A PRELIMINARY FUNCTIONAL MODEL FOR LANGUAGE BEHAVIOUR

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A functional model of the kind outlined below has as its justification the property of providing a structure into which a large number of more or less related results may be fitted and through which they may be linked. A model based on the results from normal subjects may have the additional properties of providing clinicians with an independent basis upon which they may classify defects, and anatomists and physiologists with some idea of the kinds of interconnections and functions they might expect to find in the nervous system.

In what follows, statements are sometimes made which seem assertions of undoubted truths but are in fact merely possible deductions from tentative hypotheses. Indulgence is craved for such shortcomings with the hope that no-one will be fately mislead.

The model here described is an extension of a model previously suggested to account for certain experimental findings (Morton; 1961, 1964 a). The experiment involved firstly presenting 100 subjects with sentences of the form:

Through the window she saw a ______________

and He asked the way to the ______________

Subjects were asked to complete the sentences by the addition of a single word. This we can call a **Generation Situation.** The distribution of responses gives an estimate of the Transitional Probability of words in the contexts. The Visual Duration Thresholds of certain words were then measured in sentence contexts, a **Recognition Situation,** and a relationship was found between threshold and probability.

To say then that the threshold of a word is **affected** by its probability is to make not only an error in logic, but also, I would submit, an error in research strategy. After all, Transitional Probability is not an abstract immutable number, it is a measurement of behaviour, and the behaviour in the Generation Situation is the same as that in the Recognition Situation: the response of a word. We can regard the two situations as connected as in Figure 1.

It seems reasonable to assume that when a particular word is available as a response there is an event in the nervous system in a particular place regardless of the circumstances leading to the word availability. Such a part of the nervous system can be called a “neural unit”, which is defined by its properties, of which the primary are:

P1. When a unit fires, a particular word is available as a response.

P2. Each unit has a basic, relatively stable level of activation.

P3. The level of activation can be increased by "noise" or by outside events.

P4. Each unit has a threshold; when the level of activation exceeds the threshold the unit fires.

The collection of units makes up a "dictionary". (The "units and "dictionary" defined here are similar to those in a model produced by Anne Treisman, 1960).

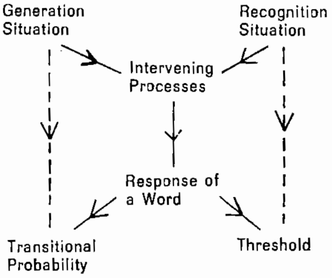

Fig. 1.

From the above assumptions and definitions further properties of the system may be deduced. Clearly, any event which increases the likelihood of a word being available as response must increase the level of activation in the appropriate unit or reduce its threshold for firing (at some stage it may be necessary to distinguish between these alternatives but at the moment they will be regarded as largely equivalent). The general scheme which follows is shown in Figure 2.

When a sentence context is presented to a subject, it acts to increase the amount of activation of unit **i** by an amount **C**i. The value of **C**i for any unit and context is determined by the **Sequential Processes** which for the moment will be left undefined.

In a Generation Situation the subject is asked to produce a word fulfilling certain conditions, and a **Selection Mechanism** operates to cause a unit to fire in such a way that the relative probability of units firing depends upon their relative levels of activation. In the presence of a context these will depend largely but not entirely upon values of **C**i. From the responses in such a situation we obtain the measures of transitional probability of words in the context. These probabilities reflect what is called the **Response Bias.**

A **Recognition Situation** differs in two respects from the above. In the first place sensory information is available; secondly certain instructions will have to be given to the subject such as "If you are not sure then guess" or "Report only what you see", etc. Such instructions will affect the mode of operation of the Selection Mechanism. The sensory information is assumed to be analysed by some network as it becomes available, and "visual cues" are extracted. The longer the (visual) stimulus is on view, and the greater the contrast, the more cues are available. These cues include the length and shape of the word, and individual letters (see Morton, 1964 a).

