Using visual codes for comparisons of pictures*

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In two experiments, Ss indicated for a series of trials whether or not two pictures of common objects had the same name (a positive or negative response, respectively). The pictures were separated by one of three interstimulus intervals (ISIs), and reaction time (RT) was recorded. In Experiment I, positive trials involved pictures that were identical (identity match), mirror images (mirror match), or physically different but had the same name (name match). The stimuli came from either an S set, in which name-match pairs were physically similar, or a D set, in which name-match pairs were physically dissimilar. The mean RTs for mirror and identity matches were virtually the same but faster than name-match RTs, an advantage that decreased with increasing ISI. It was expected that name-match RT for the S set would be less than for the D set, indicating a facilitative effect of physical similarity; however, the identity-match RTs showed the expected difference. These results were extended in Experiment II, which involved only the identity and name matches, in pure sessions (which included positive trials of just one type) or mixed sessions (which included both types of positive trials). For mixed sessions, name- as well as identity-match RTs differed between the S and D sets. These results provide evidence for the use of visual codes in comparing nonidentical pictures, codes that apparently vary with experimental context and task demands.

Theories of short-term memory (STM) have emphasized an acoustic format for the storage of verbal material (e.g., Atkinson & Shiffrin, 1968). However, short-term storage of visually presented stimuli in a visual format has also been demonstrated (Klatzky & Atkinson, 1971; Kroll, Parks, Parkinson, Bieber, & Johnson, 1970; Murray & Newman, 1973; Posner, 1969; Posner & Mitchell, 1967; Salzberg, Parks, Kroll, & Parkinson, 1971; Scarborough, 1972; Smith & Nielsen, 1970; Sternberg, 1967). These short-term visual codes are distinguished from the iconic perceptual trace found to persist briefly after a stimulus is visually presented (e.g., Neisser, 1967; Sperling, 1960).

One experimental paradigm which has been used to study short-term visual codes was developed by Posner and his associates. (See Posner, 1969, for a review.) In one form of this paradigm, Ss are required to indicate whether or not two letters are the same (a positive or negative response, respectively), and reaction time (RT) is recorded. The same-letter criterion for positive responses in this task includes two distinct conditions: The two letters may be physically identical (an identity match) or nonidentical but have the same name (e.g., B and b, a name match). Typically, RT for identity matches is found to be approximately 75 msec less than RT for name matches when the two letters are presented simultaneously. However, when an interstimulus interval (ISI) occurs between presentation of the first and second letters, the relative efficiency of identity matches is affected. It has been found that as the ISI increases to

approximately 2 sec, identity-match RT increases relative to name-match RT, causing the difference between name- and identity-match RT to decrease to zero.

The results of the letter-matching experiments have been interpreted as indicating that the processes underlying the two types of positive responses are quite different (Posner, 1969; Posner, Boies, Eichelman, & Taylor, 1969; Posner & Mitchell, 1967). Name matches are thought to be based on verbal stimulus representations and identity matches on visual representations. The observed decay of the advantage of identity matches relative to name matches is attributed to decay of the visual code of the first stimulus during the ISI, so that at ISIs greater than 2.0 sec, the visual code is no more useful than a verbal code for matching identical letters.

Support for the visual/verbal hypothesis has been obtained in studies of cerebral hemispheric asymmetries in the letter-matching task (Cohen, 1972; Geffen, Bradshaw, & Nettleton, 1972). These experiments suggest that identity matches are performed in the right hemisphere of the brain, thought to be specialized for processing visual information, and that name matches occur in the left hemisphere, the verbal processor.

That the visual code used for identity matches is appropriately labeled short term, and not sensory, is supported by the finding that variables which could be expected to affect perceptual processing (e.g., luminance or exposure duration) have equivalent effects on both types of positive responses (Posner, 1969). The manipulation of such variables therefore does not affect the function relating name-match RT minus identity-match RT to ISI, indicating that the relative efficiency of the visual code is unaffected. For these

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reasons, the locus of the visual representation appears to be at a deeper processing level than a sensory trace.

Still another set of findings supports the distinction between short-term visual codes and sensory traces. In several experiments, evidence has been found suggesting that visual representations like those used for identity matching can be produced from information in long-term memory (LTM). For example, Posner et al (1969) found that presenting the first letter auditorily in a letter-matching task resulted in RTs comparable to those of identity matches at ISIs of approximately 1 sec. Posner (1969) suggested that Ss could use the ISI to "generate" a visual representation to be used for comparisons, given the letter name. Shepard and Klun (in a study reported in Cooper & Shepard, 1973b) had Ss indicate whether a visual form was a letter rotated from its normal upright position in the presentation plane or a rotated mirror image of the letter. The RTs for this task followed the same pattern as those obtained when the normal form was presented along with the rotated form; however, in the former case the object of comparison must have been produced from LTM. Still other studies (Cohen, 1969; Tversky, 1969) support the idea that Ss can form expectancies from verbal descriptions which subsequently facilitate comparisons with visual stimuli. In all these cases, it appears that comparable visual codes can be generated from LTM and produced by direct visual stimulation. Such visual codes must differ from sensory traces.

