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32 Organization in the Kitchen

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Our models for memory ignore the complexity of the organization of our knowledge of the world. A few examples are given of the kind of complexity which seems to be justified both by intuition and data. First we postulate a difference between semantic and "scientific" stores of information. Such a distinction helps to resolve some seeming paradoxes in data from a verification task. A number of tasks concerning food stuffs are then discussed. The derived view of the cognitive organization changes with the task in a way that seems sensible but has, as yet, no formal description. It is clear that process and structure are undecidable.

I. Introduction

Our aim in this paper is to describe an approach to the psychology of memory, illustrated by examples from a variety of ongoing experiments. It will not have escaped the attention of those prone to introspecting about their own mental processes that the majority of studies of Long Term Memory systematically fail to reveal the richness and complexity of our mental "data base". By "data base", both here and throughout, we mean the entirity of the information stored in the brain and its organization there. There is increasing evidence of awareness of this problem. Norman (1970) talks about retrieval as problem solving; Bower (1972) dismisses the "simplistic, associationistic approach to memory" specifically for its failure to give any account of the "Executive" functions which operate on the data base; Rumelhart, Lindsay and Norman (1972) go further in suggesting that "there need be no formal distinction between the information which is part of the data base and that which is a process operating upon the data base". Tulving (1972) makes the distinction between episodic and semantic memory and a number of other people have made related divisions, and the borderline between verbal memory and imagery has become very blurred.

It remains a problem as to how to exploit this liberating atmosphere. Data collection continues within the established experimental framework or is ignored, depending respectively upon whether the scientist seeks to maintain the traditional level of control over experiments or sees the first task as one closer to linguistics or artificial intelligence i.e., producing systems that work at all rather than trying to model the human organism. We are attempting to follow a third path which draws heavily on what people *say* they are doing and what they *say* about what they are doing, as well as on our observations of their behaviour.

Primarily we are seeking to investigate the nature of real-world cognitive organizations. We have practical reasons for this aim, stemming from the problem of designing man-computer interactive systems which use a computer data base of some complexity. We believe that for efficient use the structure of the data in the machine should match the cognitive structure in the user. We have chosen to concentrate initially on the domain of food and cooking largely because of the ready availability of data from our subject panel. As will be seen, the kind of data we obtain force us to acknowledge the complexity that our intuitions suggest. Before discussing food we would like to illustrate what happens if we follow our programme in analyzing a more conventional task.

II. Verification—Two Kinds of Knowledge

Consider a recent paper by Rips, Shoben and Smith (1973). These authors used a verification task in which subjects had to judge whether an instance was a member of a specified category, e.g., A GOAT IS AN ANIMAL/A MAMMAL, A HAWK IS A BIRD/AN ANIMAL, A DODGE IS A CAR/VEHICLE. They found that for birds, the verification time was faster when the target category was a direct superordinate (bird) than when it was a higher level superordinate (animal), while for another category (mammal) this finding was reversed. They discuss the implications of their results for models of semantic memory taking in turn Network models (e.g., Collins and Quillian, 1969) and set-comparison models (e.g., Meyer, 1970; Schaeffer and Wallace, 1970). In a network model, objects and attributes are connected by means of relationships. To verify statements of the form "an A is a B", the mechanism must find a connection involving only the *is a* relationship between A and B. This accounts for the result (Collins and Quillian, 1969) that "a corgi is a dog" takes less time to verify than "a corgi is an animal"; in the latter case the pathway between *corgi* and *animal* would be longer, involving the intermediate, *dog*. However it does not seem possible to construct a network model which would take longer to verify "a goat is a mammal" than "a goat is an animal" and yet still confirm that "all mammals are animals". But this is just what Rips, Shoben and Smith find, so they prefer a set-comparison of "features" model. To verify "an A is a B", their set-comparison mechanism would first compare the sets of "functional features" of A and B for overall similarity, and secondly compare their "defining features" only (ignoring "characteristic features"). This second stage can be "abbreviated or omitted entirely" if the overall functional feature similarity (or lack of it) is striking enough. While they give an account of the effects described above in terms of this mechanism, the distinction between the two kinds of feature remains obscure. We would like to propose a different account which we believe captures the difference between two kinds of knowledge, and particularly reflects the kind of response you get when you ask someone, say, "Is a robin an animal?". The typical response, in a non-experimental situation, would be "it depends what you mean by animal".

