tested in each experimental session. Each set of sentences was studied once and tested once. In the study phase of the experiment, the *E* presented each sentence on an 8 × 5 in. flashcard for 8 sec. After all 32 sentences in a set had been studied, *S*s wrote their cued recall, self-paced, in experimental booklets. On one page of the booklet was a sentence with both verb and object missing and the *S*'s task was to try to recall the verb and object. After attempting this recall, *S* turned to the next page of the booklet which contained the same sentence with just the object missing which the *S* was again to try to recall. Recall for all 32 sentences was probed in this manner. The *S*s were informed of the method of testing before the experiment began. A different randomized order of sentence presentation was used in the study phase of each experimental session. One of two random orders of sentences for test was randomly selected for each *S*. A short rest period intervened between the learning of the two sets of 32 sentences. The total experimental session lasted about 45 min. Thirty-two *S*s (16 males and 16 females; 17 to 23 years in age) were recruited through an advertisement in a local newspaper and were paid $1.75 for their services.

RESULTS AND DISCUSSION

For each *S*, we computed the probability that (a) both the verb and the object were recalled to the cue of the subject, (b) just the verb or just the object was recalled to the subject cue, (c) nothing was recalled to the subject cue. The means of these three probabilities are given in the first three lines of Table 1; as can be seen, partial recall (i.e., just verb or just object) was a fairly frequent occurrence under all conditions of verb repetition. Such partial sentence recall is contrary to the spirit of the Gestalt model, but is in keeping with the associationist model. In none of the conditions did partial recall occur less than 50% as frequently as total recall. Line 4 of Table 1 gives the recall of the verb alone; there is a marked increase with verb repetition. Line 5 gives the recall of the object alone; there is a marked decrease with verb repetition.

For each *S*, the probability of recall of the object to the subject cue was calculated for each condition of verb repetition. The means of these scores are given in the sixth line of Table 1. To normalize scores, percentage correct recall for each *S* was transformed by the arcsin transformation and used in the statistical analysis suggested by Winer (1962, p. 105) for a single-factor experiment with repeated measures. The factor of verb repetition was not significant, $F(3,93) = 0.28$, for overall recall scores (in Line 6). This is as predicted and it replicates the findings of Rohwer and Lynch (1967).

The mean probability of recall of the object to the cue of subject plus verb, conditional on non-recall to the subject-only cue, is given in the seventh line of Table 1. As predicted, this conditional probability of recall decreased as the verb occurred in more sentences, and this effect was highly significant, $F(3,90) = 9.66$; $p < .001$. In that

TABLE 1

SUMMARY DATA—MEAN PROBABILITY RECALL[a]

Cueing condition	Recalled item	Number of sentences in which verb occurred			
		1	2	4	8
1. Subject	Both verb and object	.244	.248	.285	.277
2. Subject	Just verb or just object	.129	.199	.263	.430
3. Subject	No correct recall	.627	.553	.451	.293
4. Subject	Just verb	.066	.146	.232	.422
5. Subject	Just object	.063	.053	.031	.008
6. Subject	Object	.307	.300	.316	.285
7. Subject plus verb given non-recall to subject	Object	.186	.078	.094	.051
8. Subject plus verb	Intragroup object intrusion	.112	.156	.170	.211
9. Subject	Intragroup object intrusion	.066	.102	.106	.154
10. Subject	Verb from group	.401	.553	.590	.699
11. Subject	Correct verb	.311	.395	.518	.699
12. Subject only, to which no verb from the group was recalled	Intragroup object intrusion	.016	.013	.019	.058

[a] There were 512 observations taken at each value of the verb repetition variable.

analysis of variance, only 31 *S*s contributed data since one *S* did not fail to recall something to any of the subject-only cues. A test for monotonic decreasing trend in the means of Line 7 was performed using, in a planned comparison, the coefficients suggested by Abelson and Tukey (1963), and that trend was highly significant, $F(1,90) = 25.90$; $p < .001$. The variance due to the repetition factor, but not accounted for by this comparison, was not significant, $F(2,90) = 1.59$. Thus, the main predictions that motivated the experiment were confirmed.

The prediction of decreased object recall with increased verb repetition hinges upon the supposition that repetition of the verb would create verb-to-object associative paths for other sentences that would compete with the correct verb-to-object path. We should therefore expect increased *intrusions* of other objects with which the verb was paired. Such intrusions would occur every time the *S* decides to guess among the competing verb-to-object paths (he may sometimes simply inhibit recall altogether), and selects the wrong path and hence the wrong object.

To test this last prediction we will require the concept of an *intragroup intrusion.* A *group* refers to the 8 sentences in the set of 32 that contributed to one of the four verb repetition conditions. An intragroup intrusion is the intrusion (recall) of an object from one of the other sentences in the same group as the test sentence. The number of such intrusions in the condition where the verb occurs in only one sentence provides a baseline measure of how frequently such intrusions should occur when there is no confusion of objects due to verb repetition. Such baseline intrusions are due to unidentified factors which presumably are constant across the levels of the verb repetition factor. But if intrusions arise due to verb repetition, then the number of intragroup intrusions to the cue of subject plus verb should increase with verb repetition in some monotonic manner from this baseline.