Klatzky (1972) used the Posner matching paradigm in an experiment for which the stimuli were pictures of common objects (e.g., dogs, trees, etc.). In her experiment, S made a positive response if two pictures represented the same object. The pictures were separated by ISIs ranging from .1 to 4.0 sec. Klatzky's experiment was primarily concerned with the role of cerebral hemispheric specialization in task performance, but it also provided a set of data for common-object pictures which could be compared to data from the letter-matching experiments (discussed in Posner, 1969). This comparison showed that the function relating the difference between name- and identity-match RTs to ISI decreased more slowly for picture stimuli than for letters, suggesting that the short-term visual codes of common-object pictures were useful for longer periods than the codes of letter stimuli.

Klatzky (1972) suggested that the relatively long duration of the visual codes of object stimuli might reflect a basic difference between those stimuli and letters. The suggestion was derived from a more general proposal of Elias and Kinsbourne (1972), who noted that the use of letters in reading determines that the physical form of a letter is much less important than its categorical identity (name). Thus, conversion of the visual form of a letter to a verbal representation may be a well-learned automatic response. Klatzky's stimuli, in contrast, would be more likely to be retained in visual form, because a comparable bias toward rapid recoding

to a label would not be present for common-object pictures.

The hypothesis of Elias and Kinsbourne (1972), stated more generally, proposes a negative relationship between the duration of the visual code for a stimulus and the strength of a tie between the stimulus and a corresponding label. To test this proposal, they used in a matching task stimuli which minimized the connection between physical stimuli and category names. The stimuli were formed by rotating either the letter F or its mirror image 90 or 270 deg from its upright position. The nature of the stimuli made it difficult for Ss to attach labels to them, and Elias and Kinsbourne accordingly predicted that visual codes of the F forms would be maintained for longer periods than the codes of letters. These predictions were supported by the data. In fact, still another difference between F forms and letters was obtained. In one of their experiments, RT for name matches (matches between stimuli which differed only by a rotation in the presentation plane and not a mirror reversal) approached identity-match RT at the longer ISIs. This suggested that visual codes might have been generated by rotation of the first stimulus presented and used for name matching.

The foregoing analysis suggests that the short-term visual codes which follow the presentation of a stimulus vary with the nature of the stimulus. First, visual codes of some stimuli appear to be maintained longer than codes of others. In the stimulus-matching paradigm, this is evidenced by the finding that some categories of stimuli lead to relatively slow decreases in the advantage of identity matches. Second, the suggestion has been made that, for those visually durable classes of stimuli, nonidentical stimuli might be compared on a visual basis. For other classes, most notably letters, nonidentical stimuli appear to be matched on the basis of labels.

The experiment of Klatzky (1972) suggests that pictures of common objects, as a stimulus class, are maintained as visual codes for longer periods than are letter stimuli. This raises the question of whether there might be a second difference between letter and object stimuli. That is, it is possible that common-object pictures are compared on some visual basis even when those pictures are not identical. In the present experiments this question was investigated.

In these experiments S took part in a series of trials. On each trial S was required to indicate whether or not two temporally separated pictures of common objects represented the same object category (i.e., had the same name). Positive responses could occur if the two pictures were physically identical (an identity match), and they could also occur under conditions where the two pictures were not identical but nevertheless had the same name. In the latter case, the similarity between the two pictures was varied.

The similarity conditions used in these experiments were of three types. The first, used only in Experiment I, was the mirror-image relationship: One

picture-matching condition was a mirror match, defined as the presentation of a given stimulus followed by its mirror image. The second similarity condition, used in both experiments reported here, involved what will be called structural similarity: Some name matches were of pairs of stimuli which resembled each other with respect to shape and orientation. These two similarity relationships thus determine two types of comparisons: between stimuli having the same name, the very same features, but not necessarily the same orientation and shape (mirror matching), and between stimuli having the same name, similar orientation and shape, but nonidentical features (structural similarity). A third set of same-name comparisons involved stimuli which differed in both feature identity and structure.

Similarity was manipulated in these experiments in an effort to determine whether or not nonidentical objects could be compared on a visual basis, even when comparisons could take advantage of a readily available verbal label. If visual similarity is found to affect name-match RT, one can infer that the matching process utilizes visual information. Moreover, the nature of the similarity relationship which affects RT can be used for inferences about the nature of the visual information that is contained in the stimulus code and, therefore, available for use. In addition to similarity manipulations, several ISIs were used in these experiments to investigate temporal characteristics of visual coding and object comparisons.

EXPERIMENT I

Method

Subjects. Eight students enrolled in the introductory psychology course at the University of California, Santa Barbara, served as Ss. There were four males and four females.

Stimuli. The stimuli were 48 pictures (drawings) of familiar objects. No picture was symmetrical about the vertical or horizontal axis. Each picture was approximately 3.2 cm in diam. The 48 pictures represented 12 common objects (names). For each name there were four pictures; however, two of these four pictures were mirror images of the other two. That is, there were two different pictures for each name, as well as the mirror image of each of those pictures. For ease of exposition, the two differing pictures corresponding to each name will be termed a pair; the mirror images of those pictures form another pair. The selection of stimuli to form pairs is described below.

