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PICTORIAL AND VERBAL ENCODING IN SHORT-TERM MEMORY

by

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ABSTRACT

PICTORIAL AND VERBAL ENCODING IN SHORT-TERM MEMORY

by Barbara Adele Gans Tversky

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Encoding into memory occurs when information is abstracted from or added to incoming information, or when incoming information is regrouped for memory storage. Experimental evidence for encoding processes comes from systematic errors of recall and correlations of amount recalled with hypothesized encoding strategies. Rate of presentation, modality of input, type of material, prior training, and anticipated use of the information seem to influence encoding strategy.

The present research attempted to manipulate the encoding modality of pictorial and verbal material by manipulating Ss' expectations of the way the material was to be used. Stimuli were schematic faces with well-learned names, constructed so that pictorial similarity correlated negatively with verbal similarity. It was hypothesized that Ss would perform more accurately and faster when the encoding modality was the same as the response modality, irrespective of stimulus modality. Encoding modality was expected to be revealed in type of errors and relative speed of processing certain kinds of information.

In the first experiment, eight faces were presented on each trial, after which one was cued. The S then tried to select that one from a set of all faces or all names. Since a common error is substitution of a similar response for the correct response, pictorially similar errors were expected where pictorial encoding was expected, that is, where S knew he was to select the correct stimulus from a set of faces. Likewise, with selection from a set of names, verbal encoding, and, therefore, errors of verbal similarity were expected. The data of two Ss supported this hypothesis, while the data of the other two Ss indicated pictorial encoding irrespective of selection from names or faces.

In the second experiment, a single name or face was presented, followed by another one; the S was asked to respond "same" if the stimuli had the same name, and "different" otherwise. The majority of second stimuli of any session were either faces or names. It was hypothesized that if S had encoded the first stimulus in the modality of the second, his judgment should be faster than if he had not appropriately encoded the first stimulus. Thus, slower reaction times were expected to stimulus pairs where the second-stimulus modality was infrequent. This result was obtained for all eight Ss. Further evidence that encoding of the first stimulus was in the frequent second-stimulus modality comes from the finding that "different" responses were shorter when the stimuli differed on more than one attribute in the encoding (second-stimulus) modality, regardless of the modality of the first stimulus, or the particular modality of the second stimulus.

Despite the generality of pictorial and verbal encoding across Ss, individual differences were evidenced in speed of response to particular modalities of first and/or second stimuli.

The finding that "same" responses were faster than "different" responses, in addition to the finding that "different" responses were slower when the stimuli shared all but one attribute along the encoding modality can be accounted for by assuming that stimuli are first tested for "same," and if this test is failed, the locus of difference is sought, or by assuming that the failure of "same" is sufficient for the acceptance of "different" but that the latter response is biased to take longer.

Thus, evidence is presented that not only can verbal material be pictorially encoded, but that whether both verbal and pictorial material is verbally or pictorially encoded depends on the S's anticipation of what he is to do with the material.

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CHAPTER I

ENCODING PROCESSES IN MEMORY

The processes occurring after a stimulus has been attended to and recognized and prior to storage in memory have been referred to variously as: coding, encoding, recoding, selection, organization, tagging, grouping, and so on. Three logically distinguishable processes are encompassed by these terms: the subject may abstract information from the stimulus, committing only a part of it to memory; the subject may add information from long term memory to the stimulus, storing that in addition to or instead of the stimulus; the subject may group several stimuli together, forming, in effect, a new stimulus which may be operated upon just as the original stimulus is. All, some, or conceivably none, of these processes may occur.

That these encoding processes do occur is supported by increasing evidence and is increasingly incorporated into theoretical formulations. Underwood (1963) distinguishes between the nominal stimulus, that which the experimenter presents to the subject, and the functional stimulus, those "characteristics of the stimulus which S actually uses to cue a response" (p. 33). He reviews a number of experiments, mainly using paired-associates, presenting evidence that when the nominal stimulus is a compound, the subject selects a component of it, usually the more meaningful part, in order to cue the response.

Addition of information to the stimulus has been used to explain acoustic confusions in written recall of visually presented consonants (Conrad, 1964) as well as differential recall of dichotically presented verbal

material (Yntema & Trask, 1963). It has been proposed that the visually presented consonants are subvocally rehearsed, and thereby acoustically encoded and stored. In the case of dichotic listening, it is contended that the verbal material is "tagged" as to type, say word or digit, channel, say left or right ear, as well as to order of presentation, and that these tags or additions to the stimuli aid in retrieval. Similarly, in the recall of visual figures, it is proposed that the figures are implicitly named, and that the labels are stored in memory (Glanzer & Clark, 1963a, b).

The third type of encoding process has been used to explain increases in recall above the memory span, which is about seven items. Subjects are presumed to group or "chunk" input items. The chunks, each of which represents several items, are stored in memory instead of the items so that a long list of items can be reproduced from a smaller number of chunks. Miller (1956a, b) has referred to this process as chunking or recoding; Tulving (1962), as subjective organization. Chunking may occur by explicit rules, as when a string of binary digits is recoded to octal digits (Miller, 1956b) or a nonsense trigram is reordered to form a word (Underwood & Keppel, 1963); by a category name or common associate, as in the clustered recall of randomly ordered lists of words from several categories (Cofer, 1966; Cohen, 1966); by idiosyncratic grouping, as in the increasing sequential redundancy of output over trials in the recall of unrelated uncommon nouns (Tulving, 1962, 1966).

The theoretical formulation which encompasses all of the encoding processes discussed is that of Lawrence (1963). He asserts that all stimulus-response correlations are mediated by a coding operation, which assigns a label to each of a set of (stimulus) objects or events. The

coding operation, in interaction with the sensory input, produces a new event or code item which represents the stimulus, the "stimulus-as-coded" or "s-a-c." It is the s-a-c which is associated with and elicits overt behavior, or in our terms, which is stored in memory.

Evidence of two types for encoding processes in memory will be considered: evidence from types of errors in memory and evidence from experiments comparing the amount retained with the hypothesized encoding modality. Then the various acoustic and verbal theories of encoding which have been proposed will be entertained, followed by a discussion of studies of retention of non-verbal material, the results of some of which do not conform well to the verbal theories of encoding. Concluding the introduction will be a discussion of the variables affecting the type of code subjects use to store information in memory, along with directions for research in this area.

Evidence for Encoding Processes

Errors

According to most theories of memory, errors are not viewed as random occurrences solely dependent on passage of time. More errors are likely to occur when the to-be-remembered material is similar, and errors are likely to take the form of intrusions from similar stimuli. Similarity, in turn, depends on encoding; the same two stimuli may be similar or different, depending on the way in which they are stored in memory. Consider the following words:

though through threw

If they are encoded "visually," according to their spellings, then the first two words are the most similar pair, and should be most often confused;

if they are encoded "acoustically," according to their sounds, the majority of confusions should occur between the last two words. Likewise, if many stimuli are encoded similarly, there should be more forgetting. With visual encoding, learning a list of words like the first two words should be more difficult than learning a list of words like the last two words. With acoustic encoding, the results should be reversed. Thus, both the type of error and the relative frequency of error are clues to subjects' encoding modalities.

Serial position errors.--One common error in the learning of lists of digits, words or nonsense syllables is an intrusion based on serial position. Given that an item is not correctly recalled, a very probable substitution is the item in the same position in the just-preceding list (Conrad, 1959, 1960; Peterson & Gentile, 1965; Noyd, 1965). That the item and its serial position are encoded separately to some degree is evidenced by serial position intrusions, in which the position may be recalled while the item is forgotten, and by transposition errors, also commonly found (Conrad, 1959), in which the item may be recalled while its position is confused with that of the adjacent item. Studies of transfer from paired-associate lists to serial lists (Underwood, 1963) indicate that reinstatement of the verbal context may not be sufficient for recall of the item. Serial position recall of some sort also seems necessary, again attesting to at least partially independent encoding of serial position.

Acoustic confusions.--A type of error frequently observed in studies of short-term memory is based on acoustic confusion. Conrad (1964) found that intrusions in the recall of strings of consonants correlated highly

with listening errors for consonants embedded in noise. This result has been replicated with letters (Conrad, 1967; Conrad, Freeman & Hull, 1965) and vowels (Wickelgren, 1965c), with written recall (Wickelgren, 1965a), with visual presentation and with visual presentation in the presence of a masking noise (Hintzman, 1965), revealing considerable generality for encoding in this modality. Just as errors of acoustic confusion indicate acoustic encoding, so does greater difficulty of recall of lists of acoustically similar items. Lower recall of highly acoustically confusing lists has been found with consonants (Conrad, Baddeley & Hull, 1966; Conrad & Hull, 1964; Wickelgren, 1965d) and with words (Baddeley, 1964, 1966a, b; Conrad, 1963; Dale & Gregory, 1966; Goggin & Melton, 1966), with recognition (Wickelgren, 1966c) as well as with recall. When acoustically similar items precede (Wickelgren, 1966b) or follow (Wickelgren, 1965b) the to-be-remembered items, recall is lower than if the proactive and retroactive items were acoustically different.

Semantic similarity.--Although not as thoroughly investigated, changes in semantic similarity seem to affect memory in much the same way as changes in acoustic similarity, indicating that subjects also encode according to word meanings. Several experimenters have found (Baddeley, 1964, 1966a; Dale & Gregory, 1966; Goggin & Melton, 1966) depressed recall of lists of semantically similar words as compared with lists of semantically different words. There has been some dispute as to whether semantic effects are as great as acoustic effects in short-term memory, and some rather weak evidence that acoustic effects are greater at short rather than long retention intervals (Baddeley, 1966b; Conrad, 1967) while semantic effects are stronger at longer intervals (Baddeley, 1966b). Such assertions are quite difficult to support because there is no way at present of knowing whether one pair of words is more acoustically similar than

another pair is semantically similar, nor have the same procedures with the proper lists been carried out with both long and short retention intervals. In any case, it seems clear from the study of errors in memory that items may be encoded into storage on the basis of serial position, sound, and meaning.

Type of Code and Recall

If subjects put material into storage according to specific codes, then material more readily encoded should be easier to recall. Conversely, a correlation between recall and some aspect of a hypothesized encoding mode or strategy lends support to the validity of that strategy. Several experimenters have hypothesized encoding or strategies, and have looked for evidence of these in memory tasks.

Codability.--The first group of studies propose that memory for perceptual stimuli is predicted by some index, primarily verbal, of the codability of the stimuli. Brown and Lenneberg (1954) devised an index of "codability" of colors, the factor emerging from a factor analysis of length of color name, latency of naming, intrapersonal and interpersonal reliability of names. Intersubject agreement had the highest factor loading. Codability was then successfully used to predict recognition accuracy and recognition memory for colors. Van de Geer (1960) was able to account for recognition memory for colors from a similar "identificability" (sic) index which was based on the latency of color naming, the number of different color names used by subjects, and the number of subjects using the most frequent name. Using an identificability index for photographs of facial expressions, van de Geer and Fridja (1960) were able to predict recognition memory for the photographs of faces. These studies, as well

as that of Brown and Lenneberg, have attempted to show that stimuli which are easier to encode are easier to remember and that codability is related to linguistic factors. Glanzer and Clark (1963a, b) found that the brevity of verbal descriptions of stimuli correlated highly with reproductive recall of arrays of simple figures which could be black or white (1963a) and of strings of binary digits (1963b). The authors propose that perceptual stimuli are encoded as their verbal descriptions and that just as short strings of words are better remembered than long strings, so stimuli with short verbal labels are better remembered than those with long descriptions. Lantz and Stefflre (1964) were able to account for recognition memory for colors by their index of communication accuracy. Communication accuracy is the mean error score for each color between a group of encoders, who described the colors, and a group of decoders, who tried to pick the color corresponding to the description from a set of colors. Furthermore, this measure better accounted for color memory than either Brown and Lenneberg's codability or Glanzer and Clark's verbal brevity. Lantz and Stefflre maintain that a subject describes to-be-remembered stimuli to himself in the same way as he would to others, and that stimuli eliciting verbal descriptions which allow accurate decoding to the original stimuli are more likely to be remembered.

