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Individual differences in the verbal coding of familiar visual stimuli

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Two experiments were performed both of which involved the same-different comparison of pairs of alphabet letters. "Same" reaction times were obtained for both physical matches (e.g., AA) and name matches (e.g., aA). The results of both experiments supported the hypothesis that individual subjects would differ with respect to whether or not they based their physical matches on a comparison of verbal codes. In Experiment I, subjects differed in the size of their reaction time difference between physical and name matches, and in Experiment II, individuals differed with respect to whether or not the frequency of usage of the letters affected their reaction time for physical matches. In both experiments, the individual differences in verbally coding physical matches were related to Hock's (1973) individual differences distinction between subjects emphasizing analytic processes and subjects emphasizing structural processes.

Recent research by Hock (1973), and Hock, Gordon, and Marcus (1974) has provided evidence for individual differences in the processing of visual information. In Hock's (1973) study, which involved the same-different comparison of pairs of dot patterns, a significant positive correlation was obtained between the effects of symmetry (symmetrical vs. asymmetrical patterns) and rotation (familiar vs. rotated-familiar patterns) on "same" reaction time. Based on the hypothesis that structural processes involve the use of rules (i.e., symmetry) to organize the parts of a stimulus into a well-formed whole, Hock concluded that subjects with large symmetry effects (as well as large rotation effects) had emphasized a structural mode of processing. Based on the hypothesis that analytic processes involve the decomposition of the stimulus information into features, rather than the organization of the information into wholes, Hock concluded that those subjects with small symmetry effects (as well as small rotation effects) had emphasized an analytic mode of processing.

In a subsequent study, Hock, Gordon, and Marcus (1974) examined individual differences in the detection of embedded alphabet letters. Subjects with large rotation effects for pairs of intact letters were inferred to emphasize structural processes; emphasis on analytic processes was inferred for subjects with small rotation effects. As hypothesized, the analytic subjects detected the embedded figures more rapidly than the structural subjects. This was the case when the target letter and embedded letter were physically identical (e.g., A, A), and when they were physically different but had the same name (e.g., a, A).

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The present study was concerned with whether analytic and structural subjects differ with respect to the verbal coding of familiar visual stimuli in a same-different comparison task. According to Bruner's (1957) theory of perceptual readiness, which focuses on feature analysis as the basic perceptual process, the categorization or identification of familiar stimuli is inferential in nature. This means that the identity of a stimulus can be inferred by attending only to its distinctive or criterial features and ignoring its irrelevant features. In this way, subjects emphasizing analytic processes could achieve efficiency in a same-different comparison task by identifying each member of the same-different stimulus pair with a minimal amount of perceptual processing, and basing their response on a comparison of verbal codes rather than a perceptual comparison of the letters.

While Bruner's theory shows how analytic processes could lead to perceptual efficiency by minimizing the amount of stimulus information that must be processed enroute to coding verbally a familiar stimulus, it has been contended that structural processes involve organizing *all* the information in a stimulus into a whole. This contention, which has been supported by Hock (1973), and Hock, Gordon, and Marcus (1974), implies that efficient verbal coding cannot be achieved by minimizing perceptual processing, as hypothesized for analytic processes. This does not mean that verbal coding cannot result from structural processing. Rather, it suggests that subjects emphasizing structural processes would perform most efficiently in a same-different task if their responses were based on a comparison of visual information, structured into well-organized whole, rather than a comparison of verbal codes.

Individual differences with respect to the verbal coding of familiar visual stimuli were examined in two experiments. Both experiments were based on Posner and Mitchell's (1967) same-different reaction time task, with "same" responses required for both physical matches (e.g., AA) and name matches (e.g., aA). Of concern in both experiments were individual differences in the verbal coding of letters that were physically identical. In Experiment I, it was hypothesized that subjects emphasizing analytic processes would base their physical matches on a comparison of verbal codes, while subjects emphasizing structural processes would base their physical matches on a perceptual comparison of the letters. Since name matches require that all subjects, whether structural or analytic, base their responses on a comparison of verbal codes, it was predicted that analytic subjects would have a relatively small difference in response time between name and physical matches (they compare verbal codes for both types of match), while structural subjects would have a relatively large difference in response time between name and physical matches (they compare verbal codes only for name matches).

