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Visual-Field Differences in Picture–Word Interference

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Picture–word interference refers to the fact that if a picture (i.e., line drawing) is presented centrally with a word superimposed, picture-naming latency is longer than if that same picture is presented alone. This phenomenon, like the Stroop phenomenon, seems to be strongly influenced by the nature of the to-be-ignored word. That is, if the word names a member of the picture's semantic category additional interference is observed; however, if the word is replaced by a phonetically unviable consonant string interference is reduced. In the present experiments these effects were examined in the situation where the picture–word stimuli were presented unilaterally in either the left or right visual field. For right-visual-field presentations, phonetic and semantic factors both influenced performance just as in central presentations. As such, these results can be satisfactorily explained in terms of response competition processes. However, the results for the left-visual-field presentations were quite different. Although substantial interference was observed for all types of stimuli, the amount of interference was essentially independent of the linguistic nature of the superimposed letter string. These results do not appear to be explainable in terms of response competition processes. Instead, it is suggested that the best way to explain these results is in terms of the perceptual capabilities of the right hemisphere.

Picture–word interference refers to the fact that if a picture (i.e., line drawing) is displayed with a word superimposed picture-naming latency is longer than if that same picture is presented alone (Lupker, 1979; Rosinski, 1977; Smith & Magee, 1980). This phenomenon, like the Stroop (1935) phenomenon, has typically been explained in terms of response competition processes. That is, while subjects are intentionally processing the picture they are also automatically processing the word. Automatic

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word processing inevitably leads to the retrieval of the word's name more rapidly than the subject can retrieve the picture's name. A situation is, thus, created where the word's name gains a preeminent position in the single motor-output channel. In order to produce the correct response the subject must clear this channel by suppressing the tendency to say the word's name, a process which takes time. It is this suppression process which, presumably, accounts for the difference between the picture–word condition and the picture-alone condition.

An additional finding in the picture–word interference paradigm that will be relevant to the present discussion is a result which can be called the semantic-category effect. If the superimposed word is a member of the picture's semantic category, an additional delay in picture-naming latency is observed (Lupker, 1979; Rosinski, 1977). Lupker and Katz (1981) have interpreted this result as follows. Apparently, in addition to its name code, the word also allows the automatic retrieval of certain semantic information. Whenever the word is a member of the picture's semantic category the semantic information it supplies will match fairly well with the visual information the picture is supplying. As such, the subjects will have a certain amount of difficulty determining that the word's name is not an appropriate label for the picture. It is the additional time necessary to make this determination which, presumably, is responsible for the semantic-category effect.

In recent years a considerable amount of research effort has been devoted to ascertaining the differences in the way the two components of picture–word stimuli are processed (e.g., Fraisse, 1968; Paivio, 1971; Potter & Faulconer, 1975). One of the more interesting findings is that these two components seem to be processed somewhat differently by the two cerebral hemispheres. Since each hemisphere initially receives information from the contralateral visual field researchers have been able to investigate these hemispheric differences by presenting stimuli to only one visual field at a time. Using this technique, it can be demonstrated that for most individuals words can be identified more rapidly when they are presented in the right visual field and initial processing takes place in the left hemisphere (Barton, Goodglass, & Shai, 1965; Mishkin & Forgays, 1952). On the other hand, visual-field differences seem to disappear, or at least shrink considerably, when more pictorial stimuli like faces and forms are used (Geffen, Bradshaw, & Wallace, 1971; Terrace, 1959; Young, Bion, & Ellis, 1980).

These findings are presumed to result from the fact that for most individuals language skills are much better developed in the left hemisphere, while the right hemisphere is more concerned with spatial relationships (McGlone & Kertesz, 1973; Milner, 1971). Thus, when linguistic stimuli, like words, are presented in the left visual field, they cannot be processed rapidly and efficiently by the hemisphere that initially receives the information. In addition, since the ability to produce language seems to be localized solely in the left hemisphere (Gazzaniga & Sperry, 1967), the right-visual-field advantage is maintained when considering the time needed to produce a word's name (Soares & Grosjean, 1981). In contrast, the ability of the right hemisphere to process pictorial stimuli may be nearly equivalent to that of the left hemisphere. Thus, these stimuli can be processed equally rapidly when presented in either visual field. However, this equality typically disappears if a rapid vocal response is required (Geffen et al., 1971), since for left-visual-field stimuli additional time is needed to transfer the information across the corpus callosum to the left hemisphere in order to allow the production of a vocal response.