Verbal recoding.--The next group of experiments demonstrate increased recall of nonsense syllabels when verbal recoding is encouraged. Underwood and Keppel (1963) tested recall of trigrams which could be reordered to form words. When free (unordered) recall of the letters within the trigrams was permitted, subjects informed of the recoding possibility recalled better than those who were not informed. The reverse was true, however, when recall of the letters of the trigrams in correct order was required. Apparently, it was more difficult to remember the recoded word along with

a decoding rule than just to remember the trigram. Lindley (1963) found better recall of low-meaningful trigrams when they were presented with recoding cues, that is, embedded in words (e.g., XPO presented as eXPOse), and still better recalled when decoding cues, the verbal context (e.g., e___se), were presented at recall. For high-meaningful trigrams, themselves familiar words, recoding cues at presentation hindered recall. Presentation of a trigram with an associate also facilitated recall (Schaub & Lindley, 1964; Lindley & Nedler, 1965), presumably because the associate provided a cue for encoding the trigram. Interestingly, requiring recall of both the trigrams and their associates did not decrease recall of the trigrams, as if the associates had been stored along with the trigrams anyway.

Tagging.--Yntema and Trask (1963) suggest that items are stored in memory with tags, which are used by a processor in retrieval. Thus, the item "elephant" might be tagged as an animal, as beginning with the letter e, and so on. This notion is demonstrated in a dichotic listening experiment, in which the subject is presented with different information simultaneously to both ears. Broadbent (1958) originally discovered that with simultaneous presentation of digit pairs, subjects preferred to recall the digits presented to one ear first, followed by the digits presented to the other. In fact, subjects performed better this way than when pair after pair recall was required. Gray and Wedderburn (1960) later found that when syllables forming words or words forming phrases were presented alternately to each ear, and simultaneously with digits to the other ear, free recall grouped by word(s) and digits was superior to free recall grouped by input channel (ear). They asserted that recall by channel is

an optional tactic used in recall which could be ignored, and another tactic employed, when the stimuli could be grouped by meaning. Similarly, Yntema and Trask presented three digit-word pairs dichotically, where the stimuli of one type could be presented to the same ear or could alternate ears once or twice. Subjects who were required to recall by stimulus type performed better than those required to recall by input channel, who, in turn, recalled better than those required to recall by pair. It seems likely that recall by pair could be similarly improved by making the pairs meaningful units, such as first and last names of famous people. To explain preferences and differential performance in the dichotic listening situation, Yntema and Trask propose that the incoming stimuli may be tagged or encoded as to input channel and order, as well as to category or type, and that any of these tags may be used for retrieval, some more successfully than others.

Wickens, Born and Allen (1963) have found evidence for tagging by digits or consonants with the same input channel. When a short string of, say, digits is presented for recall, recall is fairly high after a short interval, say 10 sec. On successive trials with similar items at the same retention interval, recall becomes progressively worse, presumably from proactive inhibition from previous items (Keppel & Underwood, 1962). If the type of material is altered, however, the stimuli can be encoded differently, and release from proactive inhibition is expected. Such a release has been found when three-item strings of digits are switched for strings of consonants and vice versa (Wickens, et al., 1963) as well as when categories of word triads are changed (Loess, 1967), implicating vocabulary type (e.g., digits or consonants) and category as bases for encoding in memory.

Clustering.--The free recall situation has been used to study organization in recall. The subject is allowed to recall a list of items in any order, and his order of recall is taken to reflect his organization or encoding of the stimuli. When a randomized list of nouns, each of which belongs to one of four or so categories, is presented, subjects group or cluster the items in recall according to categories (Bousfield, 1953). When a randomized list of pairs of free-associates is presented, the subjects' recall is grouped by free associate pairs (Jenkins & Russell, 1952). Items in free recall may also be clustered by the categories of associated responses (Cofer, 1965) as well as by degree of learning (Battig, 1966). It seems that subjects will use any available cue to organize the list of items to be recalled. Indeed, Tulving (1962), using the free recall paradigm, has found evidence, in the form of increasing sequential dependencies of recall order over trials, for "subjective organization" of unrelated, uncommon nouns. Even when encoding cues are deliberately not presented, subjects seems to invent them to facilitate storage and retrieval.

Cohen (1966) has cited evidence for what he refers to as "some or none" characteristics of coding behavior. Given that one item from a category is recalled, some items from that category are recalled, the "some" being relatively invariant over list length (35-70 items), rate of presentation (2, 4 or 6 seconds per item), serial position of items, and size of category (2 to 5 items). Similarly, Tulving and Pearlstone (1966) found that although the mean number of words recalled was higher when recall was cued by category names, the mean recall per category remained the same. They inferred that retrieval from memory of the chunks,

or higher level subjective units, is a separate process from retrieval of the items within the chunks. It is then natural to ask what is the number of chunks or categories or the number of items per chunk which will optimize retention. Clearly, each number is optimal in the intermediate of the range possible for a given length list. A list where all the items belong to one category is in a sense equivalent to a list where each item is in a different category; recall should be worst at these points. Several experiments by Dallett (1964) indicate that the optimal number of categories for a given size list is intermediate. For a list of 12 items, recall seems best with four categories, whereas with a list of 24 items, maximal recall seems to be obtained with eight or more categories. Thus, it seems that the optimal number of categories may vary with list length. MacLean and Gregg (1967), examining ordered recall of scrambled alphabets presented in groups of 1, 3, 4, 6, or 8 items, found the optimal size of group or chunk to be 6 or 8 items, a result reminiscent of the "magic number seven plus or minus two" (Miller, 1956b). It would seem that forgetting of items within a chunk should proceed in much the same fashion as forgetting of the chunks, and that with well-integrated chunks, items within one chunk should not interfere with items within another chunk. Overloading the chunks with items or the total list with chunks should decrease recall. In such cases, "sub-chunking" should facilitate memory, and, indeed, Cohen and Bousfield (1956) found that recall of a 40-item list of four categories improved when each of the four categories could be subcategorized.

Consideration of the evidence for encoding in memory reveals that incoming information may be categorized and stored according to myriad qualities: sound, meaning, order, channel of input, associate, superordinate, as well as by idiosyncratic characteristics. These results have

led Broadbent (1966) to compare the organization of memory to the organization of a library, both of which receive information and store it in order to retrieve it at some later time. The classification system used by most libraries Broadbent finds is analogous to classification in memory: a system in which items are filed separately according to certain useful, gross categories, but are also cross-indexed according to whatever other categories might be needed in retrieval. Broadbent reports an illustrative study in which eight consonants, half red and half black, were presented to subjects. After presentation, subjects were requested to recall either the red or the black consonants. In addition, items in the color set not requested were either acoustically similar to or acoustically different from the items in the requested set. If the items were encoded only on the basis of color, the relevant attribute, the properties of the items encoded by one color should not affect recall of items encoded by the other color. More intrusions from the unrequested set, however, were found when its items were highly acoustically confusing with items in the requested set. Thus, information is not simply hierarchically stored, but rather may be encoded in several different ways simultaneously, facilitating retrieval by establishing alternative routes to the information.

Verbal or Acoustic Theories of Encoding

Most of the theoretical accounts of encoding assert that the stimulus is put into memory in some verbal or acoustic fashion. Indeed, much of the data encourage this interpretation--acoustic errors are found with visually presented consonants, length of verbal label predicts recall of visual designs, verbal codability of colors accounts for their retention. The theoretical formulations developed have had either an acoustic or a verbal emphasis.

Sperling (1960) has shown, using the method of partial report, that observers can see more information in a brief visual display (of letters) than they can report, presumably because this information is lost rapidly with time. From this finding and others, he has developed a series of models of immediate memory (Sperling, 1963, 1967). The latest model (Sperling, 1967) has several components: the first component, the scan component, scans the (visual) display; the visual image then enters the second component, the recognition buffer memory, where it is converted to a program of motor instructions, which is stored. The programs for several images may be established quickly and simultaneously. Then, the rehearsal component executes the programs, entering the image into auditory storage. From the auditory storage, the (now auditory) image can be scanned, converted to motor instructions, and rehearsed recursively. The essence of the model is conversion of the visual image, which endures less than a second, into an auditory image by rehearsal. When the short-term visual store is tapped, as in Sperling's paradigm, visual errors, and not acoustic errors, are expected. In the analysis of several thousand errors committed in the partial recall of a 4 x 4 array of consonants, Rudov (1966) found a significant preponderance of errors to be intrusions from the same position in the adjacent row or column, or from a different position in the same row or column. Diagonal errors, where both these mistakes were committed, also occurred with greater-than-chance frequency. The majority of significant letter substitutions seemed to be visual confusions (R reported for B, H for K, X for K, C for Q, B for S, W for V, etc.). No evidence for errors of acoustic confusion was found, which is consistent with data of Turvey (1967), who found no errors of

acoustic confusion even when consonants were deliberately chosen to be confusable. Glucksberg, Fisher, and Manby (1967) found no effects of varying acoustic confusability of letters presented in a brief display for partial report, but did find decreased recall with high visual confusability. The effects of differences in visual confusability seemed to have disappeared when the cue was delayed 1 sec., supporting the notion that the stimulus is held in a visual store for a very short period of time, and in some other form thereafter.

Support for a very short-term visual store also comes from studies of reaction time. Posner and Mitchell (1967) presented pairs of letters, either capital or small, to subjects, who were asked to respond "same," by pressing one of two keys, when the pair of letters had the same name (e.g., AA, Aa) and to respond "different," by pressing the other key, otherwise (e.g., AE, Ae). "Same" responses were faster when the elements of the pair were physically identical (e.g., AA) than when the elements were physically different (e.g., Aa). Posner and Keele (1967) staggered presentation of the two stimuli in time. The advantage of physical identity seemed to have disappeared when the stimuli were separated by 1.5 sec. The authors take this to be the approximate duration of the visual image, or short-term visual store, after which time the first stimulus presented seems to be encoded as its name, and the name is then compared to the second element of the pair. The authors are careful to point out that there was no reason for the subjects to maintain the visual image in this task, so that the duration of the visual store might be longer were it to the advantage of the subjects to hold the visual image of the letters.

From his data on acoustic confusions in immediate memory, Conrad (1964) proposes that subjects verbalize the visually presented consonants, rather

than storing the visual forms. Wickelgren (1965c, 1966a) elaborates this hypothesis, suggesting that subjects remember vowels and consonants as a set of distinctive phonetic or articulatory features, such as voicing, nasality, openness of the vocal tract, and point of articulation, each of which may be independently forgotten.

From their finding of a correlation between perceptual accuracy and length of verbalization, Glanzer and Clark (1963a) propose the "verbal loop hypothesis." In processing perceptual arrays for recall, the subject first "translates the visual information into a series of words," after which he "holds the verbalization and makes his final response on the basis of it" (p. 295). If either of these stages is interfered with, response accuracy will decrease. Thus, shortening the exposure time or lengthening the retention interval should both depress recall, the former because the subject may not be able to complete the translation into words, the latter because the subject may forget part of the verbalization. Using eight-place binary digits as stimuli, with increasing verbalization lengths and decreasing exposure times, Glanzer (1966) found the predicted shift (up to the right) in the serial position curve, as well as depressed recall. It should be noted, however, that these predictions follow from any hypothesis of encoding which takes time, not only a verbal translation hypothesis.

In studying the relation between language and nonlinguistic behavior, Brown and Lenneberg (1954) found that recognition memory for colors could be accounted for by "codability," which was indexed by intersubject agreement of verbal labels for colors. Lantz and Stefflre (1964) developed an index of communication accuracy, which they found accounted for color

memory better than either Brown and Lenneberg's codability or Glanzer and Clark's verbal brevity. Like these measures, however, communication accuracy is a verbal index, the accuracy with which a subject can pick out a color from an array of colors using the verbal description of another subject. This analysis implies that subjects remember colors by describing or encoding them verbally and storing the descriptions.

Retention in Non-Verbal Modalities

Thus, many researchers, arguing from a wide variety of data and situations, propose that material to be remembered, whether acoustic or visual, is encoded into memory in some acoustic or verbal fashion. While these theories make no claim for universality, memory data are accumulating which are not easily accounted for by a verbal theory of encoding into memory.