The pictures were divided into two stimulus sets. Each set contained 12 pairs of pictures, one pair representing each of six different names as well as the pairs formed by their mirror images. The names represented in the two sets did not overlap. (Examples for each set are shown in Fig. 1.) For one set of stimuli, the S (similar) set, the two stimuli in each same-name pair were structurally similar, that is, they depicted objects seen in similar orientations and similar in shape. By virtue of the mirror-image relationship, of course, the mirror pair of stimuli corresponding to that name had the same similarity relationship. Thus, the S set consisted of 24 stimuli, used to define 12 pairs. Within each pair, the two stimuli were nonidentical, nonmirror, structurally similar, and representatives of the same name.

The second set of pictures, the D (dissimilar) set, was formed in the same manner as the S set, but with one important difference. Pairs of stimuli in the D set violated the similarity criteria used to form the S pairs, that is, the two pictures

Fig. 1. Examples of stimulus pairs from the S set (top row, grapes and pipe) and the D set (bottom row, snake and zebra).

differed in structure. Six such pairs, together with the corresponding pairs formed by their mirror images, were used to compose the D set.

The similarity relationships in the two sets of stimuli, S and D, which have just been described were empirically validated in two ways. First, 21 students enrolled in the introductory psychology course at the University of California, Santa Barbara, rated the pictures in same-name pairs (one pair per name) for similarity of physical form, defined for them as a combination of shape, structure, and orientation. The pairs were rated in random order on a scale ranging from 1 (not similar) to 10 (very similar). The ratings clearly differentiated the two sets, with S-set pairs rated as more similar in form than D-set pairs [the mean difference in ratings was 3.9, $t(20) = 9.3$, $p < .001$]. Second, for each pair an objective estimate of shape similarity was obtained. This measure was based on the proportion of the total area of the two objects which overlapped when the two pictures were superimposed. By this measure, S-set pairs were significantly more similar than D-set pairs.¹

Apparatus. The apparatus consisted of a three-field Iconix tachistoscope. For use in the apparatus, each picture was mounted on a 23 x 15 cm white card. Two identical cards were constructed for each picture. The stimulus presentations were controlled by E, who sat opposite S. The S placed his head against a head mask and looked into the exposure box. The viewing distance was approximately 76 cm for each field.

On the table before S was a rectangular response panel measuring 13 x 18 cm. The panel contained two response switches, one in each of the upper corners, and a start bar 7.6 cm long, centered 3.2 cm from the lower edge. The S depressed the start bar with his thumbs and used his right and left index fingers to depress the right and left response switches, respectively. One half of the Ss used the right-hand key for a positive response and the left-hand key for a negative response, and the other Ss used the reverse arrangement.

Procedure. Each S participated in one practice session and three test sessions of 120 trials each. Within each session, trials using interstimulus intervals (ISIs) of .3, 2.0, and 4.0 sec took place. The ISI was held constant for blocks of 10 trials and changed after each block, and no ISI was repeated until both remaining ISIs had been used in intervening 10-trial blocks. The order in which ISIs occurred was held constant within a session, and a Latin-square design was used to counterbalance the sequence of ISIs over sessions and Ss. Before each block of trials, S was told which ISI would be used during that block. Three practice trials preceded each session and, for those trials, the ISI was that used during the subsequent block of trials.

For each ISI, three types of positive trials (i.e., trials in which the two stimuli had the same name) could be defined. The two objects having the same name could be physically identical, leading to an identity match; mirror images of each other, called a mirror match; or neither identical nor mirror images but nevertheless having the same name. The latter condition will be referred to as a name match, to be distinguished from identity and mirror matches. Moreover, each of the three types of

Fig. 2. Mean RT in Experiment I as a function of interstimulus interval (ISI) for each positive response condition (identity, mirror, and name match), for stimuli from the S set (left panel) and the D set (right panel). Mean RT as a function of ISI for negative responses, averaged over both stimulus sets, is duplicated in both panels.

positive trials could be further broken down into two types according to the set of stimuli (S or D) involved in the trial. Identity matches could involve two successive presentations of either a member of an S pair or a member of a D pair. Mirror matches involved the presentation of a member of either an S or D pair, followed by the presentation of its mirror image. Name matches with the S set occurred when the two members of an S-set pair were presented in succession, and name matches with the D set occurred when the two members of a D-set pair were presented. Thus, in no instance was one member of a pair presented during a single trial with the mirror image of the other member of that pair.

Within each session for each ISI, positive and negative trials occurred equally often. Within the positive trials of each session for each ISI, identity matches, mirror matches, name matches with S pairs, and name matches with D pairs occurred with equal frequencies. All stimuli occurred approximately equally often in identity and mirror matches. This distribution of trials insures that one half of the positive trials involved pairs of stimuli having identical physical features (within a mirror-image reversal) and one half involved stimuli having different features.² Within the distributional constraints, trial types were randomly arranged. Moreover, within the constraints on the selection of the first and second stimuli imposed by the distribution of trial types, stimuli were randomly selected for each trial.