Recently Wuillemin, Krane, and Richardson (1982) have reported an investigation of picture–word interference as a function of visual field of presentation. Using only the semantic–category and picture-alone conditions Wuillemin et al. reported that the interference effects observed in the two visual fields were statistically equivalent. On the basis of the above analysis, as well as the results from most previously reported interference paradigms (Cohen & Martin, 1975; Schmit & Davis, 1974; and to some extent Tsao, Feustel, & Soseos, 1979; but see Dyer, 1973), these results appear to be at least a bit surprising. That is, since the relative processing advantage words have over pictures is much larger for right- than for left-visual-field presentations, more interference would be expected for right-field stimuli. However, as Wuillemin et al. suggest the advantages enjoyed by words in the two visual fields may have been smaller than similar advantages in other interference paradigms (e.g., when the other stimulus attribute is a color rather than a picture). Thus, it is not necessary that identical results must be obtained.

The jumping-off point for the present research is the study by Wuillemin et al. First of all, it should be noted that the trend in their data was in the expected direction. That is, right-field picture–word stimuli produced 30 msec more interference than their left-field counterparts. A consideration of their methodology suggests that this difference should have been even larger. That is, like virtually all studies involving lateralized presentations of visual stimuli, stimulus exposure time was kept short (150 msec). For color–word stimuli, for example, restricting the exposure duration to this extent should not alter the task appreciably. However, picture–word stimuli, with the word written inside the picture, present an additional problem. That is, the outline of the picture, as well as any internal lines, is, effectively, a lateral masker of the word, a problem which is especially acute in the periphery (Estes, Allmeyer, & Reder, 1976; Lupker & Katz, 1982). In fact, pilot work in our laboratory indicates that subjects miss anywhere from 10 to 80% of the words in pictures at 150 msec exposure duration. Thus, although Wuillemin et al.'s pictures may have been seen relatively easily, the words probably were not, reducing the size of the interference effects in both visual fields, as well as the difference between them.

The reason Wuillemin et al. used a 150-msec exposure time was to prevent eye movements from bringing the stimulus into the fovea which would destroy the lateralization manipulation. Unquestionably, the potential for prolonged exposure durations to cause problems of this sort is a real one. Current thinking appears to be that avoiding these problems requires an exposure duration of no more than 180 msec which is the minimum time necessary to initiate a saccadic eye movement (Saslow, 1967). However, an evaluation of the nature of this strategy suggests that this restriction is an overly conservative one. To begin with, saccades often take longer than 180 msec to initiate (Saslow, 1967) and to that time must be added a small increment for movement time. Finally, the resultant foveal view must be available long enough that the subject finds the movement worth the effort. This final point is one that should not be overlooked. If a saccade is made, by the time the eyes arrive at the target the subject will have already processed the peripheral stimulus for generally more than 200 msec. In many circumstances the stimulus may have already been identified. Any desire to disregard the results of this processing and focus on the results of a brief foveal view, especially in a speeded response task, would seemingly be quite minimal. White (1969) in fact has noted that a number of studies employing exposure times as long as 450 msec have failed to produce results any different from those in studies using short (≤150 msec) exposure times. White concludes "the artifactual nature of eye movements, per se, as an important component of LD (laterality differences) must be seriously doubted" (p. 392). Pilot work for the present research indicated that a minimum exposure time of 250 msec was necessary to allow both word and picture to be correctly identified on essentially all trials. Thus, this exposure time was used in both Experiments 1 and 2.

Experiment 1 represents, first of all, a replication of Wuillemin et al.'s study using the picture–word interference task. Rosinski (1977) has demonstrated that picture–word interference is greatest when the word and picture represent concepts from the same semantic category. Thus, in order to draw a parallel to the previously reported color–word results in which the words were the maximally interfering color names, Wuillemin et al. only used words and pictures from the same semantic category. This condition will appear in Experiment 1 as well. In addition, a condition will be included in which the words are totally unrelated to the pictures. This condition also produces a significant amount of interference, although approximately 30 msec less than in the same-semantic-category condition, when the stimuli are presented centrally (Lupker, 1979). The importance of including an unrelated-word condition follows from Lupker and Katz's (1981) analysis of picture–word interference. They suggested that the naming time difference between pictures with no words and pictures with unrelated words is a phonetic effect arising at output while the additional semantic interference is a separate problem arising earlier in processing. If differential interference is obtained in the two same-semantic-category conditions the inclusion of the unrelated-word conditions should tell us whether it is a result of less phonetic interference for left-visual-field stimuli or less semantic interference (or both). Since previous research has indicated that phonetic processing is not a province of the right hemisphere (Gazzaniga & Sperry, 1967) while semantic processing probably is (Day, 1977; Zaidel, 1978) the former possibility seems much more likely than the latter.

EXPERIMENT 1

Method

Subjects. Twenty University of Western Ontario undergraduate volunteers (3 males and 17 females) received course credit for appearing in this experiment. All reported that they were exclusively right-handed and that English was their first language. None had ever been in a picture–word interference experiment before.