We would like to distinguish between information which is accessible directly from a semantic store and information which is only accessible from a special store of knowledge which has been learned but is not represented in the semantic store. We could call this the "scientific store" and decisions based on such information would have to be computed in a special way. The term "scientific" is not intended to imply any limitations on the way in which such information may be utilized, and the distinction between scientific and semantic stores is best made by considering some examples of the contents of these stores. Thus, in the semantic store we might find representations of such information as:

a robin is a bird
a goat is an animal_1
a whale is a mammal
the sun rises in the East and sets in the West
some men are more equal than others.

In the scientific store we might find:

all birds are animals_2
mammals are animals_1
all animals_1 are animals_2
all cars are vehicles
all men are equal
the sun is 93,000,000 miles away
the earth travels round the sun once a day.

Animal_2 has entries only in the scientific store, while animal_1 corresponds to the everyday usage. Note the allowability of contradictions: it is perfectly possible to have both "whales are not animals_1" and "whales are mammals" in one's semantic store, and yet "mammals are animals_1" in one's scientific store. Careful questioning of subjects can bring this to the surface and cause considerable conflict! Another difference between our suggestions and the network models is that we would allow asymmetry of representation. So if under A we find (*is a* B), there need be no entry of (*includes* A) under B. Thus the search *direction* may become critical.

In the verification task, then, the information necessary to verify the proposition "a robin is a bird" would be obtained directly; the proposition "a robin is an animal", on the other hand, would not be confirmed at the first stage (with "animal" being interpreted as $animal_1$) and extra time would be required to access and use the scientific information "all birds are $animals_2$". The verification of "a horse is an animal", in contrast, would take place at the first stage. So in the data presented by Rips *et al.*, we find the mean response times for confirming that twelve individual birds are animals are all longer than the times for confirming that twelve individual land animals are animals.

Other things being equal, we would expect that the time taken to use any single piece of scientific information would be a constant. The mean differences in Rips *et al.*'s data are: $animal_2$ — bird = 149 ms; $animal_1$ = 88 ms; vehicle — car = 112 ms. These values are really too widely spread for our comfort. However, when one looks at the differences for individual targets we see that COW is the only animal for which the mammal confirmation is faster than the animal confirmation. Among the animals, a cow is the only one whose milk supply is made explicit when subjects are asked to sketch them—and it is always made explicit. Since "*has* udders" immediately leads to "suckles young", one of the characteristics of mammals most commonly mentioned by our subjects, we could expect no need of recourse to the scientific store to verify "a cow is a mammal". Note that, since we do not demand symmetrical representation of information, we would not expect "cow" to be high on the list when subjects are asked for a list of mammals (and indeed it is unexceptional in such lists, unlike "whale"), since here search would be guided by information listed under "mammal" which need not include (*includes* cow). Again, among the birds, "hawk" gives rise to an exceptionally slow "animal" confirmation (mean time 1726 ms compared with 1584 ms for "cardinal", the next slowest). Now in the experiment under discussion, cars were one of the categories used. "Hawk" is unique among the bird names in being also the name of a car. When "a hawk is a bird" is being confirmed, the information is directly accessible. When "a hawk is an animal" is being confirmed the second stage is involved. We suggest that at this second stage the information that "a hawk is a car" is available, which would constitute evidence against the original proposition thus leading to an increase in the response time.

The last suggestion will be taken up below. Meanwhile, we wish to note that if the scores for COW and HAWK are taken out of Rips *et al.*'s data we obtain mean times for use of scientific knowledge as follows: $animal_2$ = 118 ms; mammal = 102 ms; vehicle = 112 ms. These figures are sufficiently close together to give us confidence in the notion that it takes a constant time to apply a scientific proposition. We are aware of the dangers in tinkering with data in the way in which we have just done. We could also

take note, for example, that the vehicle-car differences are smallest for TOYOTA and TRIUMPH, which are also makes of trucks and motorcycles respectively and so doubly vehicular. Our main aim is to indicate our belief that the verification of propositions is a complex process and that we should no more expect a singular process to be operating here than we do in short term memory experiments.

