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The effect of correlated linguistic dimensions on speeded classification of visually presented trigrams*

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The influence of two types of linguistic dimensions, word-nonword and consonant pronunciation, on classification speed of trigrams in card-sorting tasks of two levels of complexity was examined. In complex grouping tasks, which required the evaluation of more than one letter to classify each stimulus, sorting times were faster when the linguistic dimension was correlated with, rather than orthogonal to, the response categories. For tasks in which each stimulus could be classified on the basis of a single letter, no effect of the correlated vs orthogonal linguistic dimension was observed, even when performance was degraded by visual noise. These results provide further evidence that, while linguistic properties of visual stimuli may influence classification time in complex tasks, they are of little importance in the performance of tasks only requiring the discrimination of a single visual feature.

A variety of perceptual tasks using discrimination speed as the measure of performance have been used by psychologists to study the effects of redundant stimulus information and irrelevant stimulus information on processing of multidimensional stimuli. While much of this research has dealt with visual stimulus attributes such as brightness and saturation of color chips (Garner & Felfoldy, 1970), there has been considerable recent interest in the influence of linguistic and conceptual attributes of stimuli on discrimination or classification speed. Studies using various modifications of the Stroop color-word task, for example, provide illustrations of how the verbal encoding of irrelevant stimulus information can severely disrupt stimulus classifications, even in tasks which require no overt verbal response (Hock & Egeth, 1970; Dyer, 1973). An experiment by Morton (1969), in which the speeded classification of numerals was facilitated when the numerals were spatially repeated the same number of times as the value of the numerals (e.g., 1, 22, 333, etc.), provides an example of how correlated linguistic (or numeric) information from two sources can be integrated to increase classification speed. It is thus apparent that there are conditions under which redundant stimulus information resulting from verbal or conceptual encoding may increase classification speed, as well as circumstances in which the verbal encoding of irrelevant or competing stimulus information results in a large decrease in classification speed.

WHEN DOES VERBAL ENCODING ACTUALLY SAVE TIME IN MAKING CLASSIFICATIONS OF VISUAL STIMULI?

Verbal encoding of stimuli clearly requires a finite amount of time. For example, name matches of letters differing in case or style take longer than matches of

identical letters (Posner, 1969; Paley, 1973). These findings suggest that simple visual matches of stimuli which are potentially verbally encodable may occur at a preverbal level of encoding. Morton's (1969) results which demonstrated that Ss integrated numeric information from two sources, counting and reading, are thus of particular interest, since they paradoxically suggest that classification speed was actually increased by the use of a higher level of encoding than is logically required by the task.

However, classification tasks such as Morton's, in which stimuli are assigned to more than two response categories, impose a greater processing load than simple same-different matches and two-alternative discrimination tasks, due to the complexity of the response assignments. Processing loads are also present in classification tasks such as memory scanning (Sternberg, 1966), grouping, and condensation (Posner, 1964), since each of these tasks requires the mapping of stimuli into fewer response categories than the number of stimulus alternatives. Reductions in classification speed in such complex classification tasks may be attributable, in part, to the time required for a memory search to determine the correct response assignment. Thus, the performance limitations arising from the processing load are distinct from performance limitations arising from either energetic factors or stimulus similarity (Garner, 1970; Hodge, 1973).

One possible way in which the "extra" step of verbal encoding of stimulus information might result in an overall faster stimulus classification time is by reducing those performance limitations caused by the complexity of the response assignments. Numeric encoding of numerals, for instance, might serve to increase the stimulus-response compatibility in a card-sorting task such as that used by Morton (1969), since the positions of the response piles could be arranged in numeric order. In other complex classification tasks, such as one requiring the grouping of several visually different stimuli into only two response categories defined by a

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Table 1
Stimulus Classifications for the Sorting Tasks
Used in Experiment I

Type of Dimension	Grouping Tasks			Filtering Tasks		
Word-Nonword	WG1	rat	rit	WF1	rat	rit
		hit	dat		hat	dit
Orthogonal	WG2	rit	rat	WF2	rit	rat
		hat	dit		hit	dat
Hard-Soft Consonant	CG1	cif	kif	CF1	cif	kof
		sof	cof		sif	cof
Orthogonal	CG2	cof	kof	CF2	cof	kif
		sif	cif		sof	cif

single linguistic attribute (such as word-nonword), it seems likely that verbal encoding would facilitate speeded classification by reorganizing the task as a two-alternative *conceptual* discrimination. The amount of time saved by using verbal encoding to reduce the processing load would more than compensate for the time required for the verbal encoding of each stimulus.

