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THE ROLE OF MEMORY IN THE ATTENTION PROCESS

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ABSTRACT

The difference between auditory and visual presentation in the error scores on the final items in serial recall tasks and the selective effect of a stimulus suffix following auditory presentation led Crowder and Morton to postulate a precategorical acoustic store (PAS). The absence of cross-modal suffix effects under conditions where the suffix had to be processed together with the increase in the effect of a contralateral suffix following a monaural stimulus under the same conditions and the total absence of semantic influences effectively rules out the possibility of the phenomena being economically accounted for postcategorically. The results and the consequent analysis cast doubt on the effectiveness of the distinctions made in the current controversy on the location of selection.

1. INTRODUCTION

I would like to talk about the implications for theories of attention of some recent studies involving techniques of short term memory. In these studies the stimuli are unconnected items, usually digits, presentation is auditory and recall is serial. Between stimulus and recall another acoustic item is presented – the stimulus suffix. In early experiments this suffix was the digit 'zero' or 'nought'. The suffix produces a very striking and reliable effect, selectively impairing the recall of the final digits (CROWDER, 1967). It should be noted that the suffix was redundant – it occurred after all the lists in a block of trials, and was irrelevant – the subject (*S*) never had to respond to it. In addition its effect differs widely from that of a similar event, the 'response prefix' where the 'zero' between stimulus and response is spoken by the *S*. This affects performance, but equally at all serial positions. Bob Crowder and I are reasonably happy that the suffix effect is a property of a precategorical acoustic store or PAS (CROWDER and MORTON, 1969; MORTON, 1970).

Our use of 'precategorical' is made clear by the very simple conceptual model with which we are working. The central feature of this model, depicted in fig. 1, is the 'logogen' system (MORTON, 1968, 1969) where sensory and contextual information relevant to a particular response

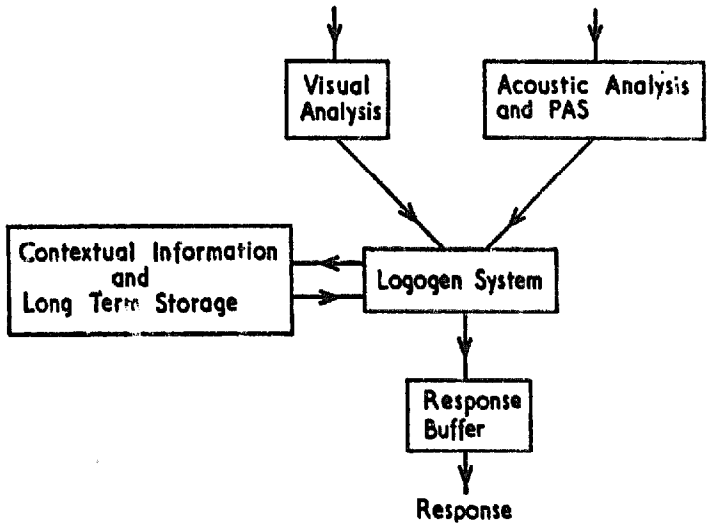

Fig. 1. A simplified flow diagram of the flow and storage of information in tasks employing language material. For more detailed description of the interaction of the separate parts see MORTON (1970).

interact. The outcome of this interaction is discrete, and, it is supposed, coded phonologically. We term this process 'categorizing', and so label processes acting upon sensory information prior to the logogen system as being 'precategorical'.[1] PAS is then seen as a property of the acoustic analysis system which precedes the logogen system, and thus is 'precategorical'.

We have suggested that, following acoustic presentation of a list of items, information relating to the last item or items remains in PAS. This information is then retrievable separately from information concerning earlier items. The information in PAS is sufficient to account for the difference in the serial position error functions following visual and acoustic presentation. With visual presentation and silent rehearsal there is very little of what is traditionally called 'recency'. With acoustic presentation or with vocal rehearsal on the other hand, performance on the final item is almost perfect (CONRAD and HULL, 1968). We have suggested that the action of a stimulus suffix, which impairs performance selectively on the final items, is to remove the information in PAS relating to these items.

In the model, the visual and auditory input channels do not converge or interact until the logogen system. PAS, then, should not be affected

[1] Our use of the term 'categorical' does not imply that the stimulus analysis systems contain no decision making functions. It is used in preference to the term 'perceptual', for reasons which will be (or will become) apparent, and in the absence of any more suitable term to capture the distinction defined.

by visual stimuli. This consequence of the model tested by CROWDER and MORTON (1969) has been confirmed by MORTON and HOLLOWAY (in press) who found no suffix effect either with an auditory suffix following visual presentation or with a visual suffix following an auditory stimulus even when the *S* is forced to respond to the suffix prior to recall.

