The effects of priming on picture recognition

Clive Warren and **John Morton**

In two experiments we show that the prior presentation of a picture serves to facilitate the recognition of that picture in a tachistoscope up to 45 minutes later. Facilitation of recognition also occurred with prior presentation of a different picture with the same name. This cannot be explained in terms of a response bias, since the presentation of a word, which the subject read aloud, had no effect whatsoever upon the subsequent recognition of the picture. The data are interpreted in terms of a categorization stage for pictures which is completely independent of the verbal system. Data from other experimental paradigms are also examined. Our categorization model enables consistent interpretation of these data, which otherwise appear contradictory.

In this paper we ask certain questions about the way in which pictures are recognized. The theoretical framework within which we pose the questions is that of the logogen model (Morton, 1969) which was developed in order to account for data concerning the recognition of words. Recent changes in the form of the model prompted the present study. These changes were forced by experiments which rely on a technique of facilitation of word recognition. The basic design involves two phases. In the first phase subjects are exposed to a variety of stimuli and respond to each with a single word. In the second phase, anything up to 45 minutes later, these words are presented for recognition under conditions of stimulus degradation. The most striking result is that when a word is presented visually in the first phase, less stimulus information is required in the second phase for it to be correctly reported. The interest then lies in whether or not other, related stimuli also facilitate recognition in the second phase. One of the early experiments using this technique was by Neisser (1954) who showed that prior presentation of a word like PHRASE had no effect on the subsequent recognition of a homonym (a word with different spelling but the same pronunciation) such as FRAYS. This experiment showed that the facilitation effect was not due to an effect on the stage of response production. Murrell & Morton (1974) later showed that strong facilitation could be produced by a pretraining word which was morphologically related to the test word. Thus, experience with the stimulus SEES had a strong effect on the subsequent recognition of SEEN. That this effect was not due to the physical overlap of the stimuli was shown in another condition in that experiment in which the prior presentation of SEED had no effect on the subsequent recognition of SEEN.* These and a variety of other results have been described in the framework of the logogen model (Morton, 1964, 1969, 1970, 1979). In the early versions of this model the logogen system was a set of categorizing elements (logogens) which received inputs from sensory and contextual sources. When any one logogen received more than a criterion amount of relevant information it sent an output to the cognitive system, where a semantic interpretation of the stimulus could be obtained, and to the response buffer, from which a response could be produced. Within this model the facilitation effects referred to above were attributed to the logogen system. The form of the model required that whenever a

* We choose to refer to this effect as morphological rather than 'semantic' for three reasons. Firstly, there have been no reports of semantic facilitation in perceptual experiments over the time intervals involved; secondly, pairs of words such as SEES and SEEN are not 'semantically' related by any of the usual measures (e.g. they very rarely occur as free associations); thirdly, the morphological relationships were predicted by Morton (1968) and use of the term is more economical. Fourthly, in the auditory domains, an unpublished experiment by Kempley & Morton shows the usual transfer for regularly inflected words but no transfer at all for irregularly related words such as BRING–BROUGHT and MAN–MEN for which the semantic relationships are equivalent.

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logogen 'fired' there would be subsequent facilitation of the appropriate word. The same effect should be found irrespective of the source of the information which led to the response. However, an experiment by Winnick & Daniel (1970, Expt 2) showed this not to be the case. These authors presented words, pictures and definitions in the pretraining phase and found that only prior experience with words had any subsequent facilitation effect on the recognition of words. Thus, if a subject had seen and named the picture of a butterfly in the pretraining session, there was no facilitation of recognition of the word BUTTERFLY in the test phase. This experiment was replicated by Clarke & Morton (in preparation) who also showed that if subjects heard a particular spoken word in the pretraining there was no significant effect on the subsequent visual recognition of the same word. Jackson & Morton (in preparation) demonstrated the converse; that visual pretraining had little effect upon the subsequent recognition of spoken words presented in a mask of white noise. This result has been replicated by Gipson (in preparation) who showed that under the right conditions there was no cross-modal transfer whatsoever. These results meant that the original model had to be changed such that the original logogen system had to be split into three. The current version is shown in a simplified form in Fig. 1. The original single logogen system has been divided into three separate processes. There are two input logogen systems, one for each modality. These are responsible for the modality specific facilitation effects. The third system is the output lexicon system which is the source of the phonological code under all conditions. In the case that the subject names a picture, those processes responsible for picture recognition lead to information being sent to the output lexicon system without passing through the input systems. Thus there is no transfer from picture naming to word recognition. An expanded version of the model is given in Morton & Patterson (1980).