At the start of each session, S viewed and named each of the 48 pictures used as stimuli. Each trial consisted of the following sequence of events: (a) S pressed the start bar and a fixation field composed of four black dots forming the vertices of a 4.4-cm square appeared in the center of S's viewing area for 1.0 sec. (b) The square vanished and the first picture appeared for .5 sec within the position defined by the dots. (c) The picture vanished and the fixation field reappeared for the interstimulus interval. (d) The field vanished and the second stimulus appeared either for .5 sec or until S responded, whichever time was less, in the same position as the first. (e) S pressed the positive response switch if the two pictures had the same name and the negative response switch if they did not. (f) E informed S if an error had been made and then inserted the stimuli for the next trial. Reaction time, defined as the interval between the onset of the second stimulus and S's response, was recorded on each trial.

Results

The principal data are mean RTs in milliseconds. The

data analysis includes correct responses only. The Ss were instructed to make as few errors as possible and the error rates over Ss ranged from 1.4% to 6.1%, with a mean of 2.9%. The data from the practice session for each S were not included in the analysis; RTs from the three practice trials of each subsequent test session were also excluded from analysis.

Figure 2 presents RT as a function of ISI for each set of stimuli (S and D), for each type of match (identity, mirror, and name). For negative responses, RTs were combined over all stimuli and are duplicated in both panels of the figure. The figure shows mean RT over all Ss; there appeared to be no consistent differences in the form of the RT functions resulting from the designated location of the positive and negative response keys.

The data of Fig. 2 can be examined for differences in RTs corresponding to the types of positive responses and differences between RTs for the two sets of stimuli (S and D) within the response types. The first examination reveals that there is essentially no difference between mirror- and identity-match RT. In fact, over all ISIs, the mean difference in RT for the two conditions is 1.0 msec for each stimulus set. There are differences between name- and identity-match RTs, however, conforming to the trends usually observed when letters are used as stimuli in this paradigm (e.g., Posner, 1969). Specifically, identity matches are faster than name matches at the ISI of .3 sec, but identity-match RT increases relative to name-match RT as the ISI increases to 4.0 sec. The mirror matches exhibit the same trend relative to name matches as do the identity matches.

When the data of Fig. 2 are examined for differences between the two sets of stimuli, no differences are obtained for the mean name-match RT pooled over ISIs. However, a difference between the S and D sets is obtained for identity matches. The mean RT for identity matches with S pairs is less than the corresponding RT for D pairs (over ISIs, $p < .05$ by sign test). Although the mirror matches exhibit the same trend as the identity matches with respect to differences between the two stimulus sets, the differences are not significant for mirror matches.

The data in Fig. 2 also show differences between the two sets of stimuli with respect to the relationship between name- and identity-match RTs. In general, the difference between name and identity RTs decreases with increasing ISI. For all Ss the difference is greater for S pairs than D pairs at the ISI of .3 sec; moreover, at the ISI of 2.0 sec, the difference is still greater than zero for S stimuli ($p < .05$ by sign test) but not for D stimuli.

Discussion

The results of this experiment generally conform to previous results with this paradigm (Klatzky, 1972; Posner, 1969). In particular, at the shortest ISI there is a marked difference between identity and name matches, and the advantage of identity matches decreases to essentially zero as the ISI increases to 4.0 sec. The decrease in the identity-match advantage is primarily due

to a corresponding increase in identity-match RT; in contrast, RT for name matches does not vary consistently with ISI. The U-shaped functions relating name-match RT to ISI which are apparent in Fig. 2 have been observed in previous work with this paradigm (Posner, 1969). The negative response RTs also resemble commonly obtained results. Although differences between name-match and negative response RTs are not invariably found (e.g., Klatzky, 1972), such differences are often obtained in the same-different judgment paradigms, particularly when stimuli are presented successively (Nickerson, 1972).

One important comparison to be made in this experiment is between the mean RTs for mirror vs identity matches, revealing no difference between the two conditions. The RT advantage for identity matches relative to name matches has typically been taken to indicate that identity matches involve visual codes. The lack of difference between identity- and mirror-match RT, therefore, suggests that mirror matches also involve visual codes. Moreover, it indicates that Ss are able to use visual codes to decide that two mirror-image stimuli are members of the same object category as quickly as they make the corresponding decision for identical stimuli.

The close correspondence between mirror- and identity-match RTs suggests that the same visual code is used for both types of comparison. It might be concluded, therefore, that the code does not include information about orientation. However, that need not be the case, for orientation can be the basis for positive vs negative responses in paradigms like the present one (Cooper & Shepard, 1973a; Elias & Kinsbourne, 1972). On the basis of those findings and other research, it seems plausible that the visual code retains orientational information but that mirror-image matching involves a specialized comparison process, one that is not affected by differences in orientation.