Margraine (1967) presented pairs of digits, one aurally, one visually, simultaneously for recall. If all incoming information, regardless of input channel, is translated into a verbal code, then no differences due to input modality are expected, and, more subtly, interpolated tasks of different modalities should not have differential effects depending on stimulus modality.

In her first experiment, either the visual or the aural list was recalled first, and recall was either spoken (verbal) or written (visual). Written interpolated recall was significantly more damaging to visually presented material, while spoken interpolated recall seemed (the difference did not reach significance) to be more damaging to acoustically presented material.

In her second experiment, digit pairs were presented simultaneously, one visually and the other aurally. Either the aural or the visual

string was rehearsed during presentation, either by speaking or by writing. One string was recalled. Again, recall of the visually presented string seemed to be worse when the auditory string was rehearsed by writing than when it was rehearsed by speaking, while recall of the auditory string was worse when the visual string was spoken than when it was written. Although the results are explained in terms of two different and independent short-term perceptual stores, one visual and the other acoustic, they are also explicable in terms of encoding. If acoustically presented or rehearsed material is acoustically encoded, then it is more similar to, and hence more susceptible to interference from other material acoustically encoded than to other material encoded differently. Likewise, if visually presented or rehearsed material is visually encoded, it is more susceptible to interference from other visually encoded material. Furthermore, encoding the same stimulus both acoustically and visually should enrich the stimulus and thereby enhance its recall, a result Margraine obtained. Aurally presented material was better recalled when rehearsed by writing rather than by speaking, while visually presented material was better recalled when rehearsed by speaking rather than by writing.

Rubin (1967) obtained data which supports this interpretation of Margraine's results. He presented word triads for recall, with shadowing of digits during the retention interval. In the first experiment, blocks of visually presented words alternated with blocks of aurally presented words, while the digits were presented either visually or aurally for a given subject. In the second experiment, blocks of either aurally or visually presented words alternated with blocks of words presented both aurally and visually; again, digits were presented either visually or

aurally for a given subject. Switching from one modality to the other, or from one modality to both modalities resulted in a release from proactive inhibition as evidenced by an increase in recall from the previous trial. Stimuli presented in both modalities were better recalled than stimuli presented in just one, and switching from bimodal to unimodal presentation did not result in a release from proactive inhibition. Retroactive effects were also modality dependent; recall of visually presented words was depressed more by visually presented digits, and recall of aurally presented words was depressed more by aurally presented digits. Thus, words and digits, although both are verbal in nature, are encoded differently depending on whether their channel of input is visual or aural.

It would appear, then, that even stimuli with readily available verbal labels can be visually encoded, or, at least, are acoustically encoded differently when visually presented than when aurally presented. But what about stimuli which have no names, or whose descriptions are lengthy and imprecise--how are these remembered? It would seem unlikely that irregular visual stimuli, kinesthetic movements and locations are acoustically or verbally encoded into memory. Even if the subject arbitrarily assigned labels to such stimuli, it would be difficult, without extensive practice, for the subject to decode the stimuli, that is, to correctly produce or recognize the stimulus from the verbal label.

Adams and Dijkstra (1966) studied the retention of a motor response, the movement of a lever from a starting position to an experimenter-designated position without visual cues. Retention declined with (unfilled) retention interval from 0 to 120 msec., and improved with number of reinforced trials (0, 6 or 15 trials). The authors argued that retention

of the motor movement was not verbally mediated because the unfilled retention interval would have allowed rehearsal of the verbally encoded stimulus thereby preventing forgetting, and because subjects, in order to have verbally encoded the motor movements, would have needed verbal labels capable of discriminating graded responses differing by only 4 centimeters.

Posner and Konick (1966) investigated retention of a visual-location task--the position of a circle on a line--as well as a kinesthetic-distance task--the (blind) distance which a lever is moved. As in the previous study, forgetting increased with retention interval for the kinesthetic-distance task, which Posner and Konick argued was not verbally mediated. Recall of the visual-location task declined only when the retention interval was filled, and declined increasingly the more the subjects' processing capacity was occupied by the interpolated task. While the difficulty of the interpolated task had no effect on retention of the kinesthetic-distance task, it is known to have a substantial effect on retention of verbal material (Posner & Rossman, 1965). Even so, Posner and Konick argued that retention of the visual-location task was not verbally mediated. In the first place, a Verbal Control group of subjects, who were asked to place the circle on the line given accurate verbal information, performed worse than almost all the subjects in the immediate recall conditions, indicating that, as with the motor task, subjects could not accurately use verbal information for finding a point on a line within the nearest one-eighteenth inch. Secondly, subjects reported using "images" to remember the stimulus; only a few subjects reported using a verbal code more definitive than left or right of center. These findings have been replicated by Posner (1967a).

Recall of visual-location, kinesthetic-location and visual-distance information does not seem to be verbally mediated, while recall of faces, colors, or arrays of geometric forms does seem to be. The difference seems to lie in the availability of verbal codes which allow rapid, specific verbal encoding of the visual or kinesthetic information, as well as precise, accurate decoding to the correct response.

Even when stimuli have accessible names, it would seem advantageous to encode them visually for certain tasks, particularly speed tasks. If the subject's task is visual, that is, if he has to recognize a stimulus or scan a display for a stimulus, the task would proceed faster--and probably more accurately--if the stimulus had originally been visually rather than verbally encoded. Although this problem has not been directly investigated, there does exist some indirect support for plasticity of encoding.

Harris and Haber (1963) have demonstrated that subjects can be trained to encode the same stimuli--pairs of arrays of figures differing in number, color, and shape--by two different strategies. Subjects trained to encode by objects--first, all attributes of one element of the pair, then all of the other--performed more accurately and encoded faster in short-term recall than subjects trained to encode by dimensions--the attribute of each element on the first dimension, then the second, then the third (Haber, 1964a, b). Not only did object encoders make fewer errors, but they also made different errors from the dimension encoders.

That subjects can be trained to encode the same stimuli in different ways, albeit both verbal, seems evident. There is also some evidence that different tasks, as well as training, can induce different encoding strategies.

Chase and Posner (as reported in Posner, 1967b) presented subjects with a test stimulus and an array of 1, 2, or 4 stimuli; the subjects' task was to respond as quickly as possible "yes" if the test stimulus is in the array and "no" otherwise. The test stimulus either appeared simultaneously with the array (visual comparison), or 10 sec. before the array (visual recognition) or 10 sec. after the array (memory search). Furthermore, the arrays were either visually confusing, acoustically confusing or neutral consonants for separate groups of subjects. In all three tasks the visually confusing set of consonants led to the longest reaction times while the acoustically confusing set produced no decrement in performance over the neutral set. In a visual search task, where subjects scanned a list of 120 letters for a target letter, the use of acoustically confusing lists produced no decrement in performance, while the use of visually confusing lists hindered performance in adults as well as children (Gibson & Yonas, 1966a; Kaplan, Yonas & Shurcliff, 1966; Gibson & Yonas, 1966b). Thus, while consonants seemed to be acoustically encoded for a short-term memory task, they seem to be visually encoded for a scanning or search task.

Variables Affecting Type of Code

There do appear to be situations, then, where verbal encoding into memory does not seem evident, nor even desirable. When the same material is presented visually rather than aurally, it seems to be encoded differently, that is, visually, as it is more subject to visual sources of interference (Margraine, 1967; Rubin, 1967). When non-visual material is presented which has neither readily accessible verbal labels nor efficient, unambigous decoding rules, it is likely to be encoded in a non-verbal form. There is also evidence to suggest that subjects can be trained to encode

the same stimuli in different manners (Harris & Haber, 1963), and that for certain tasks it might be more advantageous to use one encoding scheme, e.g., acoustic encoding of consonants for a recall task, while another encoding strategy might be more beneficial for another task, e.g., visual encoding of consonants for a visual recognition or search task. There are also individual cases where acoustic encoding would not be expected: in pre-verbal children, in the deaf (Conrad & Rush, 1966), in those with eidetic imagery (Haber & Haber, 1964). Finally, verbal encoding of material presented in some other modality would not be expected if the rate of presentation were too rapid to allow "translation" (cf. Glanzer, 1963; Aaronson, 1967).

On a priori grounds, we might expect perceptions to be encoded into memory in their own modality. Given that, it is surprising that verbal or acoustic theories of encoding account for so much (non-verbal) data and experience. If it is accepted that adoption of an encoding strategy depends on what is to be done with the material, then an explanation is nearer at hand. In fact, we have little practice in retaining sights, smells, noises and feelings in their own modality, but a great deal of practice describing these in words to others or to ourselves. The end of much of our visual, tactile, kinesthetic perceptions is conversation. Indeed, where our descriptive vocabulary for particular sensations is sparse, our recollections seem instable and vague (cf. McKinney, 1966). Thus, the desirability of communication of experiences encourages us to put them into store in verbal form, as it is in words that we are accustomed to communicate. To be sure, visual, tactile, etc., experiences could be--and often seem to be--retained as such, and translated to words at the time of communication.

It would seem, however, more efficacious to recode to words immediately, both because this would reduce error by recoding a fresh as opposed to faded experience and because we have had extensive practice in reducing interference in verbal retention (cf. Postman, 1963). Simultaneous recoding or translation, however, takes time and effort (Posner, 1966) so that pressure of time or distraction by another task might prevent or interfere with recoding. Thus, verbal encoding is to be expected when verbal material is presented, or when a verbal response is typically required, providing that time sufficient to make a verbal translation is allowed. In other situations, other modes of encoding experiences into store are expected, and may be evident in correlations with amount recalled, or in the pattern of errors made by subjects or in subjects' introspections, and may be manipulated, not only by material, rate, and task, but also by instructions, strategy, and training.

Directions for Research

While evidence is accumulating that the same material, say, digits or words, is encoded differently depending on the channel of input, visual or aural (Margraine, 1967; Rubin, 1967), it is yet to be demonstrated that the same material can be encoded differently depending on how the subject expects to use it. The research to be described is directed toward this end.

The stimuli employed, schematic faces with well-learned names, have two equivalent manifestations, pictorial and verbal, and thus they can, in principle, be encoded in either of two modalities, pictorial or verbal. The goal of the present research is to alter the modality the subject uses

to encode these stimuli, not by manipulating the modality of presentation, but by manipulating the modality of response. It is hypothesized that irrespective of the modality of presentation, the subject will be able to respond better if the encoding modality is the same as the response modality. "Better" has two aspects, more accurate and faster, corresponding to the response measures of the two experiments.

In the first experiment, the memory load is heavy, so that many errors are expected. It is assumed that the error rate can be reduced by appropriate encoding; if the presented stimulus is to be selected from faces, accuracy may be higher if the stimulus is pictorially encoded, while if the presented stimulus is to be selected from names, accuracy may be higher if the stimulus is verbally encoded. Furthermore, if subjects do alter their encoding in this manner, it should be apparent from the types of errors committed. A pictorially encoded stimulus should be more readily confused with a pictorially similar stimulus while a verbally encoded stimulus should be more readily confused with a verbally similar stimulus.

In the second experiment, pairs of stimuli are presented in succession, and the subject is asked to report as quickly as possible whether the stimuli are "same" or "different." Since the most likely modality of the second stimulus is known for each block of trials, reaction time may be decreased by encoding the first stimulus in the expected modality of the second. If subjects do alter their encoding modalities to conform to the expected second-stimulus modality, then they should respond faster when the second stimulus is of the more frequent modality than when it is of the less frequent modality.

Thus, both experiments attempt to manipulate the subject's encoding modality by manipulating the task of the subject: whether he is to select

the correct stimuli from or make "same"-"different" judgments on pictorial or verbal stimuli. His encoding modality should be revealed in the type of errors he makes in the first experiment, and in differential reaction time in the second.

CHAPTER II

EXPERIMENT I

Introduction

In the first experiment, an attempt is made to manipulate the encoding modality used by the S by altering the task required of him. More specifically, on every trial, a set of eight schematic faces with well-learned names is presented and taken away; the position of one of the eight faces is cued; then the S tries to pick that face from either a set of faces or a set of names. It is expected that when Ss perform in blocks where they pick the cued stimulus out of a set of faces, they will try to remember the stimulus set visually or pictorially. On the other hand, when Ss perform in blocks where the cued stimulus is selected from a set of names, it is expected that Ss will encode the stimulus set verbally. Underlying both predictions are the assumptions that the S can alter his encoding modality, and that it is easier for him to select the correct stimulus from a pictorial set if he has encoded it pictorially, or from a verbal set if he has encoded it verbally, so that it is to his advantage to alter his encoding modality.

