Uniformity of Associative Impairment in Amnesia

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Abstract

The fragmentation model of associative memory has the attraction of specifying neither a spatial metaphor nor a symbolic representation for remembering. It was used in order to compare the recall of groups of unrelated words by amnesic and normal people. Similarly, a schema model was used in order to compare their recall of groups of related words. It was found that the impairment in remembering with amnesia revealed by these models was remarkably uniform rather than selective. This suggests that the level at which the memory storage system is damaged in amnesia is a relatively low one. In a connectionist formulation, this would presumably correspond to widespread random damage to units and the connections between them.

Some years ago, a fragmentation model of associative memory was articulated (Jones, 1976). The model was extremely simple. It proposed that the memory for an event is represented by a fragment or group of elements of that event, and that the contents of the fragment can be recalled if and only if one of this group of elements recurs as a cue. The model had some attractive features. It was parsimonious, and it gave quantitative predictions which were surprisingly accurate. However, it also had what at the time seemed to be two problems. First, it was not expressed in terms of any of the spatially localised metaphors that were then almost ubiquitous in theories of memory (Roediger, 1980). Second, it was not expressed in terms of operations upon symbolic representations in the way that, say, the state-of-the-art HAM (Anderson & Bower, 1973) and ACT (Anderson, 1976) models of memory were. The first factor could be countered by the observation of Schacter, Eich, and Tulving (1978) that the fragmentation model resembled an earlier nonlocalised theory, the resonance model of Richard Semon (1921). And the second factor could be countered by the observation of Anderson and Bower (1980) that on occasion at least the fragmentation model's predictions were more accurate than those of HAM. Nevertheless, these two factors together perhaps meant that the fragmentation model was a bit difficult to assimilate to the then prevailing memory-model schema. We are reminded of this now because the contemporary connectionist zeitgeist has eliminated both problems. Neither spatial localisation nor symbolic representation appear as indispensable as before. With the advent of parallel distributed processing models (e.g., Hinton & Anderson, 1989; Rumelhart & McClelland, 1986) the emphasis has shifted to constructing new types of representation. These are not localised but instead distributed over many simple units, and they are also subsymbolic in that apparently complex higher order processes emerge from the iterative operation of many simple processes. So with this conceptual rehabilitation of the general nature of the fragmentation model, we decided to employ it as a tool in exploring the detailed nature of the memory deficit in organic amnesia.

To this end, we built upon previous evidence that the fragmentation model describes well the patterns of recall that occur when a person is remembering an event whose different elements are independent of each other, such as a group of words that have been selected at random (Jones, 1984). Rubin and Wallace (1989) have in fact argued convincingly that the crucial characteristic of such events is that the particular grouping should be unique. In contrast, the patterns of recall that occur when a person is remembering a group of words with a common theme are better described by a schema model (Ross & Bower, 1981). Both fragment and schema models are mathematically parametrized. We thus decided to estimate fragment and schema parameters from the remembering of unrelated and related words, respectively, and to examine the impairments in parameter values that we expected to find in moving from a normal population to an amnesic one. Let us first describe the parametrizing.

Consider a triad or group of three words. If we treat each word as equivalent, then there are three types of fragment that need to be distinguished. With probabilities ϕ, π, and $(1 - \phi - \pi)$ there may exist either a full, partial, or null fragment, respectively. A full fragment has all three words associated, a partial fragment has only two words associated, and a null fragment has no words associated. The schema model also has two parameters. The probability of one word accessing a schema is α, and that of a second word being retrieved from the schema is ρ. How do these parameters translate into predictions?

Suppose that a person is shown a triad, and then subsequently one of its words is re-presented as a retrieval cue. Further, if the first cue is unsuccessful in producing any recall, a second word may then also be given as cue. In all, four patterns of recall may be distinguished. Two words may be recalled on the first cuing; one word may be recalled on the first cuing; no words may be recalled on the first cuing, but one word may be recalled on the second cuing; or no word may be recalled on either cuing. Let the probabilities of occurrence of these patterns be denoted by p_{20}, p_{10}, p_{01}, and p_{00}, respectively. Then the fragment predictions are that

$$p_{20} = \phi$$
$$p_{10} = 2\pi/3$$
$$p_{01} = \pi/3$$

and

$$p_{00} = (1 - \phi - \pi).$$

Similarly, the schema predictions are that

$$p_{20} = \alpha\rho^2$$
$$p_{10} = 2\alpha\rho(1 - \rho)$$
$$p_{01} = \alpha\rho(1 - \alpha)$$

and

$$p_{00} = \alpha(1 - \rho^2) + (1 - \alpha)(1 - \alpha\rho).$$

Empirical estimates of the fragment and schema parameter values may be obtained from observed frequencies of each of the four patterns or recall (denoted by n_{20}, n_{10}, n_{01}, and n_{00}, respectively) by maximizing the likelihood function

$$L = \prod_i p_i^{n_i}$$

(where i = 20, 10, 01, 00). For the fragment model, this yields the maximum-likelihood estimates

$$\phi* = n_{20}/n$$

and

$$\pi* = (n_{10} + n_{01})/n.$$

For the schema model, the maximum-likelihood estimates may be obtained numerically rather than algebraically.