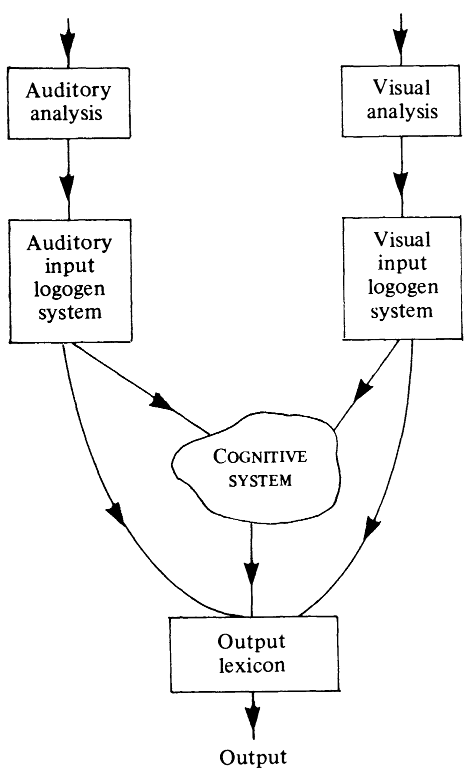

Figure 1. The current logogen model: A simplified version.

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It can be seen that the technique is a fruitful one for the partitioning of the processes involved in word recognition. The question then arises as to whether the processes involved in picture recognition can be partitioned in a similar way, and whether or not they can be affected by verbal stimuli. The nearest relevant work has used tasks such as naming and classification (e.g. Seymour, 1973; Potter, 1979). These will be described in detail in the discussion where the different tasks will be compared with each other. The present experiments use the technique of facilitation of recognition of a degraded stimulus. The first experiment is the reverse of the one by Winnick & Daniel (1970) described above. We were concerned to establish two points; firstly whether or not we could obtain facilitation of pictures under the conditions already described and secondly, whether there was transfer from word naming (i.e. reading out loud) to subsequent picture naming.

Experiment 1

The aim of the first experiment was to determine the conditions under which the recognition of a picture in a tachistoscope would be facilitated. The experiment involved presenting subjects with a sequence of mixed words and pictures which had to be named. These stimuli were presented clearly. Following this there was an unexpected free recall trial. In the final phase of the experiment subjects were required to identify pictures which were presented briefly, using the method of ascending limits. These pictures included some which had previously been named, some which had the same name as pictures previously seen and some whose names had previously been read.

Method

Materials. A set of 62 line drawings of animals or common objects selected from a variety of reading work books, were pasted onto cards and put through a screening procedure. From this were selected 16 which were given the same name by 10 pilot subjects and which had roughly the same visual recognition thresholds for a group of six pilot subjects. The latter procedure was simply an attempt to reduce the inter-item variance in the main experiment. The pictures finally selected were Jug, Bucket, Clock, Book, Horse, Dog, Mouse, Frog, Umbrella, Gate, Clown, Table, Tortoise, Hen, Monkey, Pram. These pictures, termed P_a, were to be used in the recognition phase of the experiment, as well as in the pretraining phase. There were in addition 16 other pictures of the same object types which also uniquely elicited the appropriate name. The latter set of pictures, termed P_b, were to be used only in the pretraining session. Examples of the pairs of pictures are shown in Fig. 2. A further 16 stimuli were prepared of the picture names which were typed singly in upper case on cards.

Design. There were four conditions in the experiment. These were defined by the pretraining experience which the subjects had had.

1. Same – where the pictures presented in the test phase, P_a pictures, were the same as those seen and named in the pretraining phase.
2. Sim – where the pictures seen in the pretraining phase, P_b, had the same name as those seen in the test phase.
3. Word – where the subjects had previously read aloud the typewritten name of the picture seen in the test phase.
4. Control – the control condition where there had been no relevant stimuli in the pretraining phase.

The pictures were divided up into four sets of four pictures. There were four groups of subjects and the picture sets were assigned to groups and conditions according to a Latin square design.

Procedure. Phase 1 – Pretraining. For each subject there were 12 stimuli in the pretraining phase: four words and eight pictures. Of the pictures, four were P_a (that is they would later be seen in the test phase) and four were P_b pictures. These 12 stimuli were presented in random order to subjects who had to name the pictures and read the words. Subjects were told that the experiment was concerned