The encoding modality employed is assumed to influence the errors the S makes. The names and faces are constructed and paired so that the patterns of pictorial and verbal similarity are negatively correlated. Since a large proportion of errors of memory are intrusions of similar stimuli, it is expected that Ss will be more likely to substitute stimuli pictorially similar to the correct response under pictorial encoding, but more likely to substitute stimuli verbally similar to the correct response under verbal encoding. Thus, an error which is more similar pictorially than

verbally to the correct response is called a pictorial error, whereas an error more similar verbally than pictorially to the correct response is called a verbal error. In this way, detection of the encoding modality relies on the S's performance rather than his verbal report.

There is some possibility that such systematic errors could arise from confusion at recall rather than from partial forgetting of the differentially encoded stimulus. The S may encode the stimulus consistently in one way, or inconsistently in either way, and make an error after he has decoded the stimulus to the appropriate modality. It is difficult to see how such a process could account for systematic errors but, nevertheless, a control is included for this possibility. After four experimental sessions with blocked pictorial or verbal trials, in which Ss consistently select the correct response from a set of faces or names, there are two experimental sessions with pictorial and verbal sets randomized. Furthermore, on half the trials, in blocks, the Ss are forewarned of the modality of the set, while on half the trials, in blocks, they are not. It is expected that if Ss encode differently when they expect to select the correct response from a set of faces than from a set of names, this should be revealed in the forewarned trial blocks exactly as in the previous sessions, where pictorial and verbal sets were blocked. In the trial blocks in which Ss are not forewarned, errors should not correspond to the modality of the set, unless such errors are a response effect. The danger with randomizing response set modality is that Ss may randomize their encoding strategies, or adopt the easier one, or develop a new one altogether, so that the results of the forewarning randomized blocks will not be the same as the previous modality-blocked blocks.

Method

Subjects.--Ss were four paid volunteers, women in their early twenties with three to five years of higher education.

Stimuli.--The stimuli were 2 x 2 black-on-white slides, consisting of faces or names in various arrays, with each face or name subtending a visual angle of 1° 30'. There were eight schematic faces, forming a product set of three attributes, each with two levels: face shape--fat or narrow; eyes--filled or unfilled; mouth--smiling or unsmiling (see Fig. 1). The names were constructed in a formally identical manner; the first consonant was /d/ or /g/; the repeated vowel was /i/ (as in "dig") or /o/ (as in "home"); the second consonant was /l/ or /m/ (Fig. 1). Pictorial (verbal) distance can thereby be defined as the number of differing attributes in the pictorial (verbal) representation. Thus, in each representation, for every stimulus, there were three stimuli of Distance 1, three of Distance 2, and one stimulus of Distance 3. The names and the faces were paired via a one-to-one mapping, constructed in order to maximize the negative correlation between the pictorial and verbal distances. Distances of 3 on one modality yield distances of 1 on the other modality, distances of 2 on one modality yield distances of 1 or 2 on the other modality, and distances of 1 on one modality yield distances of 2 or 3 on the other modality. Thus, 6/7 of all possible errors can be classified as pictorial or verbal, depending on whether the distance to the original stimulus is smaller in the pictorial or verbal representation.

In the slides forming the stimulus sets, all eight faces were arranged in a circular array. On every trial, one slide from the

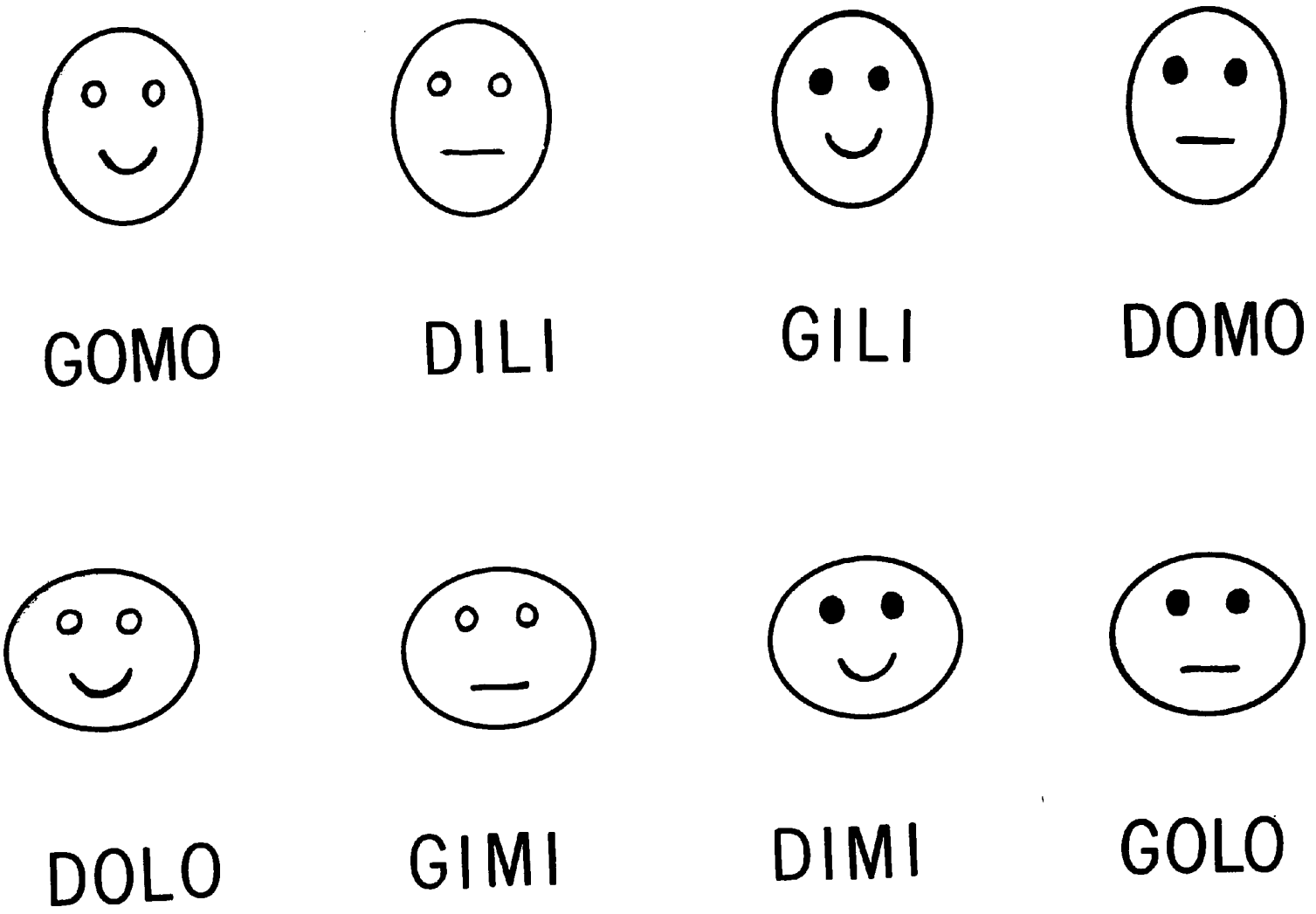


Fig. 1. Faces and associated names used as stimuli.

stimulus set was presented, after which appeared a cue slide, in which one of the eight positions was cued by an asterisk (the other positions were filled by dashes). There were 192 different slides in the stimulus set, specified such that each face appeared in each cued position three times; the faces in the other positions were selected randomly with the constraint that no two stimulus arrays be identical.

Following the cue slide appeared a slide from the scan sets. A scan set slide consisted of two stimuli in a horizontal array or four stimuli in a rectangular array, which were either all faces or all names. All possible pairs or quadruplets were used, with position selected randomly, yielding 28 different slides with two stimuli and 70 different slides with four.

Training.--The Ss were individually taught the names of the faces in a series of three or four 1-hr. sessions, no more than one a day, with a 5-min. refresher on the first experimental day. First, Ss were shown all the faces, while E named them several times, and S repeated each name after E. Then the faces were projected one at a time, in several random orders; S named each face and was corrected if wrong. Then, the names were projected and S picked the appropriate face from a circular array of all of them. These three procedures were repeated until S could name all the faces, and find the face belonging to each name quickly and accurately. Then the stimulus sets were projected, all eight faces in a circle. The S named the faces out loud in a clockwise order. When proficient and errorless at this, S "named" the faces silently as rapidly as possible, informing E when she finished. After S could perform this

last task in 7 sec. or less for about 80% of the slides for at least half a training session, training was terminated. On the last training day, the experimental task was explained and exemplified by eight practice trials. It was pointed out to the Ss that it should be to their advantage to remember the faces pictorially when the scan set was to be of faces, but to remember the faces verbally with scan sets of names.

Blocked design.--In each of the four experimental orders, there were 12 blocks of 14 trials each, totaling 168 trials. Four blocks used all possible scan sets of size two, while eight blocks used a randomly selected subset of scan sets of size four. Blocks were grouped by scan set size, with each size preceeding on alternate orders. Blocks of pictorial scan sets alternated with blocks of verbal scan sets, each one preceeding in alternate orders. Each S received a different sequence of the orders on the four experimental days.

The arrangement of blocks for each order was predetermined. Each order was then constructed by first randomizing the stimulus sets, omitting the last 24 drawn; the cued stimulus and its position had been specified for each stimulus set. Then a scan set was selected at random for each stimulus set, providing the scan set contained the cued stimulus and met the block requirements of size and modality.

Before-after design.--There were 6 blocks of 28 trials each, totaling 168 trials in each of the two orders of before-after testing. The 112 trials with size four scan sets preceeded the size two set trials in one order but followed in the other. Pictorial and verbal scan sets were randomized rather than blocked. Within these constraints, scan sets were randomly matched to stimulus sets as previously. Blocks of before trials

alternated with blocks of after trials, with before trials preceeding in one order and after trials preceeding in the other. In the before condition, the S was forewarned of the modality of the scan set of the next trial, while in the after condition, the S discovered the modality on presentation of the scan set. Three Ss began with one order, while the fourth began with the other.

Procedure.--Slides were projected automatically by a Kodak Carousel projector. On every trial, the stimulus set was projected for 8 sec.,[1] followed by the cue slide for 1 sec.; then the scan set appeared for 5 sec. during which time the S selected the cued stimulus from the scan set by pressing the corresponding dimily-lit button in a two-button horizontal or four-button rectangular array. Five seconds of rest, during which a neutral density grey slide was displayed, preceeded the next trial. For the before trials, this was lengthened by 2 sec., during which time E informed S of the modality of the next trial's scan set. The time between successive blocks was the time it took to change slide trays, except after the fourth and eighth blocks, where 5-min. breaks were given. Four practice trials preceeded the 168 experimental trials of each session. A session took approximately 80 min. The Ss performed individually, and were encouraged to relate how they accomplished the task.

Results

Errors.--An error was designated "pictorial" if it differed from the correct stimulus by one attribute pictorially or "verbal" if it differed from the correct stimulus by one attribute verbally; errors designated

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1. In Sessions 1 and 2 for S-1 and Session 1 for S-2, stimulus sets were projected for only 7 sec.