A. Contextual Effects in Verification—A Confirmatory Experiment

We suggested above that subjects' responses could be influenced by the context set up by the experiment. To demonstrate this we compared the response times to PURPLE IS A COLOUR and ORANGE IS A COLOUR in two conditions, in each of which six propositions were presented for verification. The sentences were presented for an unlimited time in a tachistoscope and the subjects spoke their responses "true" or "false", into a microphone which stopped the timer. The following were the two lists of sentences.

Group 1	Group 2
APPLE IS A FRUIT	COD IS A FISH
GOOSEBERRY IS A COLOUR	TROUT IS A COLOUR
PURPLE IS A COLOUR	PURPLE IS A COLOUR
INDIGO IS A FRUIT	INDIGO IS A FISH
PINEAPPLE IS A FRUIT	HERRING IS A FISH
ORANGE IS A COLOUR	ORANGE IS A COLOUR

After the experiment, subjects were asked whether they had realized that orange is also a fruit, and were divided into a primed and an unprimed group by their reply (of course "Group 1" subjects were usually "primed"). The time differences between the responses for ORANGE and PURPLE were 0·24s for the primed group and −0·13s for the unprimed group (see Table I). On a Mann-Whitney test the difference between the groups was significant at the 0·01 level. Q.E.D. The implications of this result for models of the verification task will be discussed elsewhere.

Table 1 Mean RT(s) for correct responses to the propositions shown

	Group 1 (n = 10)	Group 2 (n = 10)
Purple is a colour	1·46	1·30
Orange is a colour	1·70	1·17
Difference*	+0·24	−0·13

* Mann-Whitney Test $u = 11{\cdot}5$, $p < 0{\cdot}01$

III. Multiple Classification

Most of the studies of semantic memory have concentrated on subject matter where a simple tree structure is approximately appropriate, or at least can be induced by the experimental situation. The data-base related to foodstuffs, however, has a much more complicated structure. One task which displays some of this complexity is the simple one of asking people to write down a list, say, of "all the food you would need to stock an empty house for a month's holiday in a remote spot". The resulting shopping lists display clear organization in a variety of categories. Strings of items can be found sharing physical properties, their major uses, their origin, or their place in the kitchen. Some examples follow:

breakfast—". . . bacon, porridge, cornflakes, milk . . ."
dairy—". . . eggs, cheese, lard, butter . . ."
cake-making—". . . lard, margarine, plain flour, self-raising flour, currants, sultanas . . ."

Multiple classification is the rule rather than the exception and this seems to allow or induce switching of the search dimension at the item concerned.

Examples of this are shown in Table 2.

In many cases, subjects producing shopping lists report that they are

TABLE 2 Sections from shopping lists showing "switching" and multiply classified items.

	Item	fats/dairy	cake making	fruit
(a)	butter	✓		
	lard	✓		
	margarine	✓	✓	
	flour		✓	
	sugar		✓	
	raisins		✓	✓
	sultanas		✓	✓
	pineapple			✓

	Item	dairy	meat
(b)	butter	✓	
	margarine	✓	
	shortex	✓	
	eggs	✓	
	cream	✓	
	milk	✓	
	bacon	✓	✓
	sausages		✓
	gammon		✓
	chicken		✓
	meat		✓
	lamb		✓
	beef		✓

mentally looking round their own kitchens. As one step in checking such reports we asked subjects to draw plans of their kitchens, showing where all the foodstuffs are kept. The same functional units could be found in almost every plan: a store of dry groceries, a vegetable rack, a store of tins, a fridge or cold place, a "back-up" store for bulk items and so on. Only a few subjects mentioned another store, that for items in continual use. However, a follow-up showed that this was a distortion of reporting, and in fact almost every kitchen has such a shelf, table-top or other area devoted to a miscellaneous collection of frequently used items. Salt, sugar, bread, matches and coffee are frequently found here, and these items form a unit quite outside the main classification scheme. That such an important set should be forgotten shows that the kitchen search was no more purely visual than the shopping list was purely verbal. We have yet to investigate the mismatches between the remembered kitchens and the rooms themselves. We would hope to find distortions in a normative direction, which show up in positions of awkward shaped items like spaghetti or ketchup, which might occur near rice and chutney respectively in the remembered room, but by themselves (on the floor) in a real larder.