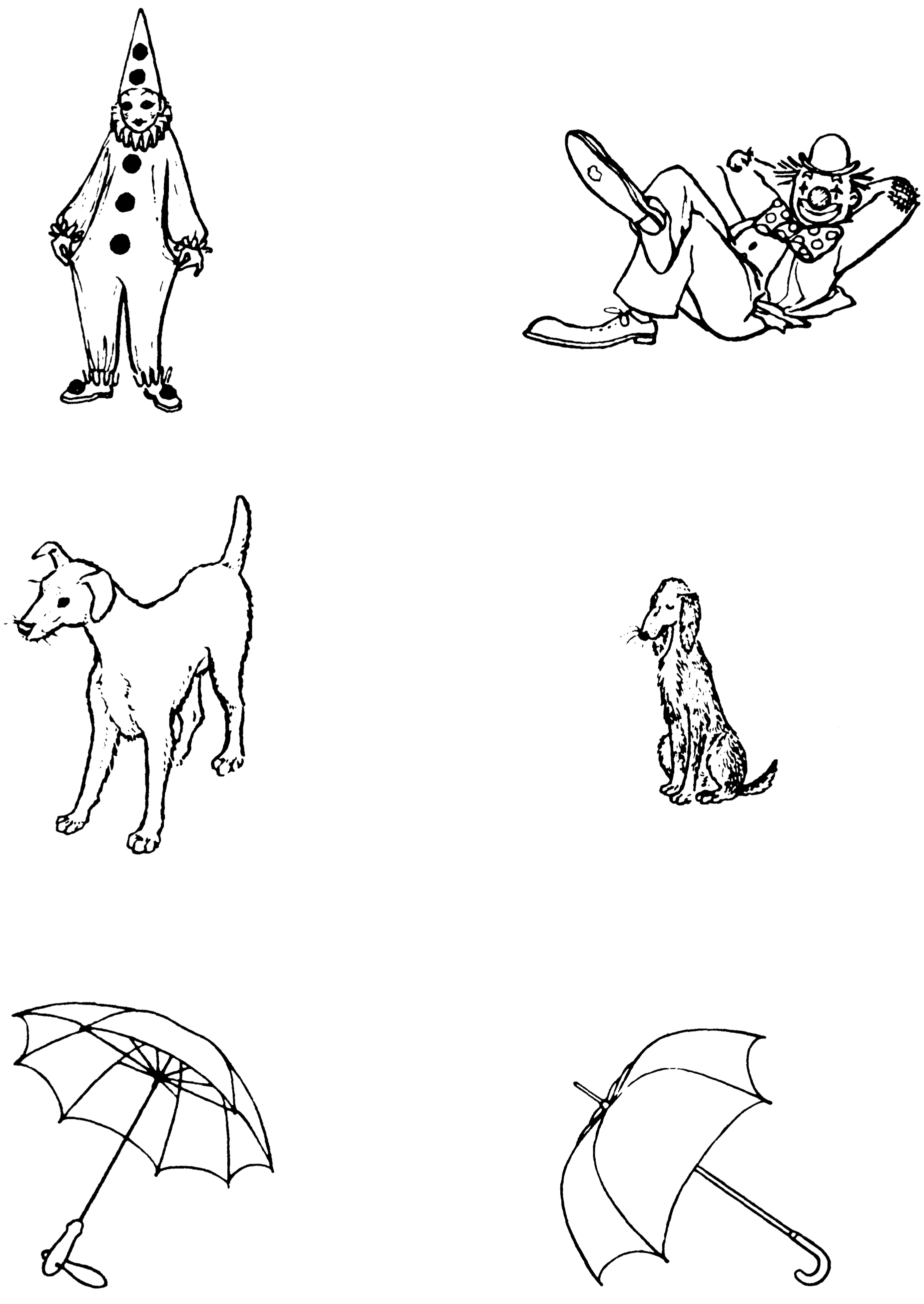

Figure 2. Examples of the picture stimuli used in Expt 1.

with speed of naming. The 12 stimuli were preceded by three filler pictures and followed by a further three filler pictures in order to minimize serial position effects on the experimental items in the recall phase which was to follow. The stimuli were presented to the subjects by flipping them over like playing cards. The stimuli were presented at about one every 2 seconds. Naming time was not in fact measured.

Phase 2 – Recall. After the last item in Phase 1 had been named, the subjects were asked to recall as many of the items as they could. Recall was spoken. No mention of this phase had previously been made to the subjects.

Phase 3 – Recognition. Stimuli were presented to the subjects in a two-field 'Cambridge' tachistoscope. There was a fixation field and a test field. The illumination in this tachistoscope could not be reduced sufficiently to give problems to our subjects at the lowest exposure duration. Thus the contrast was reduced by inserting filters in the eyepiece. Subjects were shown a number of pictures in the tachistoscope in order to accommodate them to the illumination and accustom them to the procedure. Pictures were then presented to them for recognition using the method of ascending limits. The initial exposure duration was 10 ms and exposure duration was increased in steps of 10 ms until the subject had made two consecutive correct responses. The exposure duration for the first of these responses was taken as the threshold. The exposures were triggered by a button held by the subject. The instructions included: 'I will say "Now" and you press the button, when you are ready, to flash a picture up in the machine. If you think you recognize the picture, say immediately what you think it is. If you have no idea what the picture was, say "No"... I will continue increasing the length of the flash until you recognize the picture correctly.'