On the other hand, in less complex tasks requiring the discrimination of only a single visual feature, classification speed is usually limited by the visual similarity of the stimuli rather than by the processing load. For highly discriminable stimuli, categorization in such "low-level"¹ tasks can probably be made, as Hock and Egeth (1970) have argued, on the basis of a rapid sensory comparison completed prior to verbal encoding. Simple discrimination tasks and matching tasks are typically not disrupted by the presence of irrelevant verbal information (Egeth, Blecker, & Kamlet, 1969; Triesman & Fearnly, 1969). Facilitation of such tasks from the presence of redundant verbal information would not be expected either, since the verbal encoding would take longer than the response generated from the visual comparison.

The present experiments were designed to explore the influence of redundant stimulus information, provided by two types of linguistic dimensions (word vs nonword and hard vs soft pronunciation of "c"), on the classification speed of visually presented trigrams in card-sorting tasks of varying degrees of difficulty. Experiment I was conducted to compare the effects of the linguistic dimensions on classification speed in tasks of two levels of complexity (high vs low processing load). Experiment II examined the effect of redundant linguistic information on classification speed in tasks having a low processing load, but for which three levels of task difficulty were obtained by varying visual discriminability.

EXPERIMENT I

Experimental Variables

Eight different sorting tasks corresponding to eight

experimental conditions were used in this experiment. These eight conditions resulted from the orthogonal combination of three experimental variables (types of linguistic dimension, task complexity, and the correlation between the linguistic dimension and the response categories). Each variable had two levels. However, each S provided data for four conditions, since the type of linguistic dimension was held constant for each S. All tasks required the sorting of four stimulus alternatives into two response categories. The classifications required for each task are shown in Table 1.

Linguistic Dimensions:

Word-Nonword (W) or Hard-Soft Consonant (C)

The W stimuli included the CVC word trigrams rat, hat, and hit and the nonsense trigrams rit, dit, and dat. The C stimuli included the "hard" trigrams cof, kof, and kif and the "soft" trigrams cif, sif, and sof. Each of the tasks used in this study required the sorting of either four W trigrams (two words and two nonsense) or four C trigrams (two hard and two soft).

Task Complexity:

Grouping (G) or Filtering (F)

In the G tasks, four trigrams were assigned to two response categories such that no single letter could determine the classification of each stimulus. For example, it can be seen from Table 1 that in Conditions WG1 and WG2 the classification of two of the four stimuli (those beginning with "h" and "d") can be determined by the first letter, but that the second letter must be evaluated as well in order to classify the other two stimuli (those beginning with "r"). Similarly, in Conditions CG1 and CG2, the stimuli beginning with "s" or "k" may be classified by the first letter alone, while the stimuli beginning with "c" require the evaluation of the middle letter.

In the F tasks, four trigrams were assigned to two response categories such that the middle letter ("i" vs "a" or "o") was perfectly correlated with the response category. Classification of every stimulus in the F tasks was thus possible by evaluating a single visual element. To the extent that Ss can "filter" or "gate" (Posner, 1964) the irrelevant elements, tasks of this type are equivalent to simple two-alternative discrimination tasks.

Correlation Between the Linguistic Dimension and Response Categories:

Correlated (Level 1) or Orthogonal (Level 2)

For Level 1, the linguistic dimension was perfectly correlated with the response categories. For Conditions WG1 and WF1, one category contained two words while the other category contained two nonwords. For Conditions CG1 and CF1, one category contained two

"hard" stimuli while the other category contained two "soft" stimuli. For the Level 2 tasks, however, the linguistic dimension varied orthogonally with the response categories. Conditions WG2 and WF2 thus contained one word and one nonword in each of the response categories, while Conditions CG2 and CF2 contained one "hard" and one "soft" stimulus in each of the response categories. In terms of *visual* features, however, the only difference between Tasks WG1 and WG2, and between CG1 and CG2, is that the middle letters have been interchanged with the first letters *within* stimulus categories. Similarly, the only difference between Tasks WF1 and WF2, and between CF1 and CF2, is that the first letters of two of the stimuli have been interchanged across response categories. Therefore, no change in the correlation of the linguistic dimension with the response categories affected the amount of correlation between letters and response categories.