"neutral" differed from the correct stimulus by two attributes both pictorially and verbally. Errors summed over the four experimental sessions grouped by S, scanning set size, scanning set modality and error type are displayed in Table 1. The cumulative error rate for S-1 was 28%; for

TABLE 1

NUMBER OF ERRORS ON FOUR EXPERIMENTAL DAYS BY S, ERROR TYPE, SCAN SET TYPE AND SIZE

Scan Set Type	S	Error Type: Pictorial	Verbal	Neutral
Pictorial-2	S-1	9	3	3
	S-2	6	1	5
	S-3	12	15	3
	S-4	4	5	2
Pictorial-4	S-1	49	19	11
	S-2	36	9	11
	S-3	48	35	15
	S-4	26	15	2
Verbal-2	S-1	13	9	0
	S-2	3	0	3
	S-3	11	10	6
	S-4	6	8	3
Verbal-4	S-1	46	22	12
	S-2	32	8	7
	S-3	87	42	13
	S-4	22	27	3

S-2, 18%; for S-3, 20%; for S-4, 18%. All Ss showed a marked decrease in errors from the first two experimental sessions to the last two sessions. Since the error rates of S-1 and S-3 were very close to chance in the first two sessions, only errors from Sessions 3 and 4 were subjected to statistical analysis (Table 2). Neutral errors are omitted. Inspection of Table 2

TABLE 2

FREQUENCY OF ERROR IN SESSIONS 3 AND 4 BY S, SCAN SET TYPE AND ERROR TYPE AND VALUES OF χ_I^2 FOR INDEPENDENCE OF SCAN SET AND ERROR TYPES AND OF χ_E^2 FOR EQUALITY OF ERROR TYPES

	Error Type			Error Type		
Scan Set Type	Pictorial	Verbal	Σ	Pictorial	Verbal	Σ
	S-1			S-2		
Pictorial	29	2	31	16	2	18
Verbal	31	6	37	18	2	20
Σ	60	8		34	4	
χ_I^2	1.549		n.s.	.012		n.s.
χ_E^2	49.076		$p < .001$	28.034		$p < .001$
	S-3			S-4		
Pictorial	27	20	47	9	5	14
Verbal	13	22	35	12	18	30
Σ	40	42		21	23	
χ_I^2	3.310		$.10>p>.05$	2.256		$.25>p>.10$
χ_E^2	.500		n.s.	.500		n.s.

reveals that S-1 and S-2 tended to make predominately pictorial errors regardless of trial type, while S-3 and S-4 tended to make pictorial errors on pictorial trials and verbal errors on verbal trials. The hypothesis that errors are equally likely to be of either type regardless

TABLE 3

ERRORS FOR BEFORE-AFTER SESSIONS BY ERROR TYPE AND SCAN SET TYPE AND χ^2_E FOR EQUALITY OF ERROR TYPES

	Before Error Type		After Error Type	
Scan Set Type	Pictorial	Verbal	Pictorial	Verbal
	S-1		S-1	
Pictorial	12	3	2	3
Verbal	14	4	18	5
Σ	26	7	30	8
χ^2_E	9.818	$p < .005$	11.605	$p < .005$
	S-2		S-2	
Pictorial	9	3	13	3
Verbal	5	2	6	1
Σ	14	5	19	4
χ^2_E	3.368	$.10>p>.05$	8.522	$p < .005$
	S-3		S-3	
Pictorial	8	0	4	3
Verbal	5	3	2	5
Σ	13	3	6	8
χ^2_E	5.063	$p < .05$	0.071	n.s.
	S-4		S-4	
Pictorial	6	3	6	3
Verbal	4	1	7	3
Σ	10	4	13	6
χ^2_E	1.786	n.s.	1.895	n.s.

of trial type was rejected ($p < .001$) for S-1 and S-2, but not for S-3 and S-4, according to a χ^2 test. The hypothesis that error type is independent of trial type was tested by a χ^2 for independence. The results were clearly nonsignificant for S-1 and S-2 but approached statistical significance (p is approximately .10), for S-3 and S-4.

Errors for the last two sessions are displayed in Table 3, classed as to before or after, S, trial type and error type. Here, S-1 and S-2 continued to commit predominately pictorial errors, attested by significant or near-significant χ^2 values. S-3 also committed significantly more pictorial errors in the before condition; aside from that, no pattern is observable in the errors of S-3 and S-4.

Reaction times.--Table 4 contains the average reaction times over the four experimental days for each S by trial type and correctness

TABLE 4

MEAN REACTION TIME IN SECONDS OVER EXPERIMENTAL SESSIONS BY S, SCAN SET TYPE AND CORRECTNESS OF RESPONSE

		Response	
Scan Set Type	S	Correct	Incorrect
Pictorial-2	S-1	.70	2.11
	S-2	.67	1.37
	S-3	.78	1.39
	S-4	.99	2.52
Verbal-2	S-1	1.99	2.67
	S-2	1.00	2.10
	S-3	1.00	1.86
	S-4	1.21	3.68
Pictorial-4	S-1	1.18	2.14
	S-2	1.11	2.15
	S-3	.95	1.27
	S-4	1.17	3.50
Verbal-4	S-1	1.85	2.18
	S-2	1.19	2.81
	S-3	1.11	2.29
	S-4	1.19	3.59

of response. The mean reaction time for each S for the first and last sessions are: S-1, 2.51, 2.09; S-2, 2.42, 1.75; S-3, 2.16, 1.88; S-4, 2.79, 1.92. These data were submitted to within-S sign tests, as portrayed in Table 5. For the first three hypotheses of Table 5, there were 16 possible comparisons obtained from the two block means for each of two out of three factors (correctness of response, scan set size, and scan set modality) over the four sessions. The fourth hypothesis, that there were practice effects, was assessed by comparing mean reaction times of the four blocks of Session 1 to those of Session 3, and of Session 2 to Session 4. Cases fewer than 16 are due to ties or blocks with no incorrect response. The hypotheses that incorrect responses are slower than correct responses and that choices among four alternatives are slower than those between two were supported by all four Ss. Responses to verbal scan sets were significantly slower than those to pictorial scan sets for all Ss except S-4. For all Ss except S-3, reaction times to the earlier session of each pair were significantly slower than to the later session.

Discussion

The overall error rate indicates that the memory task was difficult, although improvement over the four sessions was demonstrated in decreases in errors as well as reaction time. When tasks are very difficult, Ss may develop idiosyncratic or stereotypic ways of coping with them. The patterns of error for S-1 and S-2 strongly support the interpretation that they coped with this difficult task by pictorially encoding the stimuli, irrespective of the modality of the scan set. Their verbal reports corroborated this assertion. The remaining two Ss seemed to be able to alter their encoding strategy to fit the scan set modality. Although

TABLE 5

PROBABILITIES ASSOCIATED WITH VALUES AS SMALL AS OBSERVED VALUES OF VIOLATIONS WITH BINOMIAL TEST (SIGN TEST) FOR HYPOTHESES ABOUT REACTION TIMES FOR CORRECT OR INCORRECT RESPONSES, SCAN SET SIZE, SCAN SET MODALITY, AND PRACTICE

Hypothesis	Subject	# Cases	Violations	Probability
Reaction Time for Incorrect Response Slower than Reaction Time for Correct Response	1	16	1	.01
	2	15	2	.01
	3	16	0	.01
	4	15	0	.01
Reaction Time for Size 4 Scan Set Slower than Reaction Time for Size 2 Scan Set	1	16	5	.05
	2	15	1	.01
	3	15	4	.06
	4	15	4	.06
Reaction Time for Verbal Scan Set Slower than Reaction Time for Pictorial Scan Set	1	16	3	.01
	2	15	1	.01
	3	16	3	.01
	4	15	5	n.s.
Reaction Time for Day 1 Slower than Reaction Time for Day 3 and Reaction Time for Day 2 Slower than Reaction Time for Day 4	1	15	3	.05
	2	14	1	.01
	3	15	6	n.s.
	4	14	2	.01

the evidence from errors is only suggestive, these Ss reported that they were able to encode or remember the faces in either fashion.

In the before-after sessions, all Ss claimed they payed no attention to E's forewarning of scan set modality, and, indeed, for all Ss save S-3, the pattern of errors for the before condition is very similar to that of the after condition. For S-1 and S-2, who pictorially encoded

during the experimental sessions, the patterns again reveal pictorial encoding, attesting to the constancy of these Ss' encoding strategies. No clear patterns emerged in the errors of S-3 and S-4, though S-3 demonstrated a tendency toward pictorial encoding in the before conditions, a tendency not exhibited in earlier experimental sessions. If these Ss were able to alter their encoding strategies in the experimental sessions, but if, as they reported, they ceased to pay attention to the forewarning when the modalities were randomized, then there would be no reason to expect error patterns similar to those of the experimental sessions.

Reaction times favored pictorial scan sets for three of the four Ss, though more strongly for the two pictorial encoders. For them, because the stimuli have been pictorially encoded it is reasonable that choice among faces is faster than choice among names, where presumably an extra translation to names would be entailed. The third S showing this inequality, however, was classed as a flexible encoder, in whom no differences between responses to pictorial and verbal scan sets might be expected. The fact that this S tended to pictorially encode in the before sessions, combined with the reaction time data, may indicate a shift toward pictorial encoding.

That responses to small scan sets were faster than those to larger scan sets is consonant with results of many previous experiments (Smith, 1968) where reaction time is found to increase with number of alternatives. Shorter reaction times occurred for correct responses, where the S was sure of his responses. Where she attempted to make an educated guess, and often made an error, her reaction times were longer.

Thus, although two Ss seemed to be able to manipulate their encoding modalities to match the scan set modalities, the remaining two Ss persisted

in encoding pictorially regardless of the expected modality of the scan set. This in itself runs counter to the theories of verbal encoding discussed earlier; despite the availability of verbal labels for a verbal recognition task, some Ss find it easier or more natural to retain pictorial stimuli as such. The data from these two Ss, however, also runs counter to the hypothesis proposed earlier that encoding modality depends at least in part on the S's expectation of what he is to do with the to-be-remembered material. The difficulty of the task seems to be the main reason for stereotypic behavior on the part of two Ss, and for only weak evidence for alteration of encoding by the other two Ss. The task was difficult for the development of flexible encoding strategies in two ways: not only was the memory load high, but the short blocks of each trial type demanded rapid alternation of encoding modalities. Pressure from a heavy memory load is likely to make the S rely on whatever idiosyncratic mnemonic devices he has at his disposal, while short trial blocks may not allow him to develop two consistent encoding strategies.

These reasons for the failure to obtain strong evidence for manipulation of encoding strategy provided guidelines for construction of a task in which such evidence should be obtained. They suggest that using a simpler task may yield more uniform behavior within and across Ss; they suggest that more experimental sessions with more extensive blocks of each type may encourage the development of differential strategies. These were the requirements for the task employed in Experiment II.

CHAPTER III

EXPERIMENT II

Introduction

The second experiment again attempts to manipulate the Ss' encoding modality, this time with a task with a minimal memory load, where errors are less likely. Reaction time is used as the indicant of encoding modality. The task is modeled on that of Posner and Keele (1967). A single face or name is presented and taken away, followed by a second one. The S is instructed to respond "same" if the two stimuli have the same name, and "different" otherwise. It is assumed that if the second stimulus is pictorial (verbal) and the S has encoded the first stimulus pictorially (verbally), he will be able to respond faster than if he has not encoded the first stimulus in the modality of the second.

Since the S is paid only for correct answers, and for those in proportion to his speed, it should be to his advantage to encode as expected, if he is able to. The trials, then, are blocked by the modality of the second stimulus, with the assumption that Ss will encode the first stimulus appropriately. Since the reaction time to the second stimulus under appropriate encoding must be compared to that under inappropriate encoding, a small proportion (ca. 21%) of the second stimuli of each block type are in the inappropriate modality. The modality of the first stimulus, however, is constant within a block. Thus, there are four types of trial blocks. In two of the blocks, the second stimulus is predominately pictorial, so that pictorial encoding is expected; of these, the first stimulus of one block is pictorial, while the first stimulus of the other is verbal. In the other two blocks, the second stimulus is predominately verbal,

which is expected to yield verbal encoding, while the first stimulus is verbal in one block and pictorial in the other. The data, then, may also reveal whether it is easier to encode in the presented modality for the retention (inter-stimulus) interval employed.

There is a possibility that the predicted reaction time difference could arise from surprise due to the unexpected modality or from expectancy of a particular physical representation of the stimulus rather than from encoding in the expected modality. An additional control was included for these possibilities. After completing the experiment proper, the Ss performed for two additional sessions on the verbal-verbal type block. In place of pictorial second stimuli on 21% of the trials were slanted verbal stimuli. It might be argued that although the slanted names are a different physical representation from the upright names, they are, nevertheless, very similar. It seems very difficult in principle, however, to construct comparable stimuli in the same modality which will be as different as equivalent stimuli in another modality. If the differences in reaction time are due primarily to surprise or expectation of a particular representation or a combination of both, stimulus pairs of the expected modality should also be significantly faster than those of the unexpected modality in the control condition. If they are not, then the encoding hypothesis is strongly supported.