Empirical Estimates for Amnesic and Normal Groups

An experiment of the type previously indicated was carried out, in which triads of words were presented and then cued incrementally by two of the words. For the schema estimates, the words of each triad were related via a common theme (e.g., towel, pool, goggles). For the fragment estimates, the words of each triad were unrelated (e.g., towel, convent, dune). Both fragment and schema estimates were obtained individually for each of six amnesic patients and each of seventeen normal people. The amnesic group comprised two sufferers from Korsakoff's syndrome, two people who had suffered anterior communicating artery aneurisms, one person who had suffered encephalitis, and one person who had suffered severe frontal and temporal lobe damage in a road accident. The normal group consisted of students at Warwick University.

Two sets of 84 triads each were prepared. For one set, the words of each triad were related by a common theme. The other set was obtained by random permutation so that the three words were not related. Each person was tested half with related triads and half with unrelated triads, with the halves counterbalanced over people. In order to reduce the difference in levels of recall between the amnesic and normal groups, the former were presented with twelve sets of seven triads for 8 seconds per triad, while the latter were presented with six sets of fourteen triads for 4 sec per triad. Following the presentation of each set, each of its triads was tested by incremental cuing using two of its component words.

The frequency of occurrence of each pattern of recall in this study is shown in Table 1. It can be seen that, as expected, normal performance was better than amnesic performance, and also that related performance was better than unrelated performance. Further, if we aggregate all patterns on which some recall occurred (i.e., $[n_{20} + n_{10} + n_{01}]$ or $[42 - n_{00}]$), then we find that the amnesic decrement in performance was approximately equal for the related and for the unrelated words.

Table 1. Frequency (n_i) of each pattern of recall

		Pattern of recall			
Group	Words	20	10	01	00
Normal	Related	26.06	9.71	2.06	4.18
Amnesic	Related	4.50	7.17	1.17	29.17
Normal	Unrelated	13.41	8.94	3.59	16.06
Amnesic	Unrelated	0.83	1.83	0.33	39.00

Maximum-likelihood estimates of the schema parameters (α^* and ρ^*) and of the fragment parameters (ϕ^* and π^*) were obtained for each person from the unrelated-words data and the related-words data, respectively; the schema parameter values were obtained using a FORTRAN program employing subroutine E04JAF (minimisation subject to boundary constraints) of the NAG library (Numerical Algorithms Group, 1977). The mean values of the schema and fragment parameters are shown in Table 2.

Table 2. Mean parameter values

Model	Parameter	Normal	Amnesic
Schema	α^*	0.861	0.491
Schema	ρ^*	0.817	0.488
Fragment	ϕ^*	0.319	0.020
Fragment	π^*	0.298	0.052

It can be seen that for the schema model both α^* and ρ^* were impaired to approximately the same extent by amnesia; similarly, for the fragment model both ϕ^* and π^* were also impaired to approximately the same extent by amnesia. A curious additional result, which seems merely coincidental rather than meaningful, was that both for the normal group and for the amnesic group the values of the α^* and ρ^* parameters were approximately equal, as were also the values of the ϕ^* and π^* parameters.

Implications

The fragment model of Jones (1976) and the schema model of Ross and Bower (1981) proved to be useful analytical tools in investigating recall impairment with amnesia. The amnesic patients were equally impaired in retaining full and in retaining partial fragments of groups of unrelated words. Similarly, they were equally impaired in accessing schemata and in retrieving from them. The two models therefore provide a description of amnesia in which recall is seen to suffer blanket impairment. This suggests that amnesia is the consequence of damage at some basic, undifferentiated level of representation. In a connectionist formulation, this would presumably correspond to widespread random damage to units and the connections between them. It should be noted, however, that although recall of related words suffered a decrement in performance with amnesia approximately equal to that for unrelated words, the absolute level of recall of related words in the amnesic group (as in the normal group) was higher than that of unrelated words. In this respect, the results were similar to those in recent studies where priming effects have been reported with related but not with unrelated pairs of words (e.g., Schacter & Graf, 1986; Shimamura & Squire, 1984, 1989).

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