Method

Stimulus Materials

Each stimulus consisted of a CVC trigram typed in lowercase on a white card. Each card was approximately 8.9 x 6.3 cm, with the longer side vertical and a small piece cut off the upper left corner to maintain proper orientation. On a single trial, S was required to sort a deck of 32 such cards (8 replicates of 4 stimulus alternatives) into two piles of 16 cards each, according to the classification scheme required by the experimental condition.

Subjects

For the W tasks, Ss were 12 undergraduate students who volunteered as part of a course requirement. For the C tasks, Ss were eight graduate students from the psychology department who received \$3.50 for participation. Ss were run in a single session lasting about 1½ h.

Procedure

Before beginning the experiment, each S was shown examples of every trigram included as a stimulus alternative in each of the tasks he was to perform. These trigrams were also pronounced aloud by E. Prior to beginning each trial, each deck was shuffled and examples of the stimuli which belonged in each response category were laid out in front of S. S then held the deck in one hand and, on the spoken signal of "Ready, set, go," dealt the cards into the piles corresponding to the examples which were left in view. Each S was instructed to sort "as rapidly as possible without making errors." Sorting times were timed by a stopwatch. Both sorting time and errors were recorded after each trial. Ss were given feedback of both sorting time and errors on each trial.

Each S was run in 12 blocks of four trials each. Each block included a single trial on each of the four different experimental conditions administered to each S. Order of presentation within each block was determined by assigning each S to a row of a 4 by 4 Latin square. The first block of trials was used to familiarize each S with the tasks; only data from Blocks 2-12 were included in analysis.

Results

The overall mean sorting times for all conditions and

Table 2
Mean Sorting Times and Error Rates Per Deck of
32 Cards for Each Condition in Experiment I

Stimuli	Grouping Tasks		Filtering Tasks	
	WG1	WG2	WF1	WF2
Word-Nonword	18.02 (.205)	19.87 (.333)	14.81 (.023)	14.77 (.038)
	CG1	CG2	CF1	CF2
Hard-Soft Consonant	19.80 (.205)	21.29 (.193)	14.63 (.046)	14.62 (.046)

Note—Main cell entries are mean sorting times in seconds; values in parentheses are mean number of errors per deck of 32 cards.

error rates per deck of 32 cards (based upon 11 experimental trials) are presented in Table 2. As in previous card-sorting studies (e.g., Flowers & Garner, 1971), errors were much too infrequent to warrant further analysis. Figures 1 and 2 plot the mean sorting times for each experimental condition as a function of trials. These graphs clearly indicate a decrease in sorting time across trials for each condition which is statistically significant ($.0001 < p < .01$ by analysis of variance). Primary interest is, however, in the effect of the correlated vs orthogonal linguistic dimensions on sorting time.

The effect of the correlated vs orthogonal word-nonword dimension on sorting speed can be evaluated by comparing the sorting times of the two grouping tasks WG1 and WG2 and the two filtering tasks WF1 and WF2. As Fig. 1 illustrates, the mean sorting time across Ss for Condition WG1 was faster than for WG2 on all 11 trials. The statistical significance of the faster sorting speed for WG1 is substantiated by analysis of variance [$F(1,11) = 15.1$, $p < .01$] and by the fact that the overall mean sorting time for WG1 was faster than for WG2 for all 12 Ss. While the magnitude of this difference interacts with trials [$F(10,110) = 3.54$, $p < .01$], this may largely be a consequence of the main effect of the linguistic dimension providing differing amounts of room for improvement across trials. The faster sorting speed for WG1 is still evident on Trial 12 (where WG1 is faster for 10/12 Ss with one tie, $p < .01$ by sign test), and while it cannot be determined whether or not the effect would disappear with extensive practice, no crossover trends are indicated.