A. Sorting

We have also asked subjects to sort the names of foodstuffs into sets. Only alphabetical order was forbidden. The results of analyzing these data will be published elsewhere. They show the range of organizations displayed in the shopping lists but with a stronger emphasis of the physical properties of items (e.g. dry, liquid) or their packaging (e.g. tinned, frozen). Classes like "breakfast" or "baking" are much more rare in the sorting task than in the lists. This change in dominance between competing systems is to be expected. We assume that the shopping list task is largely "top down" (i.e. search first produces broad, inclusive categories and proceeds in a direction of specificity) and that the sorting task is largely "bottom up" (i.e. search starts from a specific item and works towards that item's superordinates). The same properties can be used for classification in both cases. However, in a top-down search, the classification features found reflect the relative dominance of superordinate headings of items, while in a bottom-up search they reflect the relative dominance of the features in the lists attached to each individual item. The difference between the two can be dramatized by forbidding subjects in the sorting task from using any of the more usual classification systems. This instruction is usually followed by a period of thought on the part of the subject and then, having decided on a system, the task is easy. Under these instructions classes like carbohydrate/fat/protein/vitamin or "needs cooking/does not-need-cooking" appear, as do classification by colour or country of origin, classifications which occur neither in spontaneous sorting nor in the lists. We suspect that these biases would not be matched in a verification task using sentences such as "sugar is sweet" v. "sugar is dry", and "tomatoes are red" v. "tomatoes are fresh". The second of each pair represents the dimension more commonly used in our tasks; we would expect the former is responded to faster.

IV. Ingredients—A Different Kind of List

In generating shopping lists, clear examples can be found of subjects running through the lists of ingredients of particular dishes. To illuminate this ability we asked housewives specifically to give us such lists. *A priori* it seemed reasonable that the order of such lists would be random, or perhaps reflect different shops from which the items would be bought or the order in which they were listed in a recipe book. So we expected no particular pattern in the hesitation pauses in the list, and we expected priming to occur when an ingredient's name also occurred in the name of the dish. The three expectations were all unfulfilled. The order in which housewives think of a dish's ingredients in fact closely mirrors the order in which she would utilize the ingredients in making the dish. It is possible that she learnt the list *while* cooking but that it is still a list. Again, no. Hesitations are not random. In a dish such as lemon meringue pie, the operations fall into three major blocks corresponding to the pastry, the filling and the meringue. And it is precisely at the jumps between these blocks that long hesitations occur. Thus we are inclined to view the blocks as subroutines which are accessed by a particular recipe, this access taking longer than the time taken to run through an already accessed routine. Finally, the priming, expected in this case on the word "lemon", just doesn't happen. Nine out of the ten subjects tested put "lemon" with the rest of the ingredients for the filling. The one exception, who started her list with "lemon", was later asked, "At what point would you actually *grate* the lemons and squeeze them?" She replied, "Well, I think I'd do it before I began, because I don't like doing things like that in the middle".

The same subjects were also asked, at a later interview, to give the full recipe. The order of the ingredients in the recipe corresponded almost completely with the ingredients list. So it does seem that a stored recipe can be covertly examined for a particular class of item, in this case "ingredients" (as opposed to "utensils" or "operations"). Further, the protocols show that this examination is often accompanied by the phenomenon of visual and kinaesthetic images of the subject cooking the dish. Only those subjects who report no imagery find the above results interesting; for the majority it is just as they expected. However there are no visible differences in the performance of the two types.

V. Menus—Retrieval and Construction

When one moves to a problem solving task the picture complicates. The situation used is to ask for a menu which fulfils certain constraints. In this situation we find that people appear to access an episodic memory in a very direct way. Thus, one subject, asked for a "cheap, colourful vegetarian meal" responded almost immediately, and commented later "I thought of the most successful vegetarian meal I'd done before". Following such comments subjects are very happy to give a wealth of corroborative detail. In other cases it appears that large numbers of dishes, or routines, are classified under their properties. So when asked to produce "an economical, impressive meal" informants often retrieved, in rapid succession, a whole series of such dishes they had served in the past. In the following example three dots ". . ." means a pause of less than two but more than one second.