There were four practice pictures before the experimental pictures were presented. The pictures were presented in the same order for all the subjects. The pictures were ordered such that each set of four successive pictures included one from each of the conditions. The experimental procedure meant that between 10 and 45 minutes elapsed between pretraining and test for all items.

Subjects. Sixteen male undergraduates were used as subjects. All had normal sight without glasses. Participation was on a voluntary basis, psychology students were excluded, and all were inexperienced in tachistoscopic recognition. There were four subjects assigned at random to the four groups.

Results

(*a*) *Recall.* The mean recall for the pictures was 3·81 out of 8; for words it was 2·68 out of 4. The probabilities were thus 0·48 for the pictures and 0·67 for the words. A two-tailed Wilcoxon test by subjects gave $T = 17$, d.f. = 14, $P < 0{\cdot}05$. In the Winnick & Daniel (1970) experiment, and in a replication by Clarke & Morton (in preparation) words were recalled less well than items which had been presented as pictures or definitions. The reversal of this in the present experiment can hardly be attributed to the depth, or other property of processing (Craik & Tulving, 1975) which could favour the words. A likely account is that the words were more discriminable in memory in some sense, owing to there having been half as many of them as pictures (cf. Jacoby & Craik, 1979). For our present purposes, however, it is sufficient that the recall experiment gives an advantage to words to contrast with the expected advantage of pictures in the recognition data.

(*b*) *Recognition.* The mean thresholds for recognition in the four conditions are given in Table 1. A two-factor mixed design analysis of variance was carried out with one between-subjects factor (item groups) and one within-subjects factor (conditions). This gave an F ratio for conditions of 6·46 (d.f. = 3, 36, $P < 0{\cdot}01$). There was no main effect of groups ($F < 1$) nor was there a significant interaction between conditions and groups ($F = 1{\cdot}99$, d.f. = 9, 36). A Neuman–Keuls test was applied to the condition means and the results of this are also given in Table 1. This analysis shows that the same condition is

Table 1. Mean recognition thresholds for P_a pictures in Expt 1

	Pretraining condition			
	Same	Sim	W	C
Threshold (ms):	35·7	40·9	43·6	43·8

From Neuman–Keuls analysis:
Same < Sim, $P < 0{\cdot}05$; Same < W, C, $P < 0{\cdot}01$.

significantly different from the sim condition at the 5 per cent level and different from the other two conditions at the 1 per cent level. The mean threshold in the sim condition was different from the means of the word and control conditions but the difference did not reach significance. The effect of word facilitation is unequivocal – there is no difference between the mean threshold in the word condition and that in the control condition. The status of the result with the sim condition is discussed below.

Discussion

The data show that pictures share with words the property that recognition is facilitated by prior presentation (cf. Clarke & Morton, in preparation). This effect appears to last over the whole time scale of the experiment, that is up to 45 min. This facilitation effect cannot be attributed to verbal response bias, since if you read a word such as CLOWN, subsequent recognition of the picture of a clown is unaffected. This happens in spite of the fact that the recall data showed that the words had been *recalled* better than the pretraining pictures. Note that we would not expect this latter result necessarily to hold if the subjects were encouraged or forced to guess or if some other manipulation were used. The important result from our point of view is that there is no *automatic* priming from word reading to picture recognition in our paradigm. Transfer between words and pictures has been found in other experimental paradigms (e.g. Guenther *et al.*, 1980). We will postpone a comparison of the different paradigms until the final discussion.

In the word condition the thresholds were the same as in the control condition. We can feel relatively confident in accepting this at face value. The position of the non-identical pictures is equivocal, however. There is no significant difference between this condition and the control condition. However, there is a numerical difference. One feature of the experiment led us to believe that subjects had been adopting a strategy which could have positively harmed recognition of the non-identical pictures. On questioning after the experiment, over half the subjects claimed to have been using some literal memories of the pretraining pictures. Thus, when seeing an indistinct fragment in the tachistoscope, subjects would consciously sort through the pictures they could remember from the pretraining session to see if they fitted the fragment. If a match was found the response would be made, and the remembered image would be used as a hypothesis for the following trial. We have no way of assessing the accuracy of these subjective reports *a posteriori*. However, if they are correct, then the procedure would impair recognition of the non-identical pictures for the following reason. Suppose a subject saw one clown in the pretraining session. He is then presented with the other clown picture in the test phase. In the course of trying to piece together fragments he might test his memory of the original clown picture against the fragments. Since these are unlikely to match (see Fig. 2), the hypothesis that the current stimulus is a clown would be rejected and a negative response bias of some sort could be set up.