2. THE SUFFIX EFFECT

The relevance of these studies to attention begins when we start to investigate the properties of the suffix that cause 'the suffix effect'. To start with, a variety of experiments have shown that the semantics of the suffix are irrelevant – again confirming that the location of the effect is prior to the logogen system (at, but not before which, meaning becomes relevant).[2] What do change the effects of the suffix are variations in its *acoustic properties*. First, if the stimulus list is presented binaurally the effect of a monaural suffix is less than the effect of a binaural suffix. Secondly, if the stimuli are monaural, an ipsilateral suffix, i.e., a suffix in the same ear, has a much greater effect than a suffix in the opposite ear, though the latter has a significant effect compared with a control, no suffix, condition. If PAS were prior to the combination of information from the two ears then we would expect that a binaural suffix would have the same effect on a monaural stimulus as would a suffix in the same ear as the stimulus since the stimulation in that ear was the same in the two conditions. In fact the effect of a binaural stimulus is much less than that of ar ipsilateral suffix there being no difference between the binaural and contralateral suffix conditions in a number of experiments. Therefore PAS must be located after the combination of information from the two ears. The data are also consistent with a filter model where information in the buffer store is segregated by its spacial location. The suffix effect could then be caused by information being overwritten in the buffer store prior to channel selection.

These possibilities are illustrated in fig. 2. If subsequent information overwrites previous information at the same location in the buffer store then the greater impairment of a suffix on the same channel as the stimulus is accounted for. If this buffer store were the sole location of PAS

[2] These experiments and the others referred to will be described in full in an article in preparation by Morton, Crowder and Prussin. The present paper owes much to Bob Crowder.

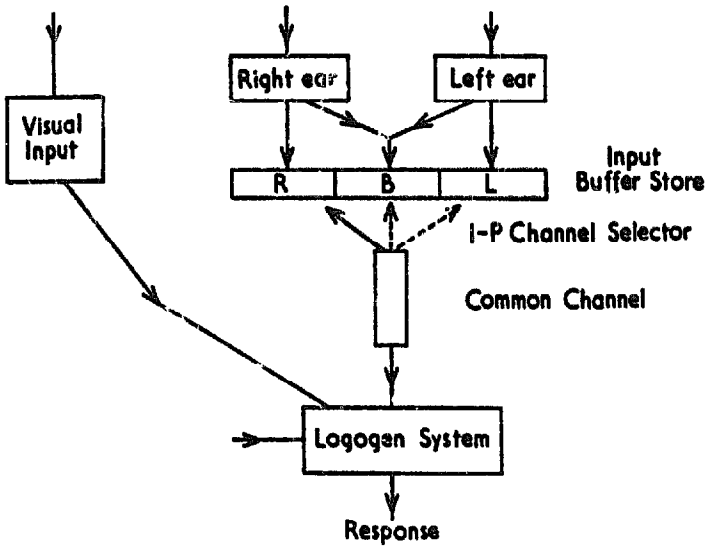

Fig. 2. An expansion of the auditory analysis system in fig. 1 which is consistent with the data from the suffix experiments. In the text it is discussed whether PAS is a property of the buffer store or the common channel. Within the buffer store 'R', 'B', and 'L' refer to those sections of the buffer store into which are separated information presented to the right ear alone, binaurally and to the left ear alone respectively. By one possible account of the data the I-P (input) channel selector is set to accept information preferentially from one of the sections of the buffer store.

however, the fact that a suffix on a different channel does have a highly significant serial position effect would require the additional supposition that the separation of the channels in the buffer was incomplete.

Other results indicate that the buffer, when viewed in this way as a series of separate physical locations, must have a rather complex structure since we have also discovered that when the suffix is louder than the stimuli that the effect is reduced, when the suffix is spoken at a different pitch there appears to be a reduction in effect and when the suffix is in a different voice the effect is reduced. The last effect is very strong indeed; in fact when the suffix is spoken in a male voice following a female stimulus list (or vice versa) the reduction in effect is about as great as when the suffix is on the opposite ear. If the buffer store does involve physical separation of channels, then these results would require that pitch, intensity, and voice quality all defined separate spatial dimensions in the store.