Several facts suggest that Ss may use some orientation-independent comparison process for mirror matching. The ability to compensate for changes in stimulus orientation has been demonstrated in many situations (e.g., Cooper & Shepard, 1973b; Rock, 1956). In fact, children often fail to distinguish between a stimulus and its mirror image (Arnheim, 1954; Gibson, Gibson, Pick, & Osser, 1962). Neisser (1967) suggests that children fail to discriminate mirror reversals because they use as the basis for their decision features that do not depend on orientation (e.g., curve or right angle). A similar mechanism has been proposed in theories of adult pattern recognition (see Neisser, 1967).

It is possible that mirror matching is relatively easy in the present case because the stimuli include features which may be relatively unaffected by mirror reversal (e.g., the contrast in the stripes of the zebra), even though reversal changes the overall shape of the stimulus. If such features are compared, reversal might not affect the matching process. One implication of this

hypothesis is that identity and mirror matching do not involve simple template comparisons. Moreover, it implies that the visual codes used for such matches retain information about features but do not necessarily resemble the stimulus in some isomorphic sense.

The preceding discussion of mirror comparisons implies that the observed relative ease with which mirror matches are performed is somewhat dependent on the class of stimuli being compared—in this case, common objects. One characteristic of these stimuli is that they are visually detailed relative to letters and other simple stimuli. They thus have many visual features which could be candidates for orientation-independent matching. This may help to explain why, for other stimuli, mirror matching can lead to increments in RT relative to identity comparisons (e.g., Bradshaw, Nettleton, & Patterson, 1973). Second, objects like those used here are commonly experienced in many orientations, unlike other stimuli such as letters. For this reason, experience with the stimuli may affect mirror-matching ability. In an experiment of Kellicutt, Parks, Kroll, and Salzberg (1973), for example, RT for identity matches of mirror-reversed letters was found to be greater than identity- and even name-match RT with normal letters. These results emphasize the role of stimulus class and suggest that the present data would not be obtained with letter stimuli. In addition, analysis of the present data also suggests that experience with these object stimuli affects mirror matching. There is a small but consistent change in the pattern of mirror vs identity RT over test sessions, with seven out of eight Ss showing a decrease in the difference between mirror- and identity-match RTs from the first session to the third.

Another hypothesis which might be proposed for mirror-image comparisons is that S rotates one stimulus around its vertical axis and then judges it for identity with the other. The present data indicate that, if rotation were occurring, it could not be the case that it occurred after an initial comparison for identity had failed, because in that case mirror- and identity-match RT would differ by rotation time plus an identity comparison time. However, it might also be possible for S to perform the rotation prior to making any comparison, for example, during the ISI. In that case, rotations would have to occur very quickly, for, even at the shortest ISI (.3 sec), mirror and identity RTs are essentially the same. However, the data from studies of mental rotation (Cooper & Shepard, 1973a) indicate that relatively few 180-deg rotations of letters take place in 300 msec or less. And even if rotation could occur, the data indicate S would have to retain a visual code of the first stimulus in its original form, as well as rotate it, and then compare both forms to the subsequent stimulus either exhaustively or in random order. For these reasons, the rotation hypothesis does not seem to be a viable one.

In terms of the focal questions of this research, the results of the mirror-match condition provide the basis

for several inferences about comparisons of common-object pictures. The correspondence between mirror and identity RTs, together with the difference between those values and the name-match RTs, indicate that nonidentical (i.e., mirror-image) stimuli can be compared on a visual basis. However, at this point that inference is restricted to mirror-image comparisons, which may involve a specialized process. Although the results of the mirror manipulation cannot provide a more general statement about the use of visual codes in comparisons of nonidentical objects, they further suggest that the codes used for mirror matching retain information about specific visual features of the stimuli and that identity and mirror matching do not involve template comparisons.

The second major RT comparison in this experiment involves the effects of structural similarity. These comparisons are between RTs for name matches with the two sets of stimuli, S and D. If name-match RT were less for S pairs than for D pairs, this could be construed as evidence for the operation of visual codes in the name-matching process. In particular, this result would indicate that name matches to some extent involve visual codes which can take advantage of the similarity between members of S pairs. In contrast, the absence of a difference between RTs for S and D stimuli would suggest that configurational properties like those which relate S pairs were of little use in name matches. The lack of effect could occur because name matches were based on verbal labels; however, it could also occur if their basis was abstract visual forms which did not retain those properties.

The data of Fig. 2 do not show an effect of the S vs D manipulation on name-match RT in this experiment. Instead, the predicted effect is found for identity-match RT; that is, RT for the S set is found to be less than RT for the D set within identity matches, not name matches. Furthermore, the difference between name- and identity-match RT decreases more slowly (over ISI) for S-set stimuli. These results are open to several interpretations. For one thing, the observed RT differences between stimulus sets might reflect inherent differences other than the differential similarity within pairs in the two sets. For example, S-set stimuli might be visually less complex. Although such an explanation cannot be conclusively negated in this experiment, certain considerations make it seem unlikely. Differences such as complexity should be reflected not only in identity-match RTs but also in name-match RTs, because their effects on encoding time should occur on both types of trials. In addition, complexity differences might be expected to interact with ISI (Snodgrass, 1972), but the identity-match RT differences between stimulus sets do not appear to vary with ISI.