"... pate to start with—home-made with liver sausage and white sauce and sherry—and ... Belgian beef casserole with cheese toasts floating on top done with a little beer, and hot grilled grapefruit".
E: *another one?*
"... *oeufs dur porc fine*—the hard-boiled eggs in a sauce ... pork pieces which are the very cheapest cuts, in bits, with prunes and chopped sage and a little cider ... and bananas baked in the oven."
E: *and another?*
"... a plate of fresh, spring vegetables in season, just the vegetables, all tiny ones ... chicken done with a little cider and mixed fresh herbs in the garden and green vegetables ... and apple slices done in a little butter and sugar to make a caramel."

The whole of this exchange took 76 seconds. This kind of performance contrasts with that where no previously used menus are available and the subject must construct the menu on the spot. Consider part of a protocol of another subject asked to find a fat-free meal for the second time in succession for the same person.

Oh, god ... (8 s pause) ... They'd need something that had some sort of roughage in it that they could bite on, because if they'd had the (previously-produced) meal the day before that hadn't really got anything to bite into, they'd need something pretty ... strong. So ... you can't make pastry, can you ... What can you make without fat ... (10 s pause) ... flour and water ... (7 s) ... And you can't really have pasta without fat in it ... (7 s) ... and they won't want fish again ... (7 s) ∴.. what other kind of protein—I can't think of other proteins that there are ... apart from, you know: cheese, milk, eggs, fish, pulses ...

This monologue took over 70 seconds. Apart from the laboured nature of the problem solving we can note: the setting up of an extra goal—"roughage" and the fact that although "fish" was explicitly rejected as a possibility it nonetheless appeared in the list of proteins. The latter implies "fish" was simultaneously in two independent stores, only one of which was modified here. This kind of phenomena occurs sufficiently often for us to regard it as evidence of some kind of semantic–episodic or semantic–working memory distinction. The results of local decisions could not be expected to disturb the organisation of permanent lists.

VI. The Task

We want to understand the way in which complex, real-world knowledge is stored and used. We have demonstrated some of the more obvious complexities of the storage system, but have not said much about the executive or problem solving system. It is here that most of the difficulty and interest lies.

Let us illustrate the magnitude of the task by reference to the protocol in the Appendix. How can we move towards giving a reasonable and productive account of this sequence of behaviour? First of all note a few features of the behaviour. We see the creation during the task of special lists which are later used. From lines 7–19 a list of rooms is created—bedroom, bathroom, living room, kitchen. This list is used on lines 23–27 for the linen and on lines 56–58 in the provision of carpets (with the exception of the bathroom which is signalled as fitted on lines 11 and 12). Then a list of categories is set up as they are searched, and this list—furniture, linen, crockery, cutlery—is explicitly run through on line 52. We see a loss of the goal "honeymoon—alone" on lines 15 and 47. We see the retrieval of "soup plates", originally omitted, on line 50. Since the same subject at a later time inserted *soup spoons* after *table spoons* when asked simply to list all cutlery, we deduce that in the protocol "soup spoons" was retrieved, and led to the retrieval of "soup plates", and that the extra load of this processing caused the omission of "soup spoons". Notice that this has produced a kind of "pop-up" (see above) of "soup plates".

It seems to us clear that one of the features of the model must be some kind of working memory with a limited capacity. We ought to be able to estimate the capacity of this memory from information load at places where things are forgotten. The information load will be made up from currently set-up lists, labels of nodes in trees that are being searched, goals and so on. Furthermore our estimates should be stable across different tasks. Extra information from the same informant can help us to understand the kind of search being used. Thus the cutlery list in the protocol matches closely the list given on a separate occasion. The linen list, on the other hand, showed a very different organization, supporting our supposition that in

the protocol the linen search was guided by the special rooms list. We will also have to use more information from the protocol than just the words. The pause lengths and intonation patterns should give us consistent information about the kind of search in progress.