Because of these possibilities we decided to redesign the experiment rather than carry out a replication of Expt 1. In this experiment we focused on investigating transfer between non-identical pictures of the same name and omitted the word pretraining condition.

What we were hoping for was to eliminate the 'active', hypothesis-testing approach by the subjects. If we succeeded we would be left with evidence for or against a passive or structural transfer between the sim pictures.

Experiment 2

The second experiment was designed with the aim of minimizing the possibility that subjects would use a conscious strategy of comparing fragments from the tachistoscopic image with remembered pictures from the pretraining. We argued that such a procedure would be likely to mask any facilitation effect in the sim condition. In Expt 2 the subjects would see 44 pictures in the pretraining, only 12 of which were relevant. We hoped that this, together with the five filler pictures with which the recognition test began, would deter the subjects from using such a strategy and thus allow the structural effects we were looking for to emerge cleanly.

Method

Materials. Some of the variance in the first experiment could be attributed to pictures being particularly easy to see or particularly difficult to see. This happened in spite of our precautions. Thus, for the second experiment we rejected those pictures used in the first experiment on which the control scores were too high or too low and selected others. There were 18 pictures in the experimental design: Clock, Monkey, Bell, Pig, Bus, Rabbit, Clown, Frog, Cow, Umbrella, Goat, Gate, Mouse, Tortoise, Kettle, Hen, Pram, Dog. In all cases there were two pictures associated with these names. The two sets were termed P_a and P_b, as in Expt 1. The P_a set were the ones used in the recognition phase of the experiment. The pictures were divided into three sets of six pictures each. There were three groups of subjects and the picture sets were assigned to groups and conditions according to a Latin square design.

Procedure. Phase 1 – Pretraining. Each subject saw 12 significant pictures in the pretraining phase; six P_a pictures for the same condition and six P_b pictures for the sim condition. In addition they saw 32 other pictures which served as fillers. The order of presentation of these pictures was: five dummies, P_a, two dummies, P_b, two dummies, P_a,..., etc., ending with a further five dummies. The P_a and P_b pictures were randomly ordered within the sets. As in Expt 1 the subjects were asked to name the pictures as quickly as possible.

Phase 2 – Recall. This was unannounced, as in Expt 1. The data were not scored, but the recall phase served to put distance between the pretraining and the test phase.

Phase 3 – Recognition. This was tested in the same way as in Expt 1. The 18 test pictures were preceded by five filler items which served as practice for the subjects.

Results

In this experiment the recall data were not of interest and they were not scored. The mean visual duration thresholds in the three conditions were: same, 35·8 ms; sim, 39·4 ms; and control, 42·8 ms. A two-factor mixed design analysis of variance was carried out as with Expt 1. This gave an F ratio for the main effect of conditions of 12·11 (d.f. = 2, 3, $P < 0{\cdot}01$). The main effect of groups was not significant ($F = 1{\cdot}94$, d.f. = 2, 15) neither was the interaction between groups and conditions ($F < 1$). A Neuman–Keuls test was carried out on the means. The results are shown in Table 2. The same condition is again significantly different from the sim condition at the 5 per cent level and from the control condition at the 1 per cent level. This time, however, the sim condition is significantly different from the control condition at the 5 per cent level. Numerically there is not much difference between the mean thresholds in the three conditions between the two experiments. However, the MS error term is less than half in Expt 2 (17·97 vs. 38·76). We can thus conclude that our manipulation has been successful, and that the subjects were

Table 2. Mean recognition thresholds for P_a pictures in Expt 2

	Pretraining condition		
	Same	Sim	C
Threshold (ms)	35·8	39·4	43·2

From Neuman–Keuls analysis:
Same < C, $P < 0{\cdot}01$; Same < Sim and Sim < C, $P < 0{\cdot}05$.

using a passive strategy. Under these conditions we can be satisfied that there is transfer from the prior presentation of a picture to the recognition of that picture in a tachistoscope up to 45 min later.

Discussion

Both experiments have shown facilitation effects in picture recognition in the case where the subject has prior experience of the stimulus picture. In addition we could find no effect whatsoever of the picture named by the word. Thus we can say two things with confidence.

(1) There is some property of the processes involved in picture identification which leads to the facilitation effect.