The preceding arguments suggest that it is the similarity manipulation which produces the RT difference in identity matches with the two sets of stimuli. Since the similarity conditions are primarily

intended to affect name matches, this effect is somewhat unexpected. A discussion of the effect is deferred until Experiment II has been described, however, since the second experiment provides a clarification of the differences between stimulus sets. In addition, it is somewhat unclear why name matches are not affected by the S vs D manipulation. One possibility is that under less complex experimental conditions, a name-match difference between stimulus sets might appear. There is also the possibility that the mechanisms involved in mirror matching are incompatible with the use of visual codes for name matches.

In order to clarify these questions, Experiment II was conducted. In the second experiment, mirror matches were eliminated; the positive response conditions retained from Experiment I were those of identity matches and name matches. Moreover, three kinds of experimental sessions were used. During pure identity sessions, only pairs of identical stimuli were presented to elicit positive responses; on no trial were nonidentical same-name stimuli presented. During pure name sessions, positive responses were elicited only by presenting two differing stimuli having the same name, never by presenting two identical stimuli. Third, mixed sessions involved both identity and name matches, randomly interspersed with negative trials. The pure identity sessions were intended to determine whether the two sets of stimuli differed in characteristics affecting visual encoding. If such differences existed, RTs for the two sets should differ in these sessions. The pure name and mixed sessions, with mirror matches eliminated, were designed to determine whether visual codes could be used for name matching in simplified situations, as well as to replicate the identity-match results of Experiment I.

EXPERIMENT II

Method

Subjects. Eight students enrolled for the spring or summer session at the University of California, Santa Barbara, served as Ss. There were four males and four females.

Stimuli. The stimuli were a subset of those used for Experiment I. Specifically, one pair of stimuli for each name used in Experiment I was retained for Experiment II, and the mirror images of those stimuli were eliminated from the stimulus set. As a result, there were two pictures representing each of 12 names. Half of the same-name pairs were from an S set; the remaining pairs formed a D set. The S and D sets were those defined in Experiment I.

Apparatus. The apparatus was the same as that used for Experiment I.

Procedure. Each S participated in one practice session of 90 trials and seven test sessions of 120 trials each. The structure of a single trial was like that of Experiment I. The test sessions were of three types, defined according to the types of positive trials (i.e., trials on which the two stimuli presented had the same name) that could occur. During identity sessions, positive trials involved identity matches only, that is, two identical stimuli were presented. During name sessions, positive trials were name matches, that is, the two stimuli presented were nonidentical stimuli having the same name. During mixed sessions, both

identity and name matches were used for positive trials. In all sessions, positive and negative trials occurred equally often and trial types were randomly mixed. Stimuli were randomly selected for each trial, within the constraints that stimuli from the S and D sets were used approximately equally often and those imposed by the distribution of trial types.

For each S the practice session consisted of 30 consecutive trials in each of three blocks. One block used the procedure of identity sessions, one used that of name sessions, and one used that of mixed sessions. During each block, there were 10 trials using each of the three ISIs to be used in test sessions. The practice session was followed by two identity sessions, two name sessions, and three mixed sessions. The order of test session types was counterbalanced across Ss and days, with the stipulation that no S used the same session type on 2 consecutive days.

During each test session, three ISIs were used: .3, 1.75, and 4.0 sec.³ The order of ISIs was determined in the same manner as for Experiment I. That is, the ISI was held constant for 10-trial blocks and ISIs were rotated within each session. The sequence of ISIs was counterbalanced over sessions and Ss. As in Experiment I, three practice trials preceded each test session, using the same ISI as the first 10-trial block.

At the beginning of each session, S viewed and named the 24 pictures used as stimuli. The S was told what type of session (identity, name, or mixed) was to occur before it began, and S was told which ISI would be used at the beginning of each block of trials.

Results

The principal data are mean RTs in milliseconds. Practice sessions and the three practice trials preceding each test session were excluded from data analysis. Trials on which errors occurred were also excluded; however, an extra trial of the same type was presented some time later during the same block of trials. Individual error rates ranged from 2.2% to 4.0%, with a mean of 3.1% over Ss. As in Experiment I, there was no consistent effect on RT due to the designated location of the positive and negative response keys.

Figure 3 presents mean RT as a function of ISI for each response condition (positive identity, positive name, and negative) and each stimulus set (S and D) for positive responses, for pure (name and identity) and mixed sessions.⁴

For both the identity and name sessions, there is no significant difference between RTs for the stimulus sets (S vs D). For the mixed sessions, there are significant differences between the two sets of stimuli in name-match RT [over ISIs, $t(7) = 2.3$, $p < .05$] and in identity-match RT [over ISIs, $t(7) = 3.2$, $p < .01$]. The effects of stimulus type are also apparent in the differences between name- and identity-match RTs for the two sets of stimuli in mixed sessions. At the .3-sec ISI, both sets of stimuli show greater name-match RT than identity-match RT [$t(7) = 3.7$, $p < .01$ for the S set and $t(7) = 4.2$, $p < .01$ for the D set]. At the 1.75-sec ISI, however, name-match RT is greater than identity-match RT only for the S set [$t(7) = 2.4$, $p < .05$]. At the 4-sec ISI, neither stimulus set shows a difference between name- and identity-match RT; however, there is at that ISI a difference between name-match RT for the two sets [$t(7) = 2.0$, $p < .05$].