The filtering conditions WF1 and WF2 were sorted considerably faster (as expected) than the grouping conditions WG1 and WG2. Unlike the grouping tasks, however, there is no evidence that the sorting times for the filtering tasks were influenced by the correlation of the linguistic dimension. The overall mean sorting time for WF1 did not differ significantly from WF2 [$F(1,10) < 1$], and this lack of significance is emphasized by the fact that only 6/12 Ss sorted WF1 faster than WF2.

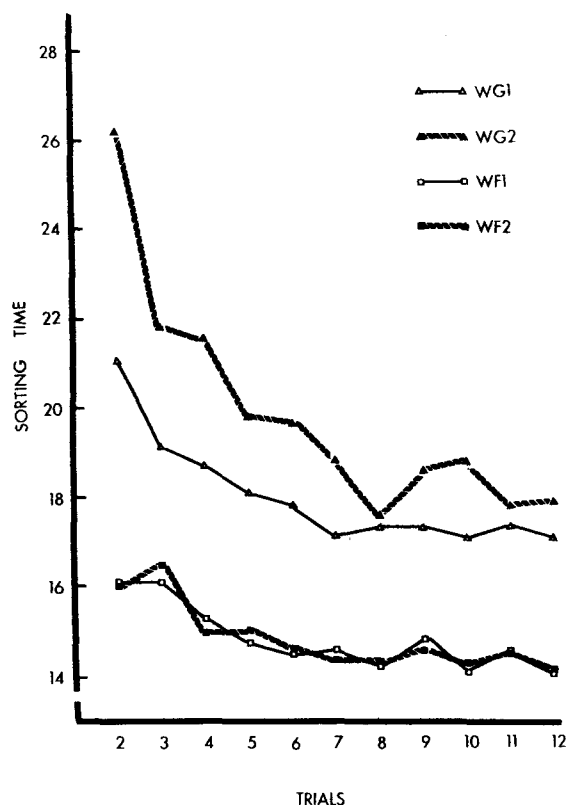


Fig. 1. Sorting time means (in seconds) for the word-nonword tasks in Experiment I, plotted over trials.

The influence of the hard-soft consonant dimension in the C tasks can be evaluated by comparing the sorting times of the grouping tasks CG1 and CG2 and the two filtering tasks CF1 and CF2. The pattern of results is essentially identical to those found with the W tasks. The grouping task in which the linguistic dimension was correlated with the response category CG1 was sorted more rapidly than Task CG2, in which the linguistic dimension was orthogonal to the required classification [$F(1,7) = 10.1, p < .02$]. While a significant Trials by Task interaction was again noted [$F(10,70) = 3.31, p < .01$], the graph in Fig. 2 does not suggest that this interaction dictates any major qualifications of the main effect.² No effect of the linguistic dimension is indicated in the comparison of the sorting times of the filtering conditions CF1 and CF2 ($F < 1$).

For both types of linguistic dimensions, therefore, the sorting times of the grouping tasks strongly suggest a facilitating effect of correlated linguistic information, while no evidence exists for such facilitation in the filtering tasks. These findings are consistent with the hypothesis that correlated stimulus information resulting from linguistic encoding may facilitate classification speed by reducing the processing load in complex tasks, even though such linguistic information is of little or no importance in tasks which permit the rapid classification of stimuli on the basis of a single visual feature.

EXPERIMENT II

A certain amount of caution is necessary in interpreting nonsignificant results in speeded classification tasks which use highly discriminable stimuli. One possible reason for the failure of the correlated linguistic information to facilitate classification in the filtering tasks used in Experiment I is that the level of performance may have provided little or no room for improvement. If it were the case that the sorting speed in these tasks was limited only by the motor aspects of executing the response, then it should not be possible to increase sorting speed by further increases in stimulus discriminability. One primary purpose of Experiment II was therefore to test whether the performance of the filtering tasks used in Experiment I was, in fact, sensitive to further increases in discriminability brought about by adding a redundant *visual* dimension. A related purpose of Experiment II was to examine the effect of correlated linguistic information on filtering tasks in which performance is substantially degraded by the reduction of visual discriminability, thereby providing levels of performance