Method

Subjects.--The Ss were eight right-handed femal undergraduates at the University of Michigan. They were paid a flat fee plus whatever they earned during the experimental sessions. Earnings averaged about $1.85 per session.

Stimuli.--The stimuli were the faces and names described in the previous study. They were displayed singly by a Kodak Carousel projector.

Training.--There were four 1-hr. individual training sessions. In the first session, the faces were shown and named; it was pointed out to the S that since there was no system relating facial to verbal characteristics, the best way to learn the names of the faces was to form an association for each pair. Ten random orders of each face with its name were projected for 10 sec. per slide. Then the faces were displayed without their names and the S asked to supply the names. Once the S could do this with almost no errors (this took half or more of the session), the names were displayed and the S was asked to point to the appropriate face in the circular display of all eight faces on a sheet of paper. There were 15 different arrangements of faces on sheets of paper and the S switched sheets every 20 or so trials to prevent learning of positions of faces. The Ss were asked to get a "clear visual image of the face" from the name before searching for the face in the array.

In the second and third training sessions, 80 trials of naming faces out loud alternated with 80 trials of pointing to the face with the projected name, for a total of 320 trials on each task on each day. Speed was encouraged in both tasks, as accuracy was nearly 100%.

This routine was repeated on the fourth training day, except that the tasks were self-paced (the S advanced the slide projector), the naming of faces was silent, as was the finding of the face on the sheet of paper. Then the experimental task was explained to the S, and eight practice trials were given.

Experimental design.--There were four types of trial blocks, schematized below:

Block Type	First Stimulus	Second Stimulus
I.	Pictorial	Pictorial 79% Verbal 21%
II.	Verbal	Pictorial 79% Verbal 21%
III.	Pictorial	Pictorial 21% Verbal 79%
IV.	Verbal	Pictorial 21% Verbal 79%

For Block Types I and II, pictorial encoding was expected, while for Types III and IV, verbal encoding was expected; in any one session, the Ss participated in blocks only of Type I and II or only Type III and IV.

There were eight random orders, subdivided into four blocks of 28 trials each, such that the probability that "same" was correct was one-half within both 79% (frequent) and 21% (infrequent) type trials and that every stimulus was paired equally often with every other stimulus within each order, and appeared equally often in every position over all orders. Each order was randomly assigned to one of the eight following conditions, defined by the sequence of trial block types:

1.	I	II	II	I
2.	IV	III	IV	III
3.	II	I	II	I
4.	III	IV	IV	III
5.	I	II	I	II
6.	IV	III	III	IV
7.	II	I	I	II
8.	III	IV	III	IV

Modality was randomly assigned to each stimulus of each order in accordance with the trial block conditions.

Experimental sessions.--The Ss performed individually, in each order successively, on separate days, with two Ss beginning with each of the first four orders. Each day's session was preceeded by an explanation of which block types would appear that session and four practice trials for the first block type. Before the second block, there were four additional practice trials of that type. Each set of practice trials always contained a second stimulus of the infrequent modality. On a typical trial, the first stimulus was projected for 1 sec., followed automatically by a neutral density grey slide for 1 sec., and then the second stimulus for 4 sec., which was more than adequate for the S's response. The S responded by pressing a key with the index finger of one hand for "same" or with the index finger of the other hand for "different." For one of the pair of Ss beginning the experiment with each order the left key was designated "same"; for the other, the left key was designated "different." After the second stimulus, a second neutral density grey slide with four horizontally-arrayed asterisks appeared, during which time feedback was given. The S then initiated the next trial by pressing a foot pedal.

After every fourteenth trial, a break long enough to change slide trays was given. During this time, the S was told the dominant modalities of the next 14 trials. The 112 trials of an entire session took about 30-35 min.

The feedback to the S was the number of points she had earned if she was correct; otherwise, she was told, when she did not spontaneously say

so herself, that she had made an error, The S gained five points if her reaction time was at her previous day's mean, plus a point for every 50 msec. faster or minus a point for every 50 msec. slower. She could receive no more than ten and no fewer than one point for a correct response. Each point was worth .2 cents over the base rate of $1.00 per session. The first session's scale was estimated from the practice trials of the last training session, but altered after the first block of trials if necessary. Each successive day's scale was estimated from the second half of the previous day's trials, except that the scale was not changed for the last two experimental sessions, nor was it changed after the reaction time worth five points got as low as 700 msec. During the control sessions the scale was again changed, if necessary.

Control.--Each S, except S-3 and S-4, who did not return to the University in the fall, served as her own control. The Ss served in two 35-minute sessions on separate days and were paid in the manner of the previous experimental sessions.

The stimuli were the name slides from the previous experimental sessions plus slides with the names printed in the same letter style and size, but in thicker letters slanted sharply to the right. Experimental Orders 4 and 6 were revised for the control sessions, such that in each of four daily experimental blocks, both the first and second stimuli were names, and the second stimuli were slanted names on 21% of the trials (the same frequency with which a face would have appeared as the second stimulus in the experimental sessions). Within the two orders, each name appeared equally often within both the 79% and 21% trial types.[1] The faces were not

1. Due to an error in making the slides, one of the names (GOMO) never appeared in its slanted form.

used at all, and the slanted names never appeared as the first stimuli. The Ss whose right index finger operated the "same" key received Order A first; the others received Order B first, followed by Order A.

The Ss were familiarized with the slanted names at the beginning of each control session; each name was projected three times in each of its two forms. Four practice trials preceeded each day's trials. The procedure was like that of the experimental sessions.

Results

Reaction times: Experimental sessions.--Table 6 displays the mean reaction times for each S and over Ss, to frequent (trials where the expected or 79% second-stimulus modality was presented) stimulus pairs categorized as to same or different, first half (first four sessions) or second half (second four sessions), first stimulus verbal or pictorial, and second stimulus verbal or pictorial. Table 7 contains the same information for infrequent (trials where the unexpected or 21% second-stimulus modality was presented) stimulus pairs. There are approximately 44 values for each S's "frequent" mean and 12 values for each S's "infrequent" mean. The effect of frequency was assessed by a sign test for the 32 comparisons (8 sessions x 4 blocks) for each S. The number of violations of the hypothesis that reaction times to second stimuli of the expected modality are faster than to those of the unexpected modality for Ss 1 through 8, in order, are: 4, 0, 1, 2, 1, 1, 2, 1. The sign test supports the hypothesis at the .001 level for each S. The average reaction time for frequent pairs was 705 msec. and the average reaction time for infrequent pairs was 873 msec. The effects of practice, same-different, first stimulus modality, and second stimulus

TABLE 6

MEAN CORRECT REACTION TIME FOR EACH S AND OVER Ss FOR FREQUENT PAIRS BY SAME-DIFFERENT, PART OF EXPERIMENTAL SESSIONS, FIRST STIMULUS MODALITY, AND SECOND STIMULUS MODALITY

	1st Stimulus Verbal		1st Stimulus Pictorial	
S	2nd Verbal	2nd Pictorial	2nd Verbal	2nd Pictorial
Same		First Half		
1	.665	.941	.619	.787
2	.737	.725	.690	.788
3	.929	.722	.848	.816
4	.728	.779	.758	.728
5	.674	.656	.616	.681
6	.682	.752	.651	.742
7	.829	.716	.812	.730
8	.702	.637	.648	.603
$\bar{x}$	.743	.741	.705	.734
Different				
1	.747	.888	.716	.784
2	.754	.814	.711	.797
3	.859	.823	.916	.828
4	.809	.856	.852	.800
5	.657	.697	.656	.695
6	.712	.802	.733	.775
7	.851	.780	.830	.743
8	.702	.662	.676	.640
$\bar{x}$	.761	.790	.761	.758
Same		Second Half		
1	.602	.709	.585	.659
2	.670	.657	.665	.673
3	.705	.674	.689	.667
4	.690	.736	.720	.699
5	.594	.580	.589	.594
6	.639	.606	.600	.610
7	.667	.610	.671	.609
8	.585	.559	.572	.564
$\bar{x}$	.644	.641	.636	.634
Different				
1	.661	.729	.664	.675
2	.704	.749	.721	.689
3	.746	.758	.739	.736
4	.745	.762	.742	.740
5	.621	.635	.613	.597
6	.693	.686	.692	.703
7	.676	.685	.657	.592
8	.617	.609	.616	.592
$\bar{x}$	.683	.702	.681	.673

TABLE 7

MEAN CORRECT REACTION TIME FOR EACH S AND OVER Ss FOR INFREQUENT PAIRS BY SAME-DIFFERENT, PART OF EXPERIMENTAL SESSIONS, FIRST STIMULUS MODALITY, AND SECOND STIMULUS MODALITY

	1st Stimulus Verbal		1st Stimulus Pictorial	
S	2nd Verbal	2nd Pictorial	2nd Verbal	2nd Pictorial
Same		First Half		
1	.919	1.315	.866	.847
2	1.023	.995	1.096	.920
3	.917	1.309	.954	.915
4	.982	1.204	.973	.981
5	.759	.805	.734	.702
6	.923	.729	.838	.771
7	.915	.937	1.008	.951
8	.725	1.013	.656	.798
$\bar{x}$	.895	1.038	.891	.861
Different				
1	1.010	.965	.886	.820
2	1.091	1.091	1.084	.893
3	1.001	1.285	1.032	.991
4	.839	1.397	.944	.884
5	.755	.787	.763	.733
6	.846	.767	.955	.856
7	.916	1.026	1.192	.943
8	.751	1.120	.786	.830
$\bar{x}$	.901	1.055	.955	.869
Same		Second Half		
1	.718	.783	.662	.779
2	.843	.971	.904	.799
3	.842	.921	.937	.819
4	.855	1.015	.899	.813
5	.710	.648	.676	.662
6	.717	.713	.729	.736
7	.819	1.151	.813	.809
8	.708	.676	.663	.725
$\bar{x}$	.777	.860	.785	.768
Different				
1	.835	.861	.821	.720
2	.883	1.054	.881	.835
3	.840	1.204	.886	.891
4	.810	1.009	.869	.754
5	.739	.718	.728	.684
6	.788	.770	.824	.822
7	.819	.918	.912	.729
8	.660	.856	.708	.673
$\bar{x}$	.797	.924	.829	.764

modality were assessed by two four-way analyses of variance per S, one on reaction times to the dominant second-stimulus modality and one on reaction times to the non-dominant second-stimulus modality. The results of these analyses of variance are displayed in Table 8 for the frequent second-stimulus modality pairs and in Table 9 for the infrequent pairs. All Ss show a statistically reliable practice effect, with an average reaction time in the first half of 841 msec., decreasing to 737 msec. in the second half. All Ss are significantly faster in saying "same" (685 msec.) than in saying "different" (726 msec.) for the frequent second-stimulus modality pairs, but this difference is notably not in evidence for the infrequent second-stimulus modality pairs. Beyond these statements, no other generalizations about effects and interactions of modalities and other factors can be advanced, although significant patterns are apparent within individuals.

Reaction times: Control sessions.--The mean reaction times to the dominant second stimulus modality (verbal) and to the non-dominant second stimulus modality (verbal slanted) for each S, along with the results of within-S t-tests are displayed in Table 10. These differences, in contrast to the frequent-infrequent differences in the experimental sessions, tend to be small. For the two Ss for whom there is a signficant difference ($p < .05$), these differences are in the direction opposite to that predicted by either a surprise or an expectation-of-particular-representation hypothesis.