In Experiment II, the frequency of usage of alphabet letters was used as an indicator of the relative availability of verbal codes for each letter. It was predicted that frequency of usage would affect response times for both the physical and name matches of subjects emphasizing analytic processes, since these subjects were hypothesized to base both types of match on a comparison of verbal codes. For the subjects emphasizing structural processes, who were hypothesized to base physical matches on the perceptual comparison of the letters, it was predicted that frequency of usage would affect response times only for name matches, which require the comparison of verbal codes.

EXPERIMENT I

Method

Stimuli. The stimuli used in this experiment, as well as the experiment that follows, were pairs of black alphabet letters (24 pt Univers, 53 Letraset) on a white background. The letters were arranged horizontally, and subtended a visual angle of 1.5 deg (at the farthest points) when presented in a two-channel Scientific Prototype tachistoscope.

For half the stimuli, the two letters were of the same case: they were either both upper-case or both lower-case. For the other half, the two letters were of mixed case, with each case appearing equally often in the left- and right-hand positions of the stimulus. When the letters were of mixed case, they were always in normal typographic relation (e.g., "gG"; the lower portion of "g" descended below the base of "G"). Of the stimuli in which the letters were of the same case, half the pairs of letters were the same and half were different. These "same" stimuli constituted the physical matches in the experiment. Of the stimuli in which the letters were of mixed case, half the letters had the same name and half had different names. These "same" stimuli constituted the name matches in the experiment.

Design. Since letters were presented in either their normal orientation or rotated 180 deg into an unfamiliar orientation, letters that were invariant under 180 deg rotation were not used. The letters selected were A(a), E(e), F(f), G(g), R(r), and T(t).

Each subject received a different randomly mixed sequence of 96 stimuli. The stimuli were assigned to experimental conditions according to the orthogonal combination of three experimental variables: Same vs. different response, same vs. mixed case letters, and normal vs. rotated orientation, with 12 stimuli falling within each combination. Preceding the experimental trials, the subjects were shown demonstration stimuli and were given 16 practice trials.

Procedure. A small fixation dot was presented for 1 sec at the start of each trial. Following this, the stimulus was presented for a duration of 3 sec unless the subject responded, whereupon the display was terminated. The subjects were required to press a "same" button for both physical and name matches; when there was no match, the subjects were not to respond in any way. The subjects were instructed to respond as quickly as possible, while keeping their errors to a minimum. Reaction time from the onset of the stimulus display was the dependent measure of primary interest.

Subjects. Sixteen undergraduate and graduate subjects at Florida Atlantic University were paid $1.75 for participating in an experimental session lasting about 25 min.

Table 1
"Same" Reaction Time (in Milliseconds) and Percentage Errors for Experiment I

	Reaction Time		Percentage Errors	
	Same Case†	Mixed Case††	Same Case	Mixed Case
Normal	517	650	1.3	3.2
Rotated	592	784	2.4	4.2****

*Note—Each * indicates the inclusion of one error of omission.*
†Physical match ††Name match

Results

The mean reaction times and errors for the "same" responses of Experiment I are presented in Table 1. The effect of rotation (normal vs. rotated orientation), $F(1,15) = 17.08$, $p < .005$, the difference between the two types of match (physical vs. name), $F(1,15) = 30.13$, $p < .005$, and the interaction between orientation and type of match $F(1,15) = 5.01$, $p < .05$, were all significant. The overall error rate of 2.8% consisted almost entirely of errors of commission, which occurred slightly more often when the letters were in an unfamiliar orientation. There was no indication that the differences in reaction time between the experimental conditions could be attributed to differences in speed-accuracy criteria.