Materials and equipment. The stimuli were line drawings ("pictures"), with words superimposed, affixed either on the left or right side of a 23 × 25.6-cm card. Viewing distance was 77 cm. The midline of the picture and the word was always 5° to the right or left of fixation. The fixation point was a bull's-eye, 3 cm in diameter, subtending a visual angle of 2.25°. The size of the pictures ranged from 2 to 8 cm in both the vertical and horizontal directions and thus, the visual angle subtended by the pictures was never more than 6.0° or less than 1.5° either vertically or horizontally. The letter strings all contained between 3 and 7 letters with an average of 4.7 over all the conditions. The letters were all 1 cm tall and the letter strings ranged from 3.0 to 6.5 cm in length. Thus, the letter strings subtended visual angles of 0.75° vertically and between 2.25 and 4.83° horizontally.

The actual pictures used were 20 simple line drawings selected from children's coloring books for their ease of identification and approximate symmetry. For each picture a pair of words was selected with both words naming members of the picture's semantic category. Each of these 40 words was presented to a given subject in only one combination of visual-field and semantic-category relationship. Thus, to counterbalance properly it was necessary to construct four different pairings of pictures and words so that each word could be seen in each combination of visual-field and semantic-category relationship. Each of these pairings was used for five subjects.

The actual procedure for creating the stimuli was a bit complex. To begin with the 20 pictures were randomly divided into sets A and B with 10 pictures in each set. In the same-semantic-category condition for the first group of subjects the pictures in set A appeared in the left visual field with one of their same-semantic-category words superimposed. The other set of pictures appeared in the right visual field with one of their same-semantic-category words superimposed. To create the unrelated-word condition the positions of the two sets of pictures were reversed from the same-semantic-category condition. Those pictures appearing on the left now appeared on the right and vice versa. The words used for the left-visual-field stimuli were the 10 words whose mates appeared on the left-visual-field stimuli in the same-semantic-category condition while the analogous situation was true for the words appearing in the right visual field. Care was taken to make sure no semantic relationship existed between the word and the picture in this condition. For the second group of subjects their stimuli were created by simply reversing the visual field of each picture–word stimulus. Thus, for this group all stimuli which appeared in the left visual field for group 1 were now presented in the right visual field and vice versa. To create the stimuli for groups 3 and 4 the entire procedure outlined above was carried out with each member of a word pair changing places with its mate. Thus, each word that appeared on a same-semantic-category picture for groups 1 and 2 appeared on an unrelated picture, while its mate now appeared on a same-semantic-category picture. Finally, for the picture-alone condition one of the sets of 10 pictures was chosen for each visual field. For groups 1 and 2 the set of pictures appearing in a particular visual field was the same as that used in the same-semantic-category condition in that same visual field. For groups 3 and 4, the set of pictures appearing in a particular visual field was the same as that used in the unrelated-word condition in that same visual field. This procedure created a situation where each subject saw a given set of pictures in two conditions in one visual field and in the remaining condition in the other visual field. However, over all the subjects each picture was seen equally often in each visual field. A complete list of the pictures and words used is presented in the Appendix.

A Ralph Gerbrands Company (model 1-3B-1C) three-field tachistoscope was used to present the stimuli. A Hunter Klockouter (model 120) timer was used to time the subject's vocal, picture-naming response. An Electro-Voice, Inc. (model 621) microphone, positioned 7 cm away from the subject's mouth, was connected to a Lafayette Instruments Company (model 18010) voice-activated relay which stopped the timer at the initiation of the subject's vocal response.

Procedure. Subjects were tested individually. As each subject arrived they were assigned to a group with the first five being in group 1, the second five in group 2, etc. Prior to testing, each subject was informed that on each trial they would be seeing a central fixation point followed by a picture which would appear either to the left or the right. Many of these pictures would have words superimposed. The subject's job would be to look directly at the fixation point and then, when the picture appeared, to name it as rapidly and accurately as possible. At the beginning of each trial the fixation point appeared for 750 msec. Presentation of the picture occurred immediately after the termination of the fixation point and lasted 250 msec. The postexposure field was dark. The first two trials were always practice trials involving pictures alone. One picture, a rabbit, always appeared in the left visual field, the other, a leaf, in the right visual field. Neither picture was used in the main experiment. The 60 stimuli for a given subject (10 in each condition in each visual field) were then presented in a random order. The response–stimulus interval was used by the experimenter to record the naming latency and reset the equipment for the next trial. Thus, this time was not held totally constant but was around 5 sec. Errors were recorded and those stimuli were randomly placed back into the set of to-be-presented stimuli. The set of stimulus cards was then shuffled and after a short (3 min) rest, the same 60 stimuli were presented again in a different random order. The entire procedure took about 40 min