We are fully aware of the hazards of protocol analysis and in particular the dangers of taking introspective reports at their face value. But we feel the risks are no greater than that of missing the whole point of cognition by taking other routes.

Appendix[1]

Subject M.

1 E: Imagine you have to stock up a little cottage for a
2 honeymoon couple to live away from the world for some
3 (0 min.) time. All the food and furniture and so on.
4 Oh . . . food *and* furniture? Food for how long?
5 E: *about a week.*
6 Oh well, let's start with the furniture. Well, they've
7 got to have a *bed* . . . and—starting with the bedroom,
8 they've got to have a *bed*, and something to hang their
9 clothes in, so I suppose a cupboard and a chest of
10 (½ min.) drawers and a mirror . . . er . . . has the bathroom got
11 a bath and a loo, that kind of thing?
12 E: *Yes*
13 Then they've got to have *fittings* for each room, so
14 they'd have . . . perhaps a sofa or two easy chairs,
15 and a chair for a guest, and a table, to eat off with
16 (1 min.) four chairs—well two is a minimum two extra if possible
17 . . . (3s) . . . and some kind of heating—electric fire,
18 say, or whatever. Coal if they can't bring electricity
19 to the cottage. Um . . . then, the kitchen, they must
20 have a cooker, and a kitchen table, and a kitchen
21 cupboard, and probably a couple of chairs, and a sink
22 . . . perhaps they'd have a sink already. And a draining
23 (1½ min.) board . . . then they've got to have . . . um . . . linen
24 they'll have to have sheets for the bed a pillowcase
25 and blankets and perhaps a quilt—if it's winter.
26 And then they'll have to have towels . . . and—bath
27 towels and drying up towels—and a kitchen towel.
28 (2 min.) Then they've got to have stuff to . . . cutlery and
29 crockery . . . so they've got to have cups and saucers
30 say four of each, four large plates, four small plates,
31 er, some kind of serving dishes, say . . . three—a
32 large plate for carving on and serving the meat, and
33 two or three vegetable dishes . . . (4s) . . . say two
34 extra bowls, one for cooking in, one for serving in

[1] Note: an ellipsis (. . .) indicates a pause of 1–2 seconds. Longer pauses are specified, thus . . . (5s) . . . represents a five-second pause. A pause of up to 1 second or segmental pauses are represented by a comma (,)

35 ($2\frac{1}{2}$ min.) . . . a frying pan, a large—am I supposed to produce
36 the *minimum?*
37 E: *whatever you want*
38 Oh, I see. Um . . . I've been rather doing it on the
39 minimum. Er . . . frying pan, couple of saucepans—
40 (3 min.) at least a large and a small but perhaps two of each
41 . . . Er, kettle . . . electric toaster if we're being
42 lavish . . . (5 s) . . . then implements: slice . . . and
43 —oh, haven't had the cutlery have I? No. Well, *cooking*
44 implements: wooden spoon and a slice and a . . . straining
45 ($3\frac{1}{2}$ min.) spoon, and a . . . pair of kitchen scissors . . . and
46 a sharp knife for cutting and a carving knife and
47 fork and, say cutlery for four people four large knives
48 four small knives four large forks four small forks
49 four spoons and four table spoons . . . (4 s) . . . um
50 (4 min.) . . . oh, I didn't have *soup* plates, in the . . . original
51 crockery . . . (3 s) Right, well now I've provided
52 furniture, linen, crockery, cutlery . . . (3 s) . . .
53 something to clean with!: perhaps a hoover or vacuum
54 of some kind, a dustpan and brush, a broom to sweep
55 with and a carpet sweeper—oh! They haven't got
56 any carpets! Um . . . well, or a carpet for the bedroom,
57 ($4\frac{1}{2}$ min.) a carpet for the living room, and perhaps lino or
58 vinyl flooring for the kitchen . . . (5 s) . . . oh!
59 Back on the cleaning utensils, a sponge mop for washing
60 the kitchen floor, and . . . a couple of—oh! a floor
61 cloth, and dusters, say . . . two or three and . . . (3 s)
62 (5 min.) . . . dishcloth, two dishcloths.

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