The primary hypothesis for this experiment concerned individual differences with respect to the generation of verbal codes. Emphasis on structural processes was inferred for subjects with large rotation effects (i.e., a large difference in reaction time between the rotated and normally oriented letter pairs); emphasis on analytic processes was inferred for subjects with small rotation effects. It was predicted that analytic subjects would verbally code both physical and name matches, while structural subjects would verbally code only name matches. This hypothesis was evaluated by correlating the effect of rotation and the difference between name matches and physical matches for each subject. The resulting correlation, which was based on the

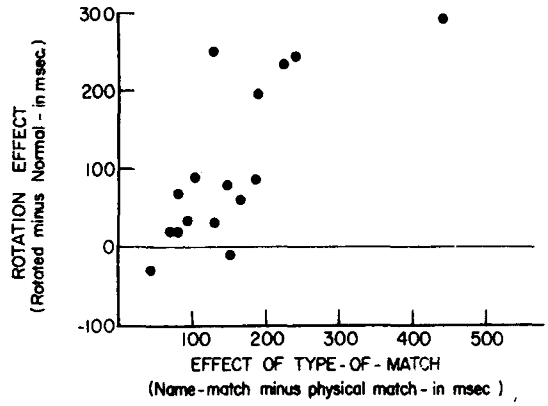

Figure 1. Scattergram for "same" responses of Experiment 1. Each dot represents one subject.

scattergram of Figure 1, was $r = 0.72$, $p < .01$. This correlation, however, was in part an artifact of performance level. That is, there was a tendency for the two terms in the correlation, the effect of rotation and the difference between the name and physical matches, to both increase proportionally for slower as compared with faster subjects. When performance level, as determined by each subject's reaction time for physical matches in the normal orientation, was partialed out (McNemar, 1962), the correlation coefficient was reduced to $r = .52$, which was still significant, $p < .05$.[1]

In order to examine more closely the difference between analytic and structural processing, the subjects were divided into two groups: The eight subjects with the largest rotation effects (structural subjects) were placed in one group, and the eight subjects with the smallest rotation effects (analytic subjects) were placed in the second group. The mean reaction times and errors for each group are presented in Table 2. As was the case in previous research (Hock, 1973; Hock, Gordon, & Marcus, 1974), analytic subjects were faster than structural subjects, $t(14) = 3.39$, $p < .01$. An examination of the errors gave no indication that differences in reaction time for the two groups were due to differences in speed-accuracy criteria.

Finally, interaction contrasts (effect of rotation on name matches minus the effect of rotation on physical matches) were computed for the subjects in each group. For the group of subjects emphasizing analytic processes, the interaction contrast was insignificantly different from zero, $t(7) < 1.0$, indicating that the rotation effect was equally small for both types of match. For the group of subjects emphasizing structural processes, the interaction contrast was significant, $t(7) = 3.27$, $p < .02$, indicating that the rotation effect was significantly larger for name matches than for physical matches.

The latter finding was consistent with the hypothesis that structural subjects base their physical matches on a perceptual comparison of the letters. When the letters were rotated, the physical matches could still be compared perceptually, even though the facilitative effect of familiarity on physical matches is lost, for structural subjects, when stimuli are rotated out of their normal orientation (Hock, 1973). Name matches, however, demand the verbal identification of the rotated letters. This would require that subjects emphasizing structural processes either mentally rotate the upside-down letters or else resort to a nonpreferred analytic mode of processing in order to identify them. In either case, the additional processing would result in the interaction observed for the structural subjects.

EXPERIMENT II

The results of Experiment I supported the hypothesis that analytic, but not structural, subjects base their physical matches on a comparison of verbal codes. In this experiment, it was predicted that the frequency of usage of alphabet letters would influence physical matches for analytic, but not structural, subjects. Since name matches require the comparison of verbal codes by all subjects, it was predicted that frequency of usage would affect name matches for both analytic and structural subjects.