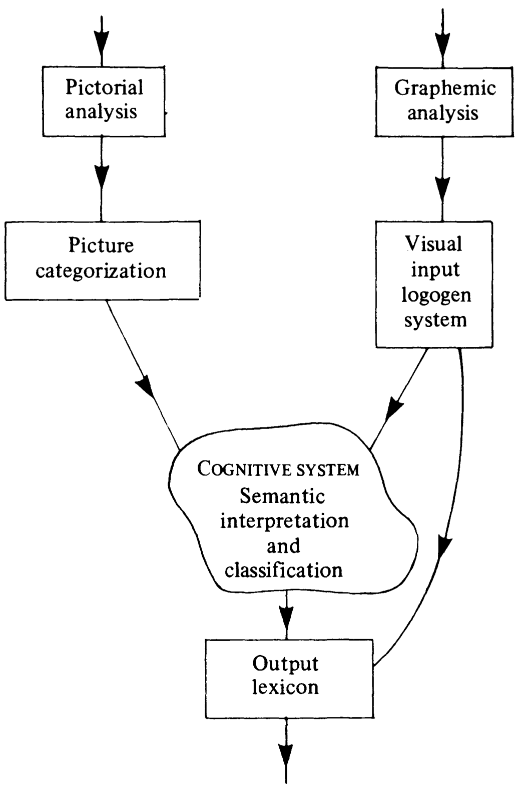

Figure 3. A form of the logogen model which includes picture processing.

(2) The processes responsible are not used when words are read aloud. The simplest possible information-processing model of the processes required to account for these data is shown in Fig. 3. This is an extension of Fig. 1 to include the processing of pictures. In the figure the auditory systems have been omitted for simplicity. The preliminary analysis of written words has been termed graphemic analysis (after Seymour, 1973) to distinguish it from the pictorial analysis required for picture recognition. We have also added a connection from the visual input logogen system to the output lexicon. This is to represent the possibility of reading words aloud without the involvement of any semantic representations. Evidence concerning the existence of this route can be found in Morton & Patterson (1980). Other evidence is described below.

We have termed the second stage in picture identification the picture categorizer.* The output from this goes to the cognitive system to permit an interpretation of the picture. We have not put another output directly from the picture categorizer to the output lexicon. Such an output would match the direct route between the visual input logogens and the output lexicon. It is clearly a theoretical possibility but there is no evidence that it exists. Some evidence against this route will be discussed later when we consider other relevant data.

For the moment let us simply consider the data we have already described. The account of the data on the facilitation of word recognition remains the same. The site of the facilitation is the input logogen system. This system is unaffected by the recognition and naming of pictures no matter by which route the latter is achieved. In the identification of pictures the first stage is the analysis of the relevant features. This may or may not share in the processes involved in graphic analysis, beyond, of course, some of the very early processing which must be in common for all visual stimuli. On can imagine that the output of the picture analysis consists of information relating to the presence of such features as legs (of furniture or animals) or ears. The precise details do not affect any of the arguments which follow. This stage is distinguished from the system which is responsible for the categorization of pictures. This is also seen as separate from processes concerned with the extraction of meaning inasmuch as these are shared with verbal stimuli. We leave open for the moment discussion as to whether there is a separable process responsible for the extraction of meaning from pictures alone. If this were to be necessary it would be inserted between picture categorization and the cognitive system.

The separation of picture processing and word processing is justified by a variety of data. To start with we can note that Oldfield & Wingfield (1965) showed that the time to name a picture was inversely related to the logarithm of the frequency of usage of the object's name. This was unlikely to be directly caused by the name itself since the effect was considerably greater than any effects which could be found for the words themselves. Thus we can presume that the effects are related to the frequency of recognition of the objects themselves. Fraisse (1964) had reported similar results for the naming of geometrical shapes, where there was a correlation of 0·73 between the naming times and an index of familiarity. Fraisse also showed that the times for naming pictures, geometrical shapes and colours were consistently longer than the times taken to read the printed names of the stimuli. Furthermore he showed that the size of the difference depended simply on the size of the ensemble from which the stimuli were selected. For an ensemble of only two stimuli there were no reliable differences between the naming times and the reading times. As the number of alternatives increased then the time for naming increased while the time of reading remained constant.

Our data show that there is facilitation between pictures which are different but which have the same name. Since there is no facilitation arising from the prior presentation of the name itself we have to assume that there is a means of categorizing pictures in which all pictures with the same name share a common fate. For this we postulate a set of units which correspond to object types much as logogens correspond to word types – in that

* We have used the word 'categorizer' here knowing that it might lead to some confusion. The term categorization has been used interchangeably with the term classification to refer to the *task* of assigning a superordinate class to a stimulus, word or picture, or in making a decision as to whether an object belongs to a pre-specified class. Our use of categorizer follows that of Crowder & Morton (1969) who used it to refer to the result of the operation of the logogen system. This operation led the change from a visual or auditorily based code to a lexical code. We are at a loss to know what other term to use for this and similar operations. 'Identify' most strongly suggests a response – and we wish to make a clear distinction between categorization with and without responses – even internalized responses. Thus, in word recognition it is now clear that a word can have semantic facilitation effects without the subject being aware that the stimulus was even present (Marcel, in press). This could only come about if a lexical representation had been achieved, that is, that the stimulus had been categorized. We hope that the context of the usage will prevent misunderstanding.

printed and written words equally facilitate a printed word (Clarke & Morton, in preparation). Seymour (1973) has termed the equivalent unit for pictures a pictogen. The hypothesis is, then, that the same pictogen is active in recognizing all clocks, for example, and that it is in the activity of the pictogen that the facilitation effects are to be located.