On the other hand it is possible that PAS occurs after channel selection instead of, or as well as, in the buffer store.[3] In addition, channel selection

[3] Note that PAS, as originally defined, is a *property* of the acoustic analysis system and is not necessarily restricted to one specific location within that system. Note also that 'location' is used in terms of function not anatomy.

can be viewed as being the simultaneous specification of a set of stimulus properties (such as location, pitch etc). Stimuli not having one or more of the specified properties would tend to be rejected by the channel selector, which is, in this variant of the model, behaving more like a multi-dimensional filter. The effect of a suffix which differed from the stimulus in some way would then be an index of the efficiency of the filter with respect to the dimension under test. Such an interpretation is supported by further data. In particular if the subject does not know in advance whether the suffix is going to come on the same ear as the stimulus list, on the opposite ear or binaurally the difference between the suffix locations is much reduced.

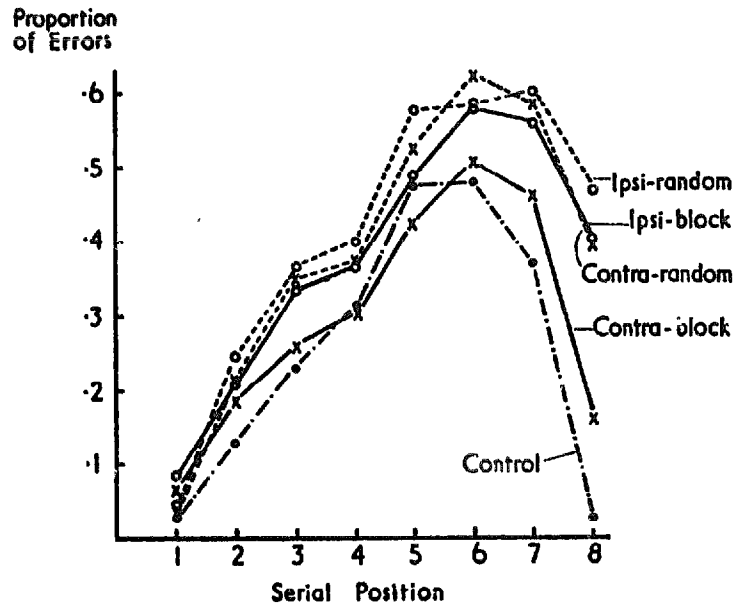

Fig. 3. Data from some of the suffix experiments. In all cases the stimulus lists were presented acoustically to one ear. In the 'ipsi' conditions the suffix was presented to the same ear and in the 'contra' conditions the suffix was presented to the opposite ear to that which heard the stimulus list. In the 'block' conditions the subjects always knew to which ear the suffix would be presented. In the 'random' conditions they had no such information. In the control condition there was no suffix.

These results are illustrated in fig. 3. The data came from three groups of subjects. The control curve (with no suffix) is typical of acoustic presentation and is taken from one group of subjects. A second group of subjects heard the stimulus lists monaurally with either an ipsilateral, a binaural or a contralateral suffix. The subjects always knew where the suffix was coming from and were presented with two blocks of twenty stimulus lists under each suffix condition. The results from the

binaural suffix condition have been omitted as they were indistinguishable from those given by the contralateral suffix. The data from this experiment are labelled 'ipsi-block' and 'contra-block' in fig. 3. In a third experiment the location of the suffix changed from list to list at random. In experiments involving the suffix the subjects were instructed to regard it as being merely a cue to recall. It will be noted in fig. 3 that performance in the ipsi condition is only slightly worse with random presentation compared with block presentation. The contralateral suffix, on the other hand, has a much greater effect in the random condition than in the block condition and in the random condition approaches the ipsilateral suffix in the magnitude of its impairment.

These data imply that the exclusion of the suffix (channel unselection) is more difficult when one doesn't know what to exclude. Merely trying to stay on a (possibly) blank channel is insufficient. The effect is accentuated further if the subject is required to respond to the suffix. In these experiments the suffix was one of the words 'tick' or 'cross' which the subjects either had to ignore or had to enter as a prefix prior to recall. In the latter case the difference between the ipsi and contralateral suffixes was reduced; it did not vanish though.

These results indicate that PAS is largely located after the channel selection; the residual difference between the ears in these experiments indicates that there is some PAS in the buffer store, and the effect of the contralateral suffix shown originally could be either an index of the overlap in the buffer store or of inefficiency in selection (or exclusion). Since there are no crossmodal suffix effects it follows that auditory channel selection takes place prior to auditory-visual channel selection.