Method

The stimuli used in this experiment were constructed in the same manner as in Experiment I. The procedure was also the same, with the exception that the duration of stimulus exposure was 1.0 sec in the present experiment. Responses not occurring within this interval were counted as omission errors. The exposure was reduced from the 3.0-sec duration of Experiment I in order to minimize the distortive effect of occasional long reaction times.

Two subsets of letters were formed on the basis of their frequency of usage (Underwood & Schulz, 1960). The high-frequency subset consisted of A(a), D(d), E(e), H(h), N(n), R(r), and T(t). The low-frequency subset consisted of B(b), F(f), G(g), J(j), M(m), Q(q), and Y(y). Physical and name matches were formed in the same manner as in Experiment I. "Different" stimuli were formed by drawing pairs of letters from within each subset.

Each subject received a different randomly mixed sequence of

Table 2
"Same" Reaction Times (in Milliseconds) and Percentage Errors for Experiment I, With Subjects Divided Into Two Groups According to Individual Differences

	Reaction Time		Percentage Errors	
	Same Case†	Mixed Case††	Same Case	Mixed Case
Analytic Subjects				
Normal	443	552	2.6	4.7
Rotated	476	571	2.6	2.1
Structural Subjects				
Normal	591	748	0	1.6
Rotated	708	997	2.1	6.3****

*Note–Each * indicates the inclusion of one error of omission.*
†Physical match ††Name match

Table 3
"Same" Reaction Time (in Milliseconds) and Percentage Errors for Experiment II

	Reaction Time		Percentage Errors	
	Same Case†	Mixed Case††	Same Case	Mixed Case
High Frequency	396	466	2.7*	2.5***
Low Frequency	402	494	2.7	2.2***

*Note–Each * indicates the inclusion of one error of omission.*
†Physical match *††Name match*

112 stimuli. The stimuli were assigned to experimental conditions according to the orthogonal combination of three experimental variables: same vs. different response, same vs. mixed case letters, and high vs. low frequency of usage, with 14 stimuli falling within each combination. The experimental trials were preceded by 16 practice trials.

Sixteen unpaid undergraduate students at Florida Atlantic University voluntarily participated in an experimental session lasting about 30 min.

Results

The mean reaction times and errors for the "same" responses of Experiment II are presented in Table 3. The difference between the two types of match (physical vs. name) was significant, $F(1,15) = 184.16$, $p < .005$, as was the effect of frequency of usage $F(1,15) = 8.14$, $p < .025$. The interaction between frequency and type of match was also significant, $F(1,15) = 4.79$, $p < .05$, with the frequency effect occurring primarily for name matches.[2] The overall error rate of 2.5% consisted almost entirely of errors of commission, which were evenly distributed across the experimental conditions. The correlation between overall speed and number of commission errors, $r = -.35$, though insignificant, indicated some tendency for subjects to trade-off speed for accuracy.

Although the difference in reaction time for physical matches between the high- and low-frequency subsets was quite small (6 msec), a letter-by-letter examination of the data indicated a significant effect of frequency of usage. This conclusion was based on the scattergram for physical matches presented in Figure 2, in which each point represents the reaction time for physical matches (averaged over all subjects) and the log frequency of usage for each letter.[3] The correlation coefficient based on this scattergram was significant, $r = -.58$, $p < .05$. Furthermore, the second scattergram of Figure 2, which involves response time for name matches, also resulted in a significant correlation, $r = .78$, $p < .01$.