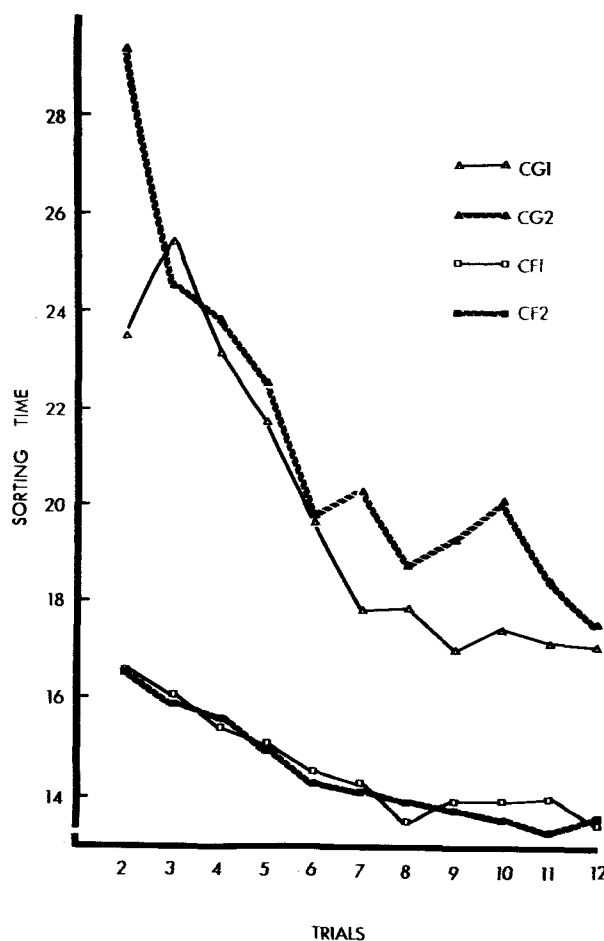


Fig. 2. Sorting time means for the hard-soft consonant tasks in Experiment I, plotted over trials.

which are more comparable to those obtained in the grouping tasks in Experiment I.

Experimental Variables

Each S provided data in six experimental conditions, two sorting tasks by three levels of visual discriminability.

Sorting Tasks

The sorting tasks were either the two word-nonword filtering tasks (WF1 and WF2) or the two hard-soft consonant filtering tasks (CF1 and CF2) used in Experiment I. As in Experiment I, the W tasks and the C tasks were given to separate groups of Ss. The two tasks given to each S therefore differed in whether the linguistic dimension was correlated with, or orthogonal to, the response categories.

Visual Discriminability

Three levels of discriminability were determined by modifying the way in which the trigrams were typed on the stimulus card. In the *color-correlated* conditions, the ink color (red or black) was always completely correlated with the response categories; the stimuli containing "a" or "o" were red, while the stimuli containing "i" were black. In the *plain black* conditions, the trigrams were printed in black ink and were therefore identical to the stimuli used in Experiment I. In the *visual noise* conditions, the trigrams were printed in lowercase black type, but were overstruck with the symbol "#," thereby visually degrading each stimulus (e.g., ###).

Method

Subjects

For the W tasks, Ss were 12 undergraduates who volunteered as part of a course requirement. For the C tasks, Ss were 12 graduate students who were paid \$3.50 for participation. Ss were run in a single session lasting about 1½ h.

Table 3
Mean Sorting Times and Error Rates Per Deck of
32 Cards for Each Condition in Experiment II

Stimuli	Color Correlated		Plain Black		Visual Noise	
	WF1	WF2	WF1	WF2	WF1	WF2
Word- Nonword	13.11 (.031)	13.11 (.021)	14.51 (.042)	14.63 (.125)	17.74 (.104)	17.52 (.094)
Hard-Soft Consonant	CF1		CF1		CF1	
	CF1	CF2	CF1	CF2	CF1	CF2
	13.53 (.073)	13.31 (.052)	14.41 (.083)	14.63 (.083)	17.01 (.083)	16.80 (.042)

Note—Tabular meanings same as Fig. 1.