All Ss were signficantly faster ($p < .001$, t-test) in responding to the frequent second stimulus modality in the two control sessions than in the comparable (first and second stimuli verbal) conditions in the last

TABLE 8

F RATIOS AND SIGNIFICANCE LEVELS FOR EACH S FOR MAIN EFFECTS AND INTERACTIONS FROM ANALYSES OF VARIANCE OF CORRECT REACTION TIMES TO FREQUENT SECOND-STIMULUS MODALITY PAIRS

Effect n = 44	S-1	S-2	S-3	S-4	S-5	S-6	S-7	S-8
A Same vs. Different	15.538 **	20.727 **	13.176 **	39.329 **	18.037 **	87.663 **	9.392 **	20.603 **
B Modality Stimulus 2	147.045 **	10.507 **	17.834 **	.599 **	6.981 **	24.843 **	37.715 **	22.538 **
C Modality Stimulus 1	36.006 **	1.080	.119	.796	2.648	1.494	1.975	9.256 **
D 1st Half vs. 2nd Half	131.455 **	43.667 **	164.601 **	40.822 **	132.333 **	127.337 **	196.082 **	108.282 **
AB	20.199 **	1.153	2.306	.250	.741	0	4.690 *	.487
AC	1.096	3.160	1.228	.026	.352	2.482	2.025	.333
AD	.442	.700	4.834 *	5.812 *	.519	5.012 *	0	1.397
BC	12.769 **	1.233	.632	12.954 **	2.574	.422	.184	.256
BD	27.000 **	9.020 **	10.415 **	.118	9.556 **	32.169 **	10.025 **	5.077 *
CD	8.205 **	.027	.029	0	0	.253	.044	4.218 *
ABC	.026	6.053 *	5.741 *	.164	9.167 **	2.976	.506	.833
ABD	3.115	.340	0	.039	.370	1.012	1.323	.385
ACD	.436	.080	1.617	.145	3.630	.084	0	.910
BCD	1.417	6.693 *	.845	1.586	4.500 *	2.458	0	.154
ABCD	.596	.040	3.347	.803	.537	.639	.272	.103

** $p < .01$

* $p < .05$

TABLE 9

F RATIOS AND SIGNIFICANCE LEVELS FOR EACH S FOR MAIN EFFECTS AND INTERACTIONS FROM ANALYSES OF VARIANCE OF CORRECT REACTION TIMES TO INFREQUENT SECOND-STIMULUS MODALITY PAIRS

Effect n=12	S-1	S-2	S-3	S-4	S-5	S-6	S-7	S-8
A Same vs. Different	.010	.582	4.470	.948	3.189	13.117 **	.057	3.654
B Modality Stimulus 2	1.439	.520	14.304 **	16.236 **	1.104	12.234 **	.100	22.520 **
C Modality Stimulus 1	10.486 **	2.472	13.400 **	20.398 **	4.066	4.508	.412	9.441 *
D 1st Half vs. 2nd Half	21.698 **	8.912 *	19.014 **	28.690 **	15.868 **	20.188 **	17.065 **	21.480 **
AB	5.714 *	.109	1.508	1.593	0	.203	5.385 *	.272
AC	.251	.831	.456	.956	.245	5.070 *	2.334	.253
AD	3.243	.001	.130	.082	1.255	1.250	4.671	.593
BC	2.695	5.301 *	28.846 **	39.915 **	.953	1.063	22.612 **	7.772 *
BD	.261	2.494	1.188	6.690 *	1.745	10.516 **	3.526	8.978 *
CD	3.429	.131	2.020	1.703	.840	.070	11.218	3.522
ABC	.476	.007	.049	4.585	.226	1.180	1.051	5.385 *
ABD	.546	.067	4.497	1.376	.038	.672	1.943	.461
ACD	1.255	.075	2.114	.387	.802	2.070	.555	.596
BCD	1.339	.104	.658	1.549	1.925	.398	.668	2.348
ABCD	3.393	.029	1.219	2.338	.547	1.367	2.270	.087

** $p < .01$

* $p < .05$

TABLE 10

MEAN REACTION TIMES FOR CORRECT RESPONSES TO FREQUENT AND INFREQUENT SECOND STIMULUS MODALITY PAIRS BY S FOR CONTROL SESSIONS

Subject	Frequent	n	Infrequent	n	Probability (t-test)
1	.474	170	.460	48	n.s.
2	.540	172	.547	47	n.s.
5	.494	171	.499	46	n.s.
6	.590	170	.527	44	$p < .05$
7	.586	167	.559	46	$p < .05$
8	.482	165	.487	48	n.s.

four experimental sessions. That this effect is not just a continuation of the practice effect is evidenced by the fact that these differences were larger for five out of the six Ss than the differences between the two halves of the experiment, and larger by twice as much for four Ss.

Reaction times: "Different" responses.--A detailed analysis of reaction times to correct "different" responses to the frequent second-stimulus modality pairs was performed. It will be recalled that for every S, "different" responses were significantly slower than "same." Reaction times to stimulus pairs differing on one relevant attribute were compared to those differing on more than one relevant attribute for each S, collapsing across modalities and sessions (Table 11). Pairs differing by three attributes were grouped with pairs differing by two attributes because the number of cases of the former was so low. For instance, reaction times for sessions in which the second stimulus was predominately verbal and the stimulus pairs differed by only one letter were grouped with reaction times from sessions where the second stimulus was predominately pictorial and the stimulus pairs differed by only one facial feature. Likewise, verbal pairs in which the second stimulus differed by two or three letters were

TABLE 11

MEAN REACTION TIMES FOR CORRECT " DIFFERENT" RESPONSES DIFFERING BY ONE VS. TWO OR THREE RELEVANT ATTRIBUTES WITH ASSOCIATED *t*-TEST PROBABILITIES FOR EACH *S*

Subject	1 Attribute	*n*	2 or 3 Attributes	n	Probability (*t*-test)
1	.758	127	.711	153	$p < .025$
2	.765	135	.726	152	$p < .01$
3	.821	128	.791	146	$p < .10$
4	.834	129	.757	151	$p < .01$
5	.669	131	.636	153	$p < .01$
6	.747	117	.714	149	$p < .01$
7	.750	129	.734	140	n.s.
8	.657	133	.627	149	$p < .01$

grouped with pictorial pairs in which the second stimulus differed by two or three facial features. Ambiguous stimuli, those differing by two verbal as well as two pictorial attributes, were omitted from the analysis. All *Ss* were faster in saying "different" when the stimulus pairs differed by more than one attribute. Furthermore, this difference was significant ($p < .05$, *t*-test) for all but two *Ss*. Inspection of the data of Table 12 reveals that this effect depends neither on the particular modality, verbal or pictorial, nor on whether the first and second stimuli were of the same modality.

The "different" responses to stimulus pairs differing by one attribute were subjected to further analysis, to assess systematic effects of particular attributes. Mean reaction times to "different" responses where the second stimulus was verbal categorized by the locus of differences and

TABLE 12

MEAN REACTION TIMES FOR EACH S AND OVER Ss FOR CORRECT "DIFFERENT" RESPONSES TO STIMULUS PAIRS DIFFERING BY ONE VS. TWO AND THREE ATTRIBUTES BY FIRST AND SECOND STIMULUS MODALITIES

Stimulus 1-Stimulus 2	Verbal-Verbal		Pictorial-Verbal		Pictorial-Pictorial		Verbal-Pictorial	
Number of Attributes	1	2 & 3	1	2 & 3	1	2 & 3	1	2 & 3
S-1	.726	.686	.706	.698	.761	.703	.836	.762
S-2	.758	.700	.727	.709	.793	.707	.783	.797
S-3	.817	.790	.849	.829	.801	.780	.817	.763
S-4	.805	.761	.880	.758	.805	.734	.848	.777
S-5	.644	.647	.651	.625	.675	.630	.703	.643
S-6	.710	.697	.720	.705	.787	.726	.768	.728
S-7	.759	.783	.744	.746	.716	.704	.776	.707
S-8	.691	.639	.667	.635	.617	.605	.644	.633
$\bar{x}$	.739	.713	.743	.713	.744	.699	.772	.726

displayed in Table 13, along with the comparable results for stimuli differing by one pictorial attribute. For pairs differing verbally, all Ss except one responded faster when the difference was in the vowels. There was no consistency over Ss in speed of response to pairs differing by the first or second consonant. It should be pointed out that the vowels were not only repeated, but were perhaps less acoustically confusing than either set of consonants. In the case of pictorial attributes, 6 out of the 8 Ss were slowest when the faces differed by the mouth, and either face shape or eyes seemed to facilitate the "different" judgment equally. For the remaining two Ss "different" responses were slowest when the faces differed by the eyes, next slowest when they differed by the mouth.

TABLE 13

MEAN REACTION TIMES FOR CORRECT "DIFFERENT" RESPONSES FOR PAIRS DIFFERING BY ONE ATTRIBUTE BY PARTICULAR ATTRIBUTE FOR EACH S

	Verbal						Pictorial					
	First Consonant		Vowel		Second Cosonant		Mouth		Eyes		Face Shape	
	RT	n	RT	n	RT	n	RT	n	RT	n	RT	n
S-1	.728	22	.687	25	.747	18	.792	18	.767	20	.769	24
S-2	.761	22	.708	23	.752	21	.817	20	.834	23	.722	25
S-3	.876	21	.794	25	.670	17	.862	19	.780	22	.795	23
S-4	.886	23	.798	22	.834	24	.837	20	.842	12	.813	23
S-5	.632	21	.626	26	.701	17	.715	20	.671	22	.687	25
S-6	.712	19	.696	23	.749	14	.803	15	.770	20	.768	26
S-7	.800	23	.674	24	.728	18	.808	17	.714	22	.728	24
S-8	.683	23	.670	26	.691	22	.668	16	.612	23	.625	22

Errors.--The error rate, averaged over Ss and experimental sessions was 5%. The rates per S, from S-1 to S-8, were: 3%, 3%, 7%, 4%, 4%, 9%, 7%, 6%. There was no systematic change in the error rate over sessions for any S, nor was there any dependence on modality. All Ss made proportionally more errors on stimulus pairs where the second stimulus modality was infrequent rather than frequent. For each S, errors tended to be faster ($p < .05$, sign test within-S) than correct responses of the same trial block. Ss 1, 5, and 6 made considerably more incorrect "same" responses, while Ss 2, 3, 4, 7, and 8 comitted considerably more incorrect "different" responses; these effects balance each other in the group average.

In the control session, the error rate decreased for each S (S-1, 2%; S-2, 2%; S-5, 3%; S-6, 5%; S-7, 5%; S-8, 4%). The proportion of errors to pairs of infrequent second stimulus modality was not higher than the expected proportion by chance for all Ss but one.

Discussion

Encoding hypothesis.--The second experiment provides stronger evidence that Ss' encoding strategies can be manipulated by the response expected from them. When the majority of the second stimuli were pictorial, Ss responded faster, by about 194 msec. for "same" and about 126 msec. for "different," than when the second stimuli were verbal, irrespective of the modality of the first stimulus. Likewise, when the majority of the second stimuli were verbal, Ss responded faster, by about 155 msec. for "same" and about 149 msec. for "different," irrespective of the first stimulus modality. This result cannot easily be attributed to either surprise or to expectation of a different physical representation, rather than expectation of a different modality. The same Ss, in control sessions, responded at least as fast to second stimuli which were infrequent and physically different, though of the same modality. Furthermore, Ss responded faster to verbal-verbal pairs in the control than in the experimental sessions, indicating that merely removing the possibility of pictorial encoding decreased processing time. Presumably, then, Ss use this extra 150 msec. or so to translate the stimulus in memory to the modality of the second stimulus or vice versa, so that a judgment may be made about the pair of stimuli.

Error data further corroborate this hypothesis. Errors were faster on the whole than correct responses, suggesting that the Ss erred when

they stopped processing and responded too soon. In the experimental sessions, error rate to pairs where the second stimulus was of the less frequent modality was considerably higher than expected, indicating that Ss were less likely to complete processing for these type of stimuli where more processing was necessary. Such a disparity in error rates to frequent and infrequent pairs did not occur in the control sessions, so that it, too, is not attributable to the effects of frequency or to expectation of a particular physical representation.

That Ss encode differently depending on the expected modality of the second stimulus is further supported by reaction times to stimulus pairs differing by one versus more than one attribute. When the pairs differed by more than one attribute along the modality of the second stimulus, Ss responded faster than when the pairs differed by only one attribute, irrespective of the modality of the first stimulus. Thus the Ss are faster in saying "different" when the stimuli are less similar, where similarity is defined in terms of the number of attributes in common in the encoding (second stimulus) modality. Recall that pairs which are similar along one modality are different along the other and that the above effect was obtained regardless of the modality of the first stimulus. Consequently this effect alone provides strong evidence that the first stimuli were encoded in the modality of the second. It is hard to see how any theory which does not assume that encoding modalities are switched could account for this finding. It might be noted that the observation that reaction time decreased with more different attributes along the modality of the second stimulus would have been difficult to make without the construction of special stimuli in which the verbal and pictorial patterns of similarity are known and negatively correlated.