Of concern was the possibility that the latter correlation between name matching and frequency of usage, as well as the difference in name matching reaction time between the subsets of high- and low-frequency letters (see Table 3), were due to fortuitously long reaction times (average of 650 msec) obtained for Q(q), the letter most extreme with respect to infrequency of usage. Before this possibility could be examined, it was necessary to account for differences in perceptual similarity between the upper- and lower-case versions of each letter. For example, since Q and q are perceptually dissimilar, name matches for Q(q) will tend to be slower than name matches for letters like Y(y), whose cases are perceptually similar, regardless of differences in frequency of usage. For this reason, subjective ratings of the similarity of lower-case and upper-case versions of each letter were obtained from a group of 18 subjects. The subjects rated the letter pairs (e.g., aA) on a five-point scale, with "1" indicating highly similar and "5" highly dissimilar.

For the scattergram involving name matches in Figure 2, a line of best fit for the six letters whose cases were judged to be perceptually dissimilar indicated that name matches for these letters, which included Q(q), were linearly related to frequency of usage. Since the names matches for Q(q) were "in line" with those of the other five letters, it could be concluded that the long reaction time obtained for this letter was not fortuitous. Similar results were obtained for the letters whose cases were judged to be perceptually similar. The line of best fit for these letters again indicated a linear relation between response time and frequency of usage. Taken together, the difference in reaction time between the two groups of letters (name matches, as expected, were faster for the letters with perceptually similar cases), along with the correlations between reaction time and frequency of usage within each group of letters, accounted for 88% of the variance in name matching reaction time.

Of primary interest were individual differences with respect to the effect of frequency of usage on physical

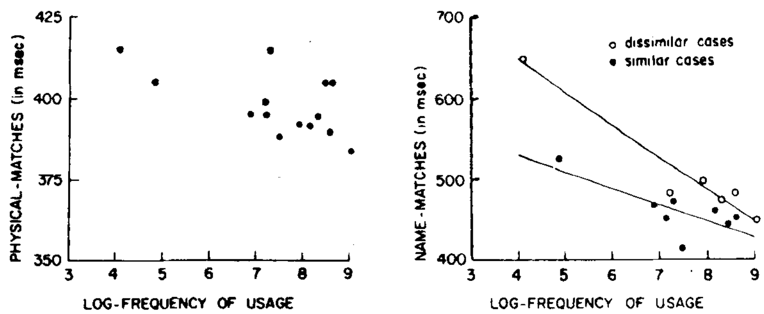

Figure 2. Scattergram for the physical matches and name matches of Experiment II, with each point representing the results for a single letter. For the scattergram involving name matches, two lines of best fit are drawn, one for the letters whose cases were judged to be perceptually dissimilar, and the other for the letters whose cases were judged to be perceptually similar.

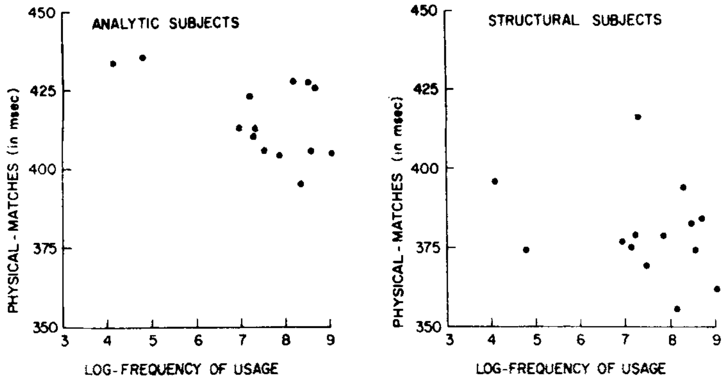

Figure 3. Scattergrams for the physical matches of Experiment II, with each point representing the results for a single letter. One scattergram is based on the data obtained for the subjects inferred to emphasize analytic processes, and the other for the subjects inferred to emphasize structural processes.

matches. Since the difference in reaction time between name matches and physical matches was found to be correlated with the effect of rotation in Experiment I, the former was used as a measure of individual differences in the present experiment. It was inferred that subjects with a small difference in reaction time between name and physical matches had emphasized an analytic mode of processing, while subjects with a large difference in reaction time between the two types of match had emphasized a structural mode of processing. Two groups of subjects were formed: The eight subjects with the smallest difference between name and physical matches (analytic subjects), and the eight subjects with the largest difference between name and physical matches (structural subjects).