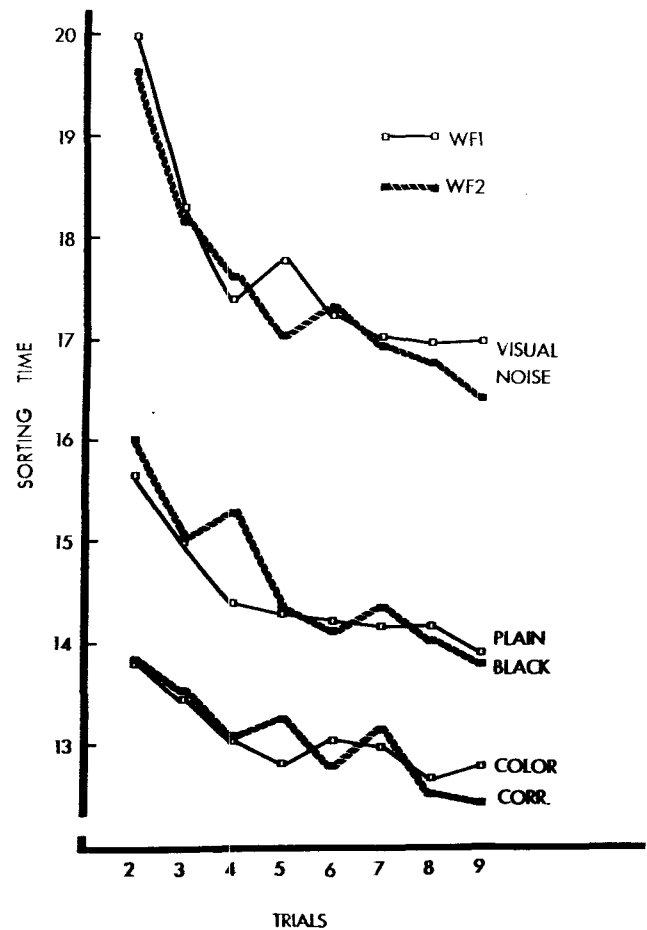


Fig. 3. Sorting time means for the word-nonword filtering tasks used in Experiment II, plotted over trials.

Procedure

Stimuli were mounted on white cards which were arranged into decks of 32 cards each, as described in Experiment I. Instructions to Ss and data recording procedures were identical to those used in Experiment I. Each S was run in nine blocks of six trials each. Order of presentation within each block was determined by assigning each S to a row of a 6 by 6 Latin square. The first block of trials was considered to be practice; only data from Blocks 2-9 were included in analysis.

Results

The mean sorting times and error rates for each condition are presented in Table 3. Error rates were again very low and were not analyzed further. The mean sorting times are plotted as a function of trials in Figs. 3 and 4.

Discriminability Levels

Figures 3 and 4 clearly show that the three levels of visual discriminability produced three distinct levels of sorting speed. This effect was highly significant for both the W and C stimuli [$F(2,22) = 70.4$, $F(2,22) = 193.1$,

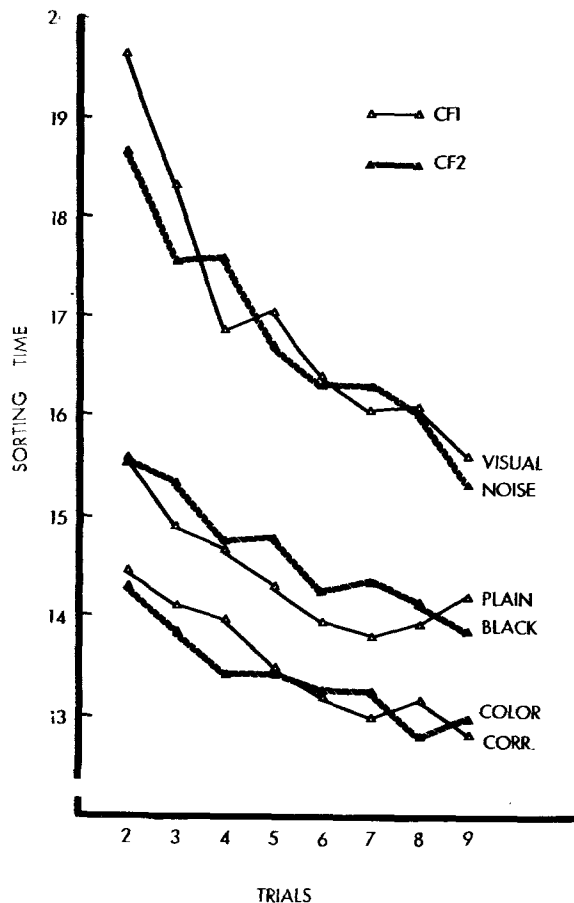


Fig. 4. Sorting time means for the hard-soft consonant filtering tasks used in Experiment II, plotted over trials.