3. Selective attention – 'perception or response'?

The next question is how these data relate to the main controversy in selective attention: that of how much analysis is undergone by 'unselected' stimuli. I must say to start with that I consider the terms in which this controversy has been couched as being rather misleading. To discuss whether attention is a perceptual or a response phenomena is to tie one down to a conceptual framework and a dichotomy that may well turn out to be as irrelevant and theory-specific as the discussion as to whether the word-frequency threshold effect was a perceptual or a response phenomena (Broadbent, 1967; Morton, 1964, 1968). Within the logogen model, for example, the subjective phenomena

of 'perception' is identified with an event involving an output from a logogen. Information entering the logogen system but not resulting in such an output has still undergone 'full perceptual analysis', as DEUTSCH and DEUTSCH (1963, 1967) have it, but there need be 'little evidence for perception of the verbal content', as Anne Treisman claims for unattended messages (TREISMAN and RILEY, 1969). Indeed there is good reason to suspect that 'rejected' messages can be analysed further than the logogen system (or its functional equivalent) without awareness.

Consider the problem of the segmentation of the speech waveform in the absence of physical gaps between successive words. One possible method of conceiving of this function is that all possible segmentations are passed along in parallel and those eliminated which are not permitted by higher order linguistic rules. Any initial, incorrect segmentation fails to reach awareness; only that which is responded to can be recalled. This is to say no more than lack of evidence for 'perception' of a stimulus does not constitute evidence for lack of its analysis except within the confines of a particular theoretical framework. If the framework is changed the implications change.

4. SELECTIVE ATTENTION – THE IMPLICATIONS OF THE SUFFIX RESULTS

If the effects of the suffix are due to the overwriting of information relating to the final items, then the implications of the suffix experiments are clear. They require that some, at least, of this overwriting takes place in the common channel (in fig. 2) which follows some mechanism which selects an auditory channel (or set of acoustic stimuli) which is specified in terms of acoustic characteristics. Our results also require, however, that this common channel is not involved in the processing of visual stimuli nor in the process of silent rehearsal.

Before jumping to conclusions about the implications of these findings for the controversy on selective attention two points must be borne in mind. Firstly there is nothing in the data reported here that is pertinent to the question of how much sensory analysis has taken place at the time of selection. It is perfectly possible that all stimuli in the buffer store are completely analysed and coded in terms of features. The second point to remember is that one cannot necessarily argue from experiments involving channel rejection, such as the suffix experiments, to those involving channel selection. One glaring example of the difference is that we have discovered no effect of a stimulus suffix comprising of a burst of noise of the same intensity as the normal suffix,

on the same ear as the stimuli, and in the suffix position. In the terms of the present discussion we would want, then, to use 'speech-like' as a dimension defining a 'channel'.[4] In the channel selection case, of course, a burst of noise will obscure any speech stimulus occurring at the same time and on the same ear.

5. The necessity for more than one selection mechanism

Furthermore, it is clear that some other mechanism must exist the result of whose operation is to exclude external stimuli from awareness and from memory. The filter postulated as a result of the present experiments is not involved with visual stimuli. Mowbray (1953, 1954) has shown, however, that when either visual or auditory stimuli are being processed material presented on the other dimension is not recoverable. Kahneman (this volume) has presented similar evidence. In addition Parlett (1969) has shown that irrelevant information presented between stimulus and response in a memory task has less effect if the subject was permitted to rehearse. This result too can be interpreted in terms of the effects of channel selection; but such selection would not be covered by the mechanisms in the present model.

Given that some other mechanism of selection must exist, and given that selection is not the same as rejection it does not seem possible to decide between the Treisman and Deutsch models. If anything, the present results indicate that both the models are inadequately formulated. Some of the limitations of the Treisman approach have been mentioned above; the most recent attempt to prove the contrary point of view – that the rejected message is blocked in the response system – also fails in the light of the current data. Norman (1969) showed that if the shadowing of a message is stopped abruptly then items just previously presented on the rejected ear can be retrieved. He considers, but rejects the idea that this result can be explained on the basis of 'sensory storage units prior to the attention mechanism' on the grounds that his data would require such a store to have 'the properties of the usual short-term memory' and that this 'would appear to be too much of a coincidence'. The 'properties' in question were almost perfect recall of the final item in the rejected-recalled list and no primacy effect whatever. I submit, however, that this similarity was brought about by the method of testing he used – the probe technique. If serial recall of the rejected

[4] It will be apparent that the usefulness of the term 'channel' is less than limited.

items were attempted I would predict that there would still be no primacy effect – unlike the properties of 'the usual short term memory'. If this prediction is falsified the model will have to be rejected, but at the moment the properties of PAS are completely sufficient to account for Norman's data.

In conclusion I feel that the above analysis shows that the title of the present paper and the preceding one in this symposium by Norman are in danger of being synonymous and tautologous. By drawing from different theoretical formulations it is possible to show that 'attention' equals 'memory' and that these both equal 'perception' and 'response'. BROADBENT (1969) has already analysed the relationship between 'perception' and 'memory' and it is incumbent on all of us to analyse our use of 'attention' and to use all these words with more care than has been our custom.

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