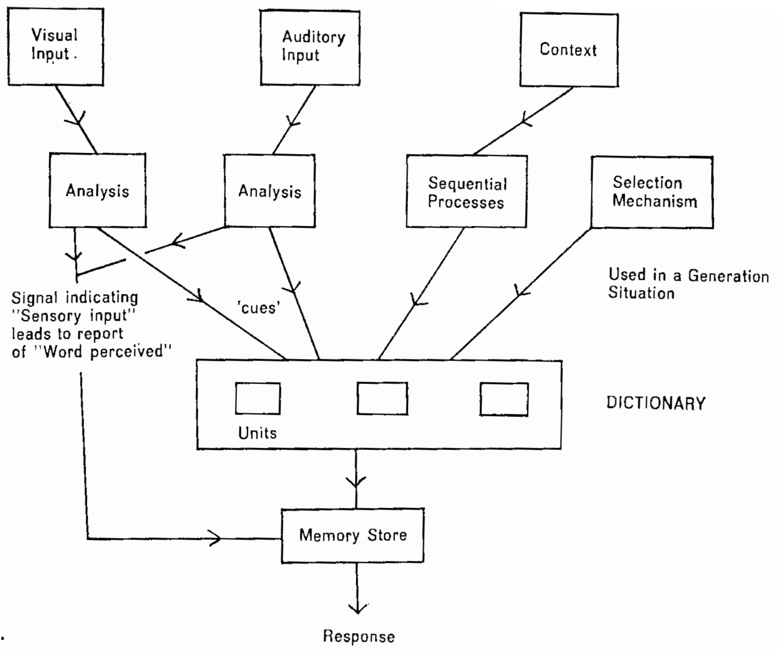

Fig. 2.

The level of activation within any unit is raised by an amount dependent upon the number of cues common to the stimulus and the word associated with the unit. When the amount of activation in the unit exceeds some threshold, the word is available as a response. When a word becomes available as a response in the presence of sensory information the subject reports that he **perceived** it. For any one word in a particular context, the relative activation due to context and sensory information will depend upon the threshold of the unit. If this is low, e. g. under instruction to guess, then the context effect will predominate; if the threshold is high, e. g. when the subject is told to report "only what he is sure he has seen", then the influence of the sensory information will be a maximum. Clearly in the latter case there will be fewer errors, but only at the cost of a higher threshold. Equally clearly the effect of context will be smaller the more sensory information is available, i. e. the longer the exposure of a visual stimulus or the higher the signal to noise ratio of an auditory stimulus. (These points have been verified by Morton, 1964 b). In addition if some of the analysis system constitutes a limited capacity channel such a Broadbent's **P** system (1958, p. 299), then under conditions where the response must be made hurriedly (as for example in shadowing, Treisman, 1960, or in rapid oral reading, Morton, 1964 c) the effects of context will re-exert themselves since a reduced amount of sensory information will be available **to the units** in the available time. With unlimited time and sensory information, we would in this system predict that the effects of context would emerge as differences in reaction time to the stimulus, since with less probable stimuli, more sensory information will be required to make a unit fire, which information will take longer to come through the analysis system.

Since the response to an auditory verbal stimulus is the same as that to the corresponding visual one, we may place a parallel system of store and analyser feeding straight into the dictionary without further assumption, (though this will be modified later).

The effects of context upon auditory threshold would then follow. Obviously it would make no difference whether the context was auditory (Miller, Heise and Lichten, 1951) or visual (Stowe, Harris and Hampton, 1963; Morton, 1964 b). In addition we would predict the transfer of effect of differential exposure to nonsense syllables, either visual or auditory, to recognition by the other channel, with one vital and logical proviso that in the case of transfer from auditory training to visual recognition there should be correspondence between the auditory and visual forms of the stimulus. If this is not the case, the "unit" formed by the auditory training will not receive the appropriate information from the visual analysis. Thus Sprague (1959), using such nonsense syllables as REBKIC and KESQIL found no transfer from auditory to visual, whereas Weismann and Crocket (1957) using such words as JESTO and SAMIG did find a transfer.

At this stage it is possible to look briefly at problems of attention. It is clear that the presentation of information simultaneously or in rapid succession to two sense organs presents problems to a subject (Broadbent 1957, 1958, 1963 a). With simultaneous presentation of verbal material to eye and ear, one set of information is apparently completely lost (Mowbray, 1953, 1954). It was thought that such explanations as were put forward to explain this phenomena also applied to dichotic situations. However, Treisman (1960) showed that words did break through from one ear when material on the other ear was being shadowed. Such words could be high probability words in the context of the shadowed ear or the subject's own name. Treisman suggests that the corresponding units have their thresholds temporarily and permanently lowered respectively, and that the material on the rejected ear is only attenuated, not blocked completely. The present writer would only suggest that the unit corresponding to the high probability word has a high level of activation not a lowered threshold, but this, for most purposes is a minor disagreement.