$p < .001$ in each case]. The color-correlated tasks were sorted faster than the plain black tasks, which in turn were sorted faster than the visual noise tasks. This ranking occurred for every S for both the W and C stimuli. Since the color-correlated stimuli were sorted more rapidly than the plain black stimuli (which were identical to those used in Experiment I), it is clear that the sorting speed for these filtering tasks was not limited by a floor effect.

Linguistic Dimensions

Although the effect of the visual discriminability produced a highly significant effect on sorting speed, no overall effect of the linguistic dimensions was observed for either the W or C stimuli ($F < 1$ in each case). Even though substantial room for improvement exists in the visual noise conditions, the differences in sorting times between CF1 and CF2, and between WF1 and WF2, do not suggest any facilitating effect of the correlated linguistic information. These data thus indicate that correlated linguistic dimensions are of little use in facilitating sorting speed in classification tasks requiring a simple form discrimination, even when performance is substantially degraded by low stimulus visibility.

DISCUSSION

The results of Experiments I and II clearly illustrate the importance of distinguishing between different sources of performance limitations in speeded classification tasks. In the grouping tasks used in Experiment I, it may be assumed that a major component of task difficulty resulted from the processing load, since no single visual feature could be used to classify every stimulus. In these tasks, the presence of a linguistic attribute which was perfectly correlated with the response categories apparently served to reduce this processing load, thereby increasing classification speed. Following their experimental sessions, several Ss (including both Ss who sorted the C stimuli and Ss who sorted the W stimuli) reported using a strategy involving overt linguistic categorization of each stimulus in those conditions (WG1 and CG1) in which the linguistic dimension was relevant. These reports provide further evidence that verbal-conceptual discriminations may be more rapid than visual classifications of stimuli, provided that the verbal encoding serves to reduce the performance limitations imposed by the processing load. Such shifts in the level of encoding are probably responsible for the findings of Pollack (1963) that increasing the number of *conceptually related* stimuli per response category has relatively little effect upon classification time, provided the number of categories is small.

No effect of the linguistic dimensions upon sorting speed was noted for the filtering conditions. Verbal reports from Ss suggest that the form of the middle letter was being used almost exclusively to perform the classification in these tasks, and no S reported using any strategy involving verbal encoding of the entire trigram. Because of the perfect correlation of a single visual feature with the response categories, the processing load was minimal. For the filtering tasks, the primary limitation upon classification speed was probably visual discriminability rather than the complexity of the response assignments; the redundant stimulus information provided by the linguistic dimensions was therefore not of a variety which was useful in increasing classification speed.

Sternberg (1966) has argued that the imposition of visual noise results in a stimulus "cleaning up" operation which is completed prior to any type of stimulus categorization. Visual noise may thus delay both linguistic encoding and form discrimination. Thus, the presence of correlated linguistic information in the filtering tasks for which performance was degraded by visual noise was probably of no more use than in the filtering tasks for which visual discriminability was high.

Neither the lack of linguistic influences on the filtering tasks in the present study nor the lack of verbal interference in same-different matches of colors (Egeth, Blecker, & Kamlet, 1969) should be regarded as proof that Ss can selectively "nonattend" to irrelevant letters in a display, thereby completely suppressing verbal

encoding. As Hock and Egeth (1970) have suggested, these results more likely stem from the fact that the responses generated from discriminating *visual* features occur both independently of and *more rapidly* than verbal encoding. Eriksen and Hoffman (1973) have, in fact, presented evidence that some degree of processing may inevitably occur to irrelevant letters in a visual display. Influence of such verbal encoding on response times, however, would appear to be limited to tasks of sufficient complexity that responses cannot be made on the basis of nonverbal processing prior to the completion of verbal encoding.

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NOTES

1. The terms "low level" and "high level" were used by Hock and Egeth (1970).
2. Unlike the interaction observed for the W stimuli, the greatest difference between the sorting times of CG1 and CG2 seems to occur after Trial 5. It seems possible that this may result from the Ss' learning to use the correlated pronunciation dimension over trials, since the "hard-soft c rule" is probably a less overlearned linguistic concept than word recognition.

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