The mean number of such intragroup intrusions to the cue of subject plus verb is reported in the eighth line of Table 1. As predicted, it shows an increasing proportion of intrusions with higher verb repetition.

Analysis of variance indicated that this effect was significant $F(3,93) = 4.31$; $p < .01$. A test for monotonic trend was highly significant, $F(1,93) = 12.66$; $p < .001$, but the deviations from that trend were not significant, $F(2,93) = 0.14$. Therefore, this detailed prediction of the model was confirmed.

There is a further effect shown in Table 1, but one which is not predicted by the model as presently formulated. The ninth line in Table 1 gives the mean number of intragroup intrusions to the subject cue alone; the model expects no trend in this statistic across verb repetition conditions. However, analysis of variance indicated that the repetition factor was significant, $F(3,93) = 5.42$; $p < .01$; the monotonic increasing trend was very significant, $F(1,93) = 16.03$; $p < .001$; and the deviations from that trend were not significant, $F(2,93) = 0.14$.

There is a plausible post-hoc explanation for this unexpected result, namely strategic guessing. Suppose that an *S*, after noticing that a verb was frequently being repeated in the study list, used that verb and one of its objects as his "guess" when he could retrieve nothing to the subject cue alone. That is, although he may not remember which verb and object occurred with the subject cue, he may nonetheless remember a verb which had occurred frequently and an object which had occurred with it and use those as guesses. This post-hoc explanation leads to the following two predictions:

1. There should be a monotonic increase across repetition conditions in the number of correct and incorrect verbs recalled within a group to the subject cue because of the bias to guess frequently occurring verbs. That this is the case is clearly confirmed by Line 10 of Table 1. The eleventh line of the table gives the probability of correct verb recall.

2. Considering only those instances in which no verb from the appropriate group was recalled to any test cue, we would expect no monotonic trend in intragroup intrusions of objects to the subject-only cue. The probability of an intragroup object intrusion conditional upon non-recall of a group verb to any cue is given in the final line of Table 1. There still may be some monotonic trend insofar as the intrusion rate in the 8-repetition condition is higher than in the other conditions. However, the frequencies of such intrusions were so low that a valid statistical test was not possible. The fact that intragroup intrusions are so

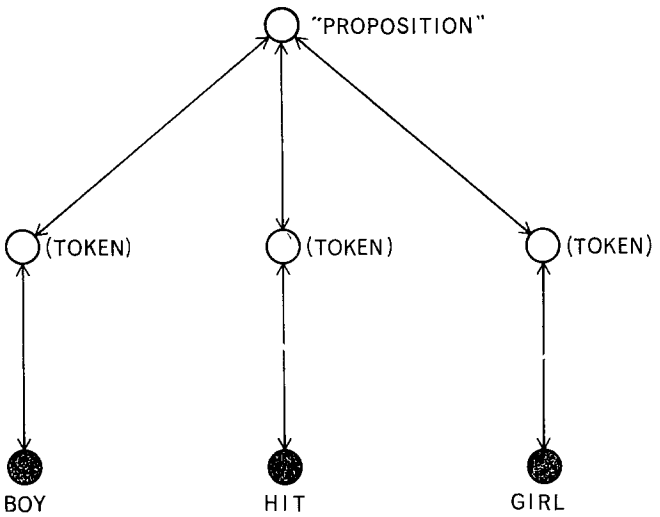

FIG. 3. An alternate associative structure for the sentence "The boy hit the girl".

infrequent when a group verb is not recalled is in accord with the "guessing" explanation.

In conclusion, then, the non-obvious predictions of the associationist model have been confirmed. An additional unexpected result was uncovered (increased intrusions to subject-alone cue), but that result appears compatible with an amended model which credits *S* with a guessing strategy. The package of results would seem to indicate that, in dealing with memory for sentences, we should suspend our intuitions about the unitary character of the simple sentence and accept something like the associationist hypothesis.

In closing, one remark is called for regarding the particular configuration of associations in Fig. 2b which was suggested by the Rumelhart *et al.* model. The predictions derived and confirmed here are compatible with several different associational memory structures for simple sentences, for example, the one in Fig. 3. In this structure, the verb token does not occupy a central position; rather, the central element is an abstract proposition node connected to agent, verb, and object. This structure is more in keeping with Fillmore's linguistic proposal in that it is isomorphic to the deep structure Fillmore would assign to the sentence. There is just no evidence in our data to indicate that the verb occupies the central position in an associative structure as Rumelhart *et al.* propose. What the present research has accomplished is to indicate that the memory trace for the simple sentence is better conceived of as a configuration of independent associations rather than as a unitary gestalt pattern. The next question is to specify the exact structure of that configuration.

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