If we draw a flow diagram such as Figure 3 the phenomena fall into some kind of place. Dichotic stimuli or verbal stimuli differing in some acoustic sense such as fundamental frequency (Treisman, 1961) or external filter characteristics (Broadbent, 1957) are separated in the **B** system, where one may be attenuated or perhaps temporarily stored. The **C** system may be regarded as a general purpose computor which may be programmed for any specific input (e. g. visual vs. auditory) and any output (e. g. verbal vs. nonverbal). If **C** can only contain one program at once, then we would expect a certain time to elapse if attention was to be switched from one input channel to another, during which time the programme would be changed. **C** could also be regarded as having a limited channel capacity, having the properties of Broadbent's **P** system (1958).

Broadbent (1964) has recently suggested that "attention" might operate either to change the response bias (e. g. listening for a particular name) or to reduce the effective signal-to-noise ratio in the brain (e. g. by analysing the acoustic energy pattern in only a limited frequency band in a signal detection task). It seems likely that many phenomena which have previously been grouped together will have to be functionally separated if they are to be understood.

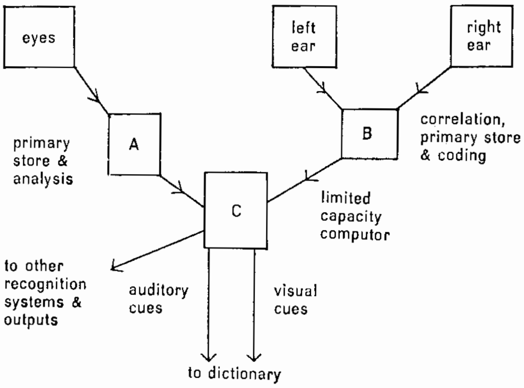

Fig. 3.

Returning to the problem of word recognition, it will be seen that with the existing model, it is possible to account for the relationship between probability and threshold without resort to the "response-bias-guessing" hypothesis of Goldiamond and Hawkins (1958). If the Context-to-Sequential Processes-to-Dictionary chain operates in both the Recognition and the Generation Situations then we would expect there to be a high correspondence between behavioural measures in the two situations irrespective of the instructions or the stimulus strength. It is clear, however, that the correspondence is not complete; that the signal does play some part, even when subjects are instructed to guess, (Stowe, Harris and Hampton, 1963). In addition the model enables one to understand how a word can be "perceived" with great confidence, but incorrectly (Morton, 1964 c).

We can generalise our statements to say that **any** context which increases the probability of words in a Generation Situation would be expected to lower their threshold of recognition. Examples of relevent results include Bruce's (1958) finding that the intelligibility of a sentence increases in the presence of a correct description of its general topic, and Taylor's (1956) demonstration of the facilitative effects of words associated with the stimulus word. The same reasoning can also be applied to explain the effect of the reduction of the number of response alternatives on word threshold (Miller **et al,** 1951). Unlike the latter authors, Stowe **et al** (1963) and others, we would predict from the model that context effects do not restrict the number of units which may fire, but rather increase the level of activation in some of them. Response suppression may take place, but subjects sometimes do report "perceiving" nonsense words, or words which are illogical or ungrammatical in context (Morton, 1964 a, 1964 b).

The units in the model have further properties which may be deduced. Since the threshold for nonsense syllables is a function of the frequency of pretraining (e. g. Solomon and Postman, 1952) we would say:

P5. Following the firing of a unit, its resting level of activation is increased sharply (and then decays more slowly).