There is some reason to believe that these results may depend on appropriate choice of interstimulus interval, which in this study was 1 sec. Had the stimuli been simultaneous, or closer in time, there probably would have been residual effects of the modality of the first stimulus. Had the stimuli been spaced further apart in time, Ss might have had difficulty retaining the stimuli in one modality or the other. Posner and Keele (1967) did find an increased tendency toward verbal (name) rather than visual encoding of letters over a 1.5 sec. interstimulus interval in a similar task, but their Ss did not know whether they would have to make a physical (visual or pictorial) or a name (verbal) match, so that these results reflect preferences rather than capacities.

Modality preferences were also expressed by the present Ss. "Preference" here is understood to mean relative ease of encoding in or responding to one modality over the other, as inferred from reaction time advantages, rather than, say, "liking" the pictorial display better than the verbal. Interesting patterns of preferences emerge from the individual reaction time protocols. S-8, for instance, always performed faster when the first and second stimuli were pictorial, while S-4 consistently responded faster when the second stimulus modality was the same as the first, showing no independent modality preferences. While such patterns may arouse endless speculation, little of a general nature can be said about them. It was seen that while in the task of the first experiment, which was difficult, the advantages of altering encoding modality did not clearly overcome individual differences, in the task of the second experiment, which was considerably easier, Ss were able to alter their encoding strategies despite marked idiosyncratic preferences.

"Same"-"Different" judgments.--The advantage in reaction time of responses to the expected second stimulus modality over the unexpected second stimulus modality was not the only marked difference in reaction time consistent across Ss. All Ss took longer to respond "different" than to respond "same" to pairs of the expected second stimulus modality. One type of model which might be used to explain this finding proposes that the "same" judgment is processed in one stage, while the "different" judgment entails two processing stages. In the first stage, the stimulus in memory is compared to the stimulus on the screen by template matching, or by an exhaustive check of attributes. Were the process self-terminating, "different" responses would be shorter than "same." If inspection reveals that the stimuli are identical (name identity; not necessarily physical), the S responds "same." If inspection does not reveal identity, however, the S apparently does not automatically respond "different" although he has the necessary information to do so. Rather, he appears to reexamine the stimulus pairs as if to discover where the difference lies, a process easier to rationalize if template matching rather than serial inspection has occurred at the first stage. It takes him longer to find a difference if members of the pair differ only on one attribute. Furthermore, he seems to search for a difference by a serial self-terminating check of attributes; in the case of words, first checking the vowels, and then the consonants; in the case of faces, first checking the eyes or face shape, and then the mouth. This analysis of the processing of "same"-"different" judgments is consistent with data collected by other experimenters. In experiments where one item is in memory and one in display, and S is asked whether the display includes the contents of memory, "no" responses are

equivalent to "different" and "yes" responses to "same." In this task, Sternberg (1966, 1967), using digits, and Nickerson (1966), using letters, found "no" responses to be significantly slower than "yes" responses. In another experiment, Nickerson (1965) found that "different" responses persisted in being slower than "same" responses to pairs of letters over 22 days of practice. While data from the many experiments of Posner and Mitchell (1967) are not internally consistent, these investigators usually found "different" responses to be slower than "same," for name as well as physical identity. Lindsay and Lindsay (1966) used a task where there were essentially two "same" responses, both of which were faster than the one "different" response. Responses were to the appearance of one of 32 geometric figures, formed from 5 attributes, each with 2 levels. To 30 of the figures, S responded by pressing his index finger; to the thirty-first, by pressing his middle finger; to the remaining figure, by pressing his ring finger. Stimuli were presented such that responses were equally probable. Not only were reaction times faster to the two stimuli with unique responses, but also reaction times to the remaining stimuli varied with the values of particular attributes, as if Ss were scanning these serially. To explain their results, these investigators propose a process similar to that discussed here.

Another type of model which might account for these results asserts that the "same"-"different" judgment is made in a self-terminating fashion, yielding faster reaction times for stimuli differing on fewer attributes, but that the "different" or "no" response takes longer to make than the "same" or "yes" response. This is not likely to be a motor effect, as half the Ss used their dominant hand for "same," and half used their

non-dominant hand. This explanation is not entirely satisfactory, since it provides no rationale for the difference in response time.

The finding that "same" and "different" response times do not differ for infrequent second-stimulus modality pairs does not discriminate between these two models, because both may be reasonably extended to account for this result. The models can be distinguished by using stimuli varying on only one binary attribute. In this case, there would be no way to ascertain or double-check a difference so that the first model would predict "different" responses to be as fast as "same" whereas the latter model would ontinue to predict a discrepancy between the reaction times of the two responses.

CHAPTER IV

SUMMARY AND CONCLUSIONS

How a person encodes his experiences into memory, what he selects to store and how he chooses to store it, may determine the type of errors he makes, as well as the speed with which he processes certain types of information. Furthermore, the manner in which he chooses to put experiences into memory may be determined by the use to which the information is to be put. Information stored in anticipation of some verbal use, say, recall, may well be verbally encoded into memory, while information stored in expectation of some visual use, say, pictorial recognition, may well be encoded visually. These hypotheses, that manner of encoding influences errors and processing time and that manner of encoding is flexible and efficient in the sense that it can be adapted in anticipation of the task for which the information will be used, were tested in two experiments.

In both experiments, stimuli were schematic faces with well-learned names, where the pattern of pictorial similarity correlated negatively with the pattern of verbal similarity. In both experiments, Ss were told to expect trial blocks of faces or trial blocks of names in an attempt to manipulate encoding modality. The S would presumably respond more accurately and more rapidly if he encoded in the anticipated modality.

The first experiment imposed a heavy memory load on the Ss, and looked for evidence of encoding modality in the errors committed. The Ss were presented with eight faces on a trial, one of which was later cued. The S then tried to select that face from either a set of faces or a set of names.

A common error of memory is substitution of a similar stimulus for the correct response. Thus, pictorially similar errors were expected under

pictorial encoding while verbally similar errors were expected under verbal encoding. The pattern of errors of two Ss supported this expectation, while the pattern of errors of the other two Ss indicated pictorial encoding.

In the second experiment, the task was simpler and the trial blocks longer. The Ss made a "same"-"different" judgment between a face or name in memory and a projected face or name. The second stimulus was either pictorial or verbal for the majority of an entire session's trials. Evidence for manipulation of encoding strategies is in the result that Ss responded faster when the second stimulus was of the frequent modality, than when it was of the infrequent modality, irrespective of the particular modality of either the first or second stimulus. Support for the encoding alteration hypothesis also comes from the finding that correct "different" responses were faster when the stimuli differed on more than one attribute in the frequent second stimulus modality, irrespective of the modality of the first stimulus.

The findings that for frequent second-stimulus modality pairs, "same" responses were faster than "different," and that speed of "different" responses depended on the number of attributes of the encoding modality shared by the stimuli suggest two alternative hypotheses. According to one hypothesis, the stimuli are first tested for "same;" if the test reveals sameness, the S responds "same." If not, he verifies that there is a difference by searching for a locus of difference. Alternatively, S checks for a difference in a self-terminating fashion, but in addition he has a bias which renders "same" responses faster than "different."

Some evidence has been presented that Ss can adopt different encoding strategies depending on what the incoming information is to be used for,

and that these strategies are revealed in the type of error committed and the speed of processing certain types of information. Previous research indicates that this capacity is not demonstrable in all tasks, nor for types of information.

The conditions under which flexible encoding strategies will occur are not clearly defined, although broad boundaries may be outlined. First of all, the task and/or material must be such as to allow the observation of such strategies if they do occur. In the typical human learning experiment, the material to be remembered is all of one type, and is presented the same way on all trials. This is also generally true of the interpolated material as well as of the response requested of the S. Even if Ss were to try a variety of encoding strategies under such conditions, the E would be unlikely to observe that, because the response measure is typically percent recall rather than say, error type, and because percent recall is typically grouped over trial blocks and/or Ss. When the stimulus material is of more than one type (e.g., Wickens, et. al., 1963; Loess, 1967) or when it can be tagged, grouped or clustered in some way (e.g., Yntema & Trask, 1963; Conrad, 1960; Cofer, 1966; Tulving, 1962), Ss tend to encode stimulus material differentially. Thus, a release from proactive inhibition is observed when consonants are presented for recall after several trials with digits (Wickens, et. al., 1960), intrusions of items from the same serial position in previous strings are a common form of error (Conrad, 1960) and items in free recall tend to be clustered by input channel (Yntema & Trask, 1963) and category (Bousfield, 1953) as well as idiosyncratically (Tulving, 1962). Likewise, when the modality is varied (e.g., Wickelgren, 1966b; Margraine, 1967; Rubin, 1967), such variations

have selective effects on retention; visually presented interpolated material, for instance, causes a larger decrease in recall of visually presented to-be-remembered material than does aurally presented interpolated material. The experiments reported here allowed detection of encoding strategies through the use of special stimulus material, with two manifestations, constructed so that the pattern of pictorial similarity correlated negatively with the pattern of verbal similarity. Furthermore, data were not grouped over Ss, which in the first experiment would have concealed differential encoding.

Not only must the task allow observation of encoding strategies, but certain tasks encourage certain encoding strategies rather than others. While visually presented letters are more susceptible to interference from acoustically similar material even with short-term written recall (Wickelgren, 1966b), such material presented for very-short-term recall reveals visual and not acoustic errors (Turvey, 1967) and such material presented in a search task is susceptible to inference from visually similar material (Posner, 1967b). Few experiments other than those which vary the modality or the type of stimulus or interpolated material have been constructed to encourage more than one encoding strategy within the same task. Those that have, such as the experiments with tagging or clustering, or with aural and visual presentation, have manipulated encoding strategy by varying the material or the mode of presentation. The present experiments attempted to obtain differential encoding strategies by varying the modality of the S's response. Even with such tasks designed so that it is to to the S's advantage to encode the stimulus material in more than one way, the S may not be able to do so. In the first experiment, for instance, two Ss were not able to overcome their propensity for pictorial encoding given

the demands of the task: heavy memory load and short trial blocks. In the second experiment, where the memory load was light and the trial blocks long, all Ss were able to encode both faces and names either pictorially or verbally. Thus, the general difficulty of the task as well as the eventual use of the stimulus material must be such as to allow the development and employment of differential encoding strategies in spite of natural tendencies and prior training.

At the same time that the human being is marvelously flexible and can rationally and with foresight alter the manner in which he stores incoming information, he is also under the control of individual talents and tendencies, and of sets of overlearned habits. Which of these aspects of cognitive processing will prevail depends to a large extent on the nature of the stimuli and the structure of the task.

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13. ABSTRACT

What is remembered, and the speed of retrieval and systematic errors in retrieval, depend on the coding of stimulus information at the time of storage in memory. This study attempted to manipulate the encoding modality of pictorial and verbal material by manipulating the modality of the expected retrieval test (visual or verbal recognition). The stimuli were schematic faces with well-learned nonsense names, constructed so that pictorial stimilarity correlated negatively with verbal similarity. It was hypothesized that Ss would perform more accurately or faster when encoding modality was the same as the response (test) modality, irrespective of stimulus modality. In Exp. 1, 8 faces were presented on each trial, one was cued, and S attempted to select that one from a set of 2 or 4 faces of names. The data of 2 Ss supported the hypothesis, the data of 2 Ss showed consistent preference for visual coding. In Exp. 2, a single face or name was presented followed by another one; S responded "same" if they had the same name, "different" otherwise. Expectancy of test modality was manipulated by having 79% of the second stimuli as faces or 79% as names. Slower reaction times were obtained for all Ss when the second stimulus was the less frequent modality, and RT was less for "different" responses when the stimuli differed on more than one attribute in the encoding (second-stimulus) modality, regardless of the modality of the first stimulus, or the particular modality of the second stimulus. It is concluded that not only can berbal materials be pictorially encoded, but that whether both verbal and pictorial material is verbally or pictorially encoded depends on the S's anticipation of what he is to do with the material.

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	ROLE	WT	ROLE	WT	ROLE	WT
1. Stimulus coding						
2. Short-term memory						
3. Visual coding						
4. Verbal coding						
5. Expectancy						