Fig. 3. Mean RT in Experiment II as a function of interstimulus interval (ISI) for each response condition (positive identity, positive name, and negative), each stimulus set (S and D) for positive responses, and for pure (left panel) and mixed (right panel) sessions.

Comparisons across session types reveal no differences between mean identity-match RT for pure vs mixed sessions or between mean name-match RT for pure vs mixed sessions. However, there is a difference between mean name-match RT for pure name sessions and that of name matches with the D set in mixed sessions [$t(7) = 5.5$, $p < .01$]. There is a similar difference between mean identity-match RT for identity sessions and that of D-set identity matches in mixed sessions [$t(7) = 3.2$, $p < .01$].

Discussion

The data of this experiment, like those of the first, generally replicate previous results with the matching paradigm (Posner, 1969). In addition, the identity-match difference between the two sets of stimuli (S and D) that was obtained in the first experiment is replicated in the present mixed-session data. In fact, differences between the sets are extended to the name-match conditions of mixed sessions. However, no differences between stimulus sets is obtained for the RTs of pure identity and pure name sessions, a result which supports the view that the stimulus sets do not differ in the time required to perceive and encode the stimuli. For this reason, the observed differences between S and D stimuli in mixed-session RTs seem attributable to visual similarity effects. Since visual similarity affects comparison time for pairs of objects, it seems reasonable to infer that comparisons are visual in nature. That appears to be the case for nonidentical as well as identical pairs of objects.

Given the view that the name matches utilize visual information, it might be thought that a source of that information is the short-term visual code of the first stimulus presented on the trial. That is, S could retain a short-term trace of the first stimulus presented and then

attempt to compare that trace to the second stimulus when it appeared. Under these conditions, a difference between stimulus sets in terms of name-match RT could be obtained, because the similarity between first and second stimuli in the case of S-set pairs could facilitate the comparison process.

This hypothesis, however, does not explain why identity-match RTs show a difference for mixed sessions. It would not predict such an identity-match difference, for the visual code of the first stimulus and an identical second stimulus should match equally well for both stimulus sets. This theory might be modified to explain the identity differences; specifically, it could postulate a difference between the sets of stimuli with respect to encoding and retention of the first stimulus presented on the trial. Possibly S could learn that the retained visual code of an S-set stimulus would be more useful for subsequent name matching than the corresponding code for D-set stimuli. In that case, S might encode the two sets of stimuli differently, encoding S stimuli in such a way that the short-term visual trace lasted longer and was more useful for identity comparisons as well as name matching. With this modification, the theory could account not only for the observed mixed-session differences between the two sets of stimuli in name-match RT but also for the identity-match differences and differences in the relationship between name- and identity-match RTs over ISIs. Moreover, the assumption of differential encoding is not implausible, for encoding variations have been found to correspond to experimental requirements and S's expectations (Frost, 1972).

The hypothesis just discussed could be called the one-code theory, because it attributes the observed similarity effects on RT to the short-term code of the first stimulus presented on a given trial. Since it is that code which is used for both identity and name matching, the hypothesis would predict that the two types of matches should vary in the same way with ISI. This prediction causes a problem for the theory. The observed identity-match RTs increase with ISI, a result which can be attributed to a weakening over time of the visual code of the first stimulus. There should be a corresponding increase in name-match RT according to the one-code theory; however, no increase is observed. For this reason, the assumption that a single visual code underlies both identity and name matching does not appear to be viable.

These difficulties with the one-code theory lead to the conclusion that identity and name matching involve different stimulus representations. This indicates a two-code hypothesis. Since it has been argued that name matching involves a visual code, it can be assumed that the visual codes which underlie name and identity matches differ. Furthermore, the facts that name-match RT is greater than or equal to identity-match RT and does not vary with ISI suggest that the visual code used for name matching is abstract, relative to that used for

identity matching. The increase in identity-match RT to meet name-match RT at the 4-sec ISI further suggests that the short-term code used for identity matches comes to resemble the more abstract name-matching code over time. One further aspect of the two-code hypothesis is dictated by the findings that the similarity manipulation affects both name and identity matches in the mixed sessions and that the similarity effects obtained in mixed sessions are not observed in pure sessions. These results indicate that the name- and identity-matching processes are interdependent. That similarity effects are not observed in pure sessions may indicate that, when task demands are sufficiently low (use of just one code is required), all stimuli can be matched equally well, regardless of similarity.

A more specific form the two-code hypothesis could take is to propose that S anticipates, or generates, the second stimulus when the first stimulus is presented on the trial. Specifically, in mixed sessions S might use the ISI to anticipate the alternate member of the same-name pair to which the first stimulus belongs, at the same time maintaining a visual code of the first. The generated second stimulus could affect name matches, and the short-term visual code of the first stimulus could be used for identity matching. This hypothesis is in accord with some Ss' reports that they try to imagine the alternate same-name stimulus during the ISI.