This effect is easily demonstrated for words (Morton, 1964 b). If some of the activation is transfered to a permanent form (e. g. biochemical rather than electrical), then we would expect the relationship between word frequency and threshold with both visual (Howes and Solomon, 1951) and auditory (Rosenzweig and Postman, 1951; Howes, 1957) presentation. The model permits the reconciliation of two opposing explanations of this effect. Thus Howes (1954) and others have suggested that it is the frequency of emission as opposed to frequency of experience of a word which influences its threshold. This contention is supported by Daston (1957) who found that subjects were more successful in recognising words emitted frequently by them in therapy interviews than other words of equal frequency in the Thorndyke-Lorge counts. Contrary evidence has been offered by Neisser (1954) and Ross, Yarczower and Williams (1956) who found that while the previous study of words lowered their duration thresholds, it did not facilitate the recognition of their homonyms, as might be expected if frequency of emission is the vital variable. Within the model, this pair of results presents no difficulties. We would say that homonyms have in common only the same effector sequence, not the same unit, so we would not expect there to be facilitation between such pairs of words.

The distinction between temporary and permanent effects in the units may be related to the distinction drawn earlier between the increase in activation in a unit and the lowering of its threshold. If one regards the units as having characteristics describable by Signal Detection Theory (Tanner and Swets, 1954; Swets, Tanner and Birdsall, 1961), then the permanent effects may be equated with a lowering of the criterion. The Selection Mechanism, which must be used in the absence of an adequate signal, can then be regarded as acting on the (biochemical) criteria of all units, rather than increasing their (electrical) activation.

When a unit fires, we should say that a signal passes to the Memory Store and the appropriate word is available as a response. The word is then in Immediate Memory (by definition of that term). Now Conrad (1962) has shown that when letters of the alphabet are presented visually for recall, the confusion errors which occur are similar to those which occur when one is listening to the names of the letters spoken through noise. If one has seen the letter C, for instance, one may recall the letter B and not O, even though visually C and O have more in common than C and B. Since it is difficult to construct an explanation of **acoustic** confusions in memory with the existing flow diagram, it might be preferable to consider the possibility that these are **articulatory** errors (since articulation correlates reasonably with the acoustic properties of the result) and that material in Immediate Memory is coded in terms of the appropriate articulation gestures. Now it is known that Immediate (short-term) memory fades with time, unless rehearsal is permitted, though it is not established whether this memory loss is due to decay effects or to interference by other activity (necessary to prevent rehearsal). Broadbent (1963 b), in a survey of this area, suggests that the material in short-term memory is recirculated through the limited capacity channel through which it originally entered the system. In the present model this would amount to recirculating through the **C** system which, at the time, would have to be appropriately programmed (for some quasi-kinaesthetic input). As Broadbent observes, the interference effects in short-term memory "do not seem to depend very much on the nature of the intervening activity" which can be almost any kind of performance "provided that it represents a high rate of information transmission through the nervous system". These remarks are consistent with the present formulation.

There are at least two other kinds of memory (or storage) which it is necessary to locate in a functional model for language behaviour. Firstly there appears to be a very short term store, the contents of which most certainly appear to decay with time. This was shown by Averbach and Sperling (1960) who flashed a number of items (e. g. letters and digits) on a screen simultaneously, followed, after an interval, by a marker stimulus which indicated the item the man was to report. As the interval increased, the proportion of correct responses fell, and since there was no intervening activity, we must conclude that the contents of this store are affected by time. Such stores are likely to be modality specific and located before the **C** system.

The second kind of memory to be considered is more long term. In particular long term memory differs from short term memory in the way

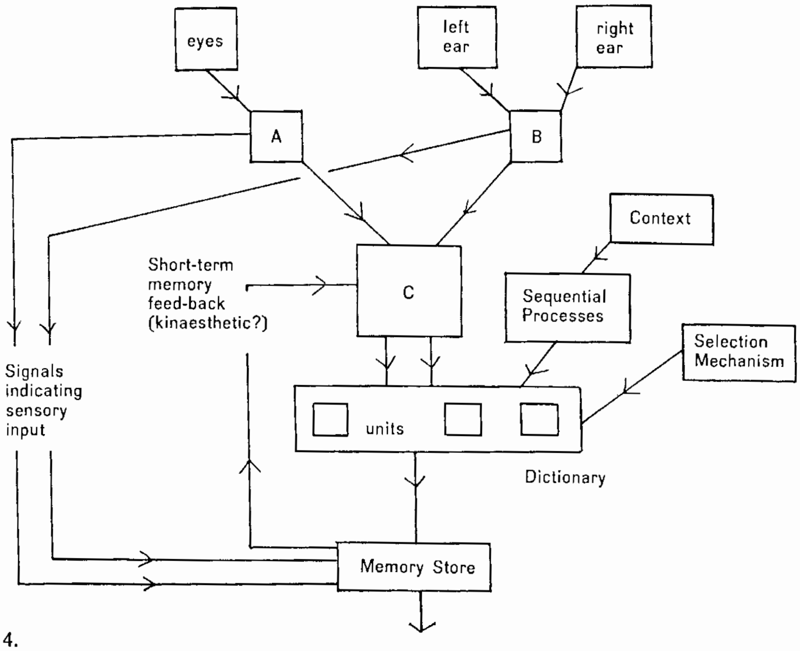

Fig. 4.