We now have to account for the fact that there is a greater facilitation for the identical picture than for a different picture with the same name. Since we cannot imagine that there existed prior to the experiments a representation of all the pictures we were about to present, we must find some other account for this effect. There seem to be two possibilities. By one of these there would be a 'literal' representation formed in memory of the pictures which had been presented. This pictorial memory would then have to be accessed either directly from the pictorial analysis or secondarily via the pictogen system. There are a number of ways in which such operations could be performed, each with their consequences in predicting the fine grain of the data. However, exactly which method is used does not affect the present discussion. This general class of explanation contrasts with a second one which would locate the specific effects in the processes of pictorial analysis. Let us examine this possibility in more detail.

We can regard the pictorial analysis as involving a number of subunits which respond to specific aspects of pictures. With two pictures of dogs there would be different sets of features which would be detected. With one picture there might be four erect legs visible together with a tail erect and a head in profile. With the other there might be a pair of legs erect, the dog sitting, and a tail at rest. In the two pictures of dogs shown in Fig. 2 we find these differences and others. It is possible, then, that the feature recognizers show effects of having been active in the same way that the pictogens and logogens are supposed to do. The recognition of the same picture would then be facilitated by use of exactly the same set of feature analysers which would then require less stimulus information to respond again. Note that here we also have a possible account of the partial facilitation of the sim pictures. The recognition of these pictures, on this account, would be facilitated to the extent that there was a feature overlap between the two pictures. There is a possible test of this in our data. The pictures were not selected with any such test in mind so the test is far from ideal. However, the design of the experiment permits us to take the pairs of pictures and compare them for transfer in the sim condition. The test involves looking first at the mean duration threshold for the pictures in the control condition. Each set was seen in this condition by one group of subjects. We can then subtract from these values the performance on the pictures in the sim condition. These values are not direct estimates of the transfer since different groups of subjects are involved in the two conditions. Since there was no interaction between subject groups and conditions in the analysis of variance, however, we can assume an additive model for the data and get a direct estimate of transfer by adjusting for the group means. Thus suppose picture P^n was assigned to subject group 1 in the control condition and to group 2 in the sim condition. The mean thresholds in these conditions we can call $P^n_{\mathrm{e:1}}$ and $P^n_{\mathrm{sum:2}}$. If the group means are G_1 and G_2 then the estimate of transfer would be $T(P^n) = (P^n_{\mathrm{c:1}} - P^n_{\mathrm{sim:2}}) - (G_1 - G_2)$. These were computed for all the pictures.

The next stage was to order the picture pairs in terms of their similarity. Owing to administrative problems three of the pairs of pictures were not available. The remaining 15 pairs were presented to 20 subjects with instructions to order them in terms of their 'visual similarity'. The resulting rank orders were averaged. These showed reasonable discrimination among the pictures with the lowest mean rank being 2·90 (the umbrellas) and the highest 13·15 (the clowns). A Pearson product moment correlation was then performed between the estimated transfer effects and the mean rankings. This gave $r = 0{\cdot}082$. A Spearman rank-order correlation between the variables gave $r_s = 0{\cdot}096$.

The data thus suggest that there is no similarity effect governing the transfer in the sim condition. The transfer between the two clown pictures, very different from each other, was, in fact, greater than the transfer between the two umbrella pictures, which are vastly more similar (cf. Fig. 2). From this, albeit imperfect, test we tentatively conclude that there is a negligible facilitation effect to be attributed to the feature analysers. Our preferred account is that there are two sources of facilitation, one due to a literal representation of the presented pictures and one due to some generic pictogen system within which there are units which respond to pictures of the same name. Any expansion of the picture categorization system would have to include both of these processes. Note that Sperber *et al.* (1980) propose (albeit without any direct evidence) that facilitation effects occur between pictures as a function of feature overlap. In the relevant experiment, however, the stimuli were presented simultaneously. We would see no conflict between finding a result under these conditions and not finding it with time delays of 10–45 min with the same stimuli. Such a pair of results would simply point to the particular properties of the feature analysers which we should not expect to correspond to those of the picture categorizers.