In the present context, the generation and maintenance processes might vary in difficulty according to the set from which the stimulus pair is taken. In the case of S-set pairs, S would generate a stimulus similar to the just presented object; in the D-pair case, the generated stimulus would be different. The data indicate, with respect to this hypothesis, that the difficulty in the D-set case of anticipating the second stimulus and simultaneously maintaining a dissimilar first stimulus creates interference with both processes relative to S-set stimuli. The effect on the short-term visual retention of the first stimulus is reflected in the observed difference between the sets in identity-match RT as well as in the function relating name- minus identity-match RT to ISI. The effect on the generated second stimulus is reflected in the fact that RT for name matching with S stimuli is less than for the D set.

The hypothesis that it is interference generated by simultaneous maintenance and generation of differing visual codes which produces differences in RTs for S and D stimuli is supported by comparison of pure and mixed sessions. Specifically, for both identity and name matches, RTs for pure sessions with both sets of stimuli are comparable to S-set RTs in mixed sessions and less than those of D-set mixed-session RTs. It can be proposed that differences between RTs for S and D stimuli are nonexistent in pure sessions because Ss need to use only a single visual code, either maintained (in identity sessions) or generated (name sessions). The use of a single code eliminates the interference produced by using two. Moreover, that the difference between mixed

and pure sessions is primarily in the D set indicates that the interference is greater in that set. Apparently, little interference is produced when visually similar (S-set) stimuli are simultaneously maintained and generated.

It should be noted that the term "generate," as used here, does not imply that S produces an internal picture which is then compared as a template to a subsequently presented stimulus. Its use is in a less restricted sense; for example, generation could involve the formation of expectancies about stimulus features which are subsequently verified or violated. Alternatively, it could involve the activation of some prototypical representation or schema (as postulated, e.g., in Franks & Bransford, 1971; Posner & Keele, 1968; Reed, 1972). In that sense, generation could involve representations that are quite abstract relative to pictures.

CONCLUSIONS

The research reported here focuses on questions about visual comparisons of common objects. One concern is whether common objects that are not physically identical can be compared on a visual basis, even under circumstances where comparisons could utilize verbal labels. An affirmative answer to this question has been indicated in two experimental contexts: where the compared objects are mirror images of each other, thus having feature identity but orientational differences, and where the objects are similar in form but do not have feature identity.

The second issue addressed in these experiments concerns the nature of the visual information contained in the memorial representations, or codes, of such stimuli. In the context of the first experiment, it was argued that the visual codes of object pictures retain information about visual features but are not isomorphic copies of the stimuli. In the case of the second experiment, evidence was found favoring the use of visual codes more abstract than those assumed to be used for matching of identical or mirror-image pairs of pictures. The RT data suggest that the codes initially used for identity matching come to resemble these more abstract codes over time.

Finally, the results of these experiments indicate that experimental context can be an important determiner of the memorial codes which are used in matching pictures of objects. Mirror-image matching was found to be facile under conditions where more generic similarity did not facilitate name-match RT (Experiment I), and structural similarity benefited name-match RT only when mirror matches were not present in the experimental conditions (Experiment II). The effects of similarity were also found to vary between pure and mixed sessions. These results strongly suggest that the maintenance and use of various kinds of visual information in stimulus matching varies with the task demands as well as the nature of the stimuli and the time course of the comparison process.

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NOTES

1. In order to estimate shape similarity, each stimulus was superimposed on a grid of .32-cm squares so that it occupied a minimum number of squares. Its perimeter was then redefined as the outer border of squares it intersected. The shape similarity of a pair of stimuli thus defined was the percent of total area of the two stimuli which intersected when the two were superimposed in their orientation of presentation. The superposition maximized the overlapping area. Two raters independently calculated the measure; for each, S-set pairs were more similar than D-set pairs (by rank test, $p < .01$).

2. This has the effect of distributing identity, mirror, and

name matches in the ratio 1:1:2. However, of greatest importance in this experiment are comparisons between the S and D stimuli and between mirror and identity matches. Since each type of stimulus was used with approximately equal frequency within each match type and identity and mirror matches occurred equally often, these comparisons are not affected by the distribution of trial types.

3. The 1.75-sec ISI replaced the 2.0-sec ISI of Experiment I. This change was adopted because the difference between name- and identity-match RTs for D stimuli reached zero at 2.0 sec in Experiment I. The 1.75-sec ISI was used in an attempt to define more closely the point at which identity-match RT reached name-match RT for D-set stimuli.

4. The negative response RTs for pure sessions can be further broken down according to session type: name and identity. The RTs are 396, 424, and 436 msec and 426, 440, and 452 msec for the .3-, 1.75-, and 4.0-sec ISIs of identity and name sessions, respectively. The name-session negative RT is greater than identity-session negative RT [$t(7) = 2.2, p < .05$].

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