that it is affected most by intervening activity when that activity is similar to the original learning activity (again, see Broadbent, 1963 b). Specifically the effects of a subsequent memory task will be directly related to the similarity of the material to that originally learned. One possible hypothesis is that this memory is related to the state of the units already defined. For example, if the level of activation of the unit corresponding to the item to be remembered decays slowly, then the item may be retrieved after a time by seeing which units have a higher level of activation than normal. Fortunately this hypothesis yields various predictions some of which are intuitively unlikely and which the writer hopes to test.

The final form of the model is shown in Figure 4. Nothing has been said up to now concerning the nature of the Sequential Processes. For certain kinds of contexts, for example associated words, it is possible that there are connections between the units whose properties reflect the conditional probabilities of associations. The manifestation of this in the model would be the amount of activation passed from one unit to another. For more complex contexts however, such a formulation becomes impractical and other, higher order processes must be invoked (Miller, Galanter and Pribram, 1960, Morton, 1964 d).

The model is complicated, one should expect no less, and is not in every detail likely to be acceptable to all psychologists. In addition, many of the concepts are not original, but their origins have been lost in a possible fourth kind of memory, in which diverse facts and relationships are structured and recorded more or less permanently. To such people as have been plagerised and unacknowledged apologies are due. Thanks are due to my past and present superiors and collegues, in particular Mr D. E. Broadbent and Dr Sylvan Kornblum.

UN MODÈLE FONCTIONNEL PRÉLIMINAIRE DU LANGAGE

Le but d'un modèle fonctionnel du cerveau est de fournir une structure qui puisse relier entre eux les résultats de diverses expériences. Les divers modèles qui existent à l'heure actuelle se distinguent principalement par leurs points de départ. Le présent modèle trouve son origine dans une tentative d'expliquer les rapports entre la conduite de prédiction et les seuils de reconnaissance de matériel verbal. Il suppose que lorsqu'un mot est disponible pour servir de réponse, quelque chose se passe dans une partie déterminée du système nerveux, indépendamment des circonstances ayant amené la disponibilité du mot (par exemple: une présentation visuelle ou auditive, ou du langage spontané). On appelle cette partie du système nerveux **l'unité** correspondant au mot. La collection des unités constitue un «dictionnaire», et les unités peuvent recevoir de l'information de diverses sources dont chacune peut augmenter le niveau d'activation dans une unité. Lorsque l'activation dépasse un certain seuil, l'unité décharge, et le mot correspondant devient disponible comme réponse. Les unités peuvent être activées par des processus relatifs au contexte et par des processus qui analysent les stimuli visuels et auditifs. Le résultat est dans chaque cas le même: une unité décharge et le mot correspondant est disponible. Le niveau d'activation qu'il faut pour faire décharger une unité depend de la situation expérimentale. Quand on demande au sujet de deviner, le critère sera moins élevé et le contexte influencera la réponse davantage. Dans ce système, « la perception » implique qu'un mot soit disponible comme réponse et qu'un signal indique qu'une information sensorielle s'est présentée.

Le canal à capacité limitée (le système **P** de Broadbent, 1958), est envisagé comme un calculateur à usage général (Boîte **C** dans les figures 3 et 4) qui ne peut être programmé que pour un input et un output à la fois. On examine brièvement les problèmes d'attention et d'aiguillage en termes de la boîte **C** et du temps nécessaire pour changer son programme.

On suggère que le matériel verbal dans la mémoire immédiate est codé en termes des mouvements d'articulation nécessaires pour reproduire le matériel, et que ces signaux codés repassent continuellement par **C**. La mémoire à long terme est envisagée en fonction des propriétés des unités.

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