We can now consider the relationship between our data and those found in other paradigms and interpret these in terms of the model in Fig. 3. First of all a number of investigators have shown that it takes less time to read a word than it does to name a picture. In addition it has been shown that it takes *less* time to judge the superordinate category of a picture than it does for a word. In an experiment by Potter & Faulconer (1975) it was found that with a set of 96 items it took 260 ms longer to name drawings than words, but 50 ms less time to decide whether the referent of a drawing was living or not than to judge the equivalent word. Results such as these guarantee that the interpretation of pictures does not depend upon their prior naming (cf. Rosch *et al.*, 1976). In terms of the model in Fig. 3, this means that we are justified in connecting directly the picture recognition system and the cognitive system.

In Expt 1 we found no cross-facilitation between words and pictures. This parallels the lack of facilitation from pictures to words reported by Winnick & Daniel (1970) and by Clarke & Morton (in preparation, pilot experiment). Some recent studies have reported cross-facilitation between words and pictures (e.g. Durso & Johnson, 1979; Guenther *et al.*, 1980). There are two reasons for the apparent discrepancy; these are the nature of the task and the time intervals concerned. The work showing cross-facilitation typically uses time intervals of a few seconds between successive stimuli, and at the most an interval of a minute and a half. In addition the tasks are those of classification or naming in which the stimuli are clearly presented. In such cases we suppose the processing limitation to be central rather than in the categorization systems. That is, where the stimulus is presented clearly the process of picture categorization operates smoothly under all conditions. Picture and word processing intersect in the cognitive system where the burden of the classification and naming tasks takes place. It is these processes, then, which are the limiting factor in those tasks which report cross-facilitation from words to pictures. A full discussion of such topics is beyond the scope of this paper but there seems to us to be no in principle difficulty in accepting that there is cross-facilitation in processes involving the cognitive system without there being cross-facilitation in the categorizing systems.

One finding of Durso & Johnson (1979) is of relevance. One of their conditions involved subjects naming a sequence of pictures and words. Items were repeated on occasions and the facilitative effect of this could be calculated. Among other things they found that there was considerable facilitation on picture naming given prior presentation and naming of the equivalent word. However, there was virtually no advantage to word naming following presentation of the picture. We see this as supporting the idea that words are read aloud via a direct connection between input and output lexicon. At the same time they are automatically subject to semantic analysis but such cognitive processing would not affect naming times. In contrast, when pictures are named, these central processes are involved in the naming itself. In this way the asymmetry in the effects can be accounted for. If we had a direct connection between the picture categorization system and the output lexicon and if this connection operated more rapidly than the indirect connection via the cognitive system we could not account for the data. Note that the same authors found relatively symmetrical effects between pictures and words in a semantic classification task. In this case both kinds of stimuli would be processed centrally.

Our proposals concerning the direct links from categorization processes to the output lexicon have some support from studies of brain-damaged patients.* Thus Schwartz *et al.* (1980) describe a patient, W.L.P., who could read single words aloud almost perfectly. On a semantic classification task, however, her performance was poor, failing to classify such words as 'bear', 'bee', 'eagle', 'elephant' and 'owl' as *animals* where the alternative classifications were *body parts* and *colours*. They interpret their findings as indicating a major breakdown of the cognitive processes in this patient. The reading performance, then, supports the idea of a direct connection between input and output lexicons, particularly since the patient managed to read correctly almost three-quarters of the irregular words she was presented with. Thus her reading success cannot be attributed to use of any grapheme–phoneme rule system which was independent of lexical information. If there existed direct input–output connections for pictures one would expect to find brain-damaged patients who could name pictures without understanding them. We have not been able to find reports of such patients in the neuropsychological literature. Such negative evidence is weak and presents a clear challenge to other researchers. For the moment, however, we feel secure in claiming that there exists no direct input–output connection for pictures or that, if it exists, it is slow in action and limited in scope.

The literature, then, gives us support in our conclusion that there is a picture categorization system which is unaffected by verbal stimuli and in which there are long-term effects of use which reveal themselves in facilitation of recognition. While equivalent systems have been postulated by other authors (e.g. Potter, 1979) on more or less logical grounds, there have not been many formal demonstrations of its separate existence. It is likely that its functioning can be affected by context (e.g. Palmer, 1975) but beyond that we know nothing of its structure. Long-term facilitation is a tool which can be used for such inquiries.

Finally we should acknowledge the link between our thinking and that of Seymour who has developed models of the relation between pictorial and verbal systems over a number of years. His most recent development (Seymour, 1979) contains a function termed the pictorial interface. The model deals extensively with pictorial memory, and Seymour has amassed a body of evidence from a variety of tasks in support of a separation of pictorial and verbal systems. We see this work as complementary to our own and the combination of different kinds of evidence as testimony of the power of converging operations in the establishing of cognitive theory.

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Requests for reprints should be addressed to John Morton, MRC Applied Psychology Unit, 15 Chaucer Road, Cambridge CB2 2EF, UK.
Clive Warren is also at the above address.