One of the scattergrams of Figure 3 involves the reaction times of physical matches for each letter averaged over the group of analytic subjects; the other scattergram averages reaction times of physical matches over the group of structural subjects. The correlation between reaction time for physical matches and log frequency of usage was significant for the group of subjects inferred to emphasize analytic processes, $r = -.55$, $p < .05$, but was insigificant for the group of subjects inferred to emphasize structural processes, $r = -.26$, $p < .05$. In examining Figure 3, it should also be noted that unlike the results of Experiment I, as well as previous research (Hock, 1973; Hock, Gordon, & Marcus, 1974), analytic subjects were not faster than structural subjects on physical matches (the difference in speed between the two groups was not significant, $t(14) < 1.0$. This failure to replicate previous evidence that analytic subjects tend to be faster may have been due to differences in error rate, since analytic subjects in this experiment seemed to adopt more conservative speed-accuracy criteria than structural subjects.

Further analysis of the data, this time for name matches, indicated that reaction time and log frequency of usage were significantly correlated for the group of subjects inferred to emphasize analytic processes, $r = -.75$, $p < .01$, as well as the group of subjects inferred to emphasize structural processes, $r = .79$, $p < 01$. The scattergrams for the two groups of subjects both resembled the scattergram for name matches presented in Figure 2.

DISCUSSION

Evidence that "same" responses to pairs of physically identical stimuli involve verbal coding has been obtained by Klapp (1971) and Friden (1973), who have shown that "same" reaction time for pairs of identical two-digit numbers depends on the number of syllables in the verbal codes for the numbers.

The present study goes a step further in indicating that physical matches are based on a comparison of verbal codes only for subjects emphasizing analytic processes. In Experiment I, analytic subjects had a smaller difference in reaction time between name and physical matches than structural subjects, supporting the hypothesis that analytic subjects verbally code the letters in both physical and name matches, while structural subjects verbally code only name matches. In Experiment II, reaction time for physical matches was negatively correlated with log frequency of usage for analytic, but not structural subjects. Based on the assumption that frequency of usage affects the availability of verbal codes, the latter finding provides further support for the hypothesis that analytic subjects base physical matches on a comparison of verbal codes, while structural subjects base physical matches on a perceptual comparison of the letters.

In verbally coding physical matches, even though they could have based these responses on a perceptual comparison, the analytic subjects in Experiments I and II seemed to function in accordance with Bruner's (1957) theory, which emphasizes the efficient determination of the categorical identity of the stimulus. Bruner, furthermore, contends that the basis of this efficiency is being able to *infer* the identity of the stimulus on the basis of a minimal number of defining features. Whether or not analytic subjects identify familiar stimuli via inferential processes is currently under investigation in a task requiring subjects to make word-picture comparisons. Support for Bruner's theory will be obtained if the analytic subjects have faster "same" responses for general than specific names of the same picture.

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NOTES

1. The relationship between performance level, as measured by reaction time for physical matches in the normal orientation, and the terms in the correlation of Figure 1 was linear, with no apparent nonlinear component. If the outlying subject in the upper right-hand corner of Figure 1 were not included, the obtained correlation would have been $r = .71$, $p < .01$ ($r = .56$, $p < .05$, with performance level partialed out).

2. Pachella and Miller (1973), using a similar experimental paradigm, have found that the probability of occurrence of a letter within the experimental session affected the speed of name matches, but not physical matches.

3. Since frequency of usage data typically involve a logarithmic relationship between frequency and the dependent variable (e.g., Oldfield & Wingfield, 1965), the frequency of usage of each letter was subject to a logarithmic transformation. The log frequency values of Figures 2 and 3 are based on Underwood and Schulz's (1960) sample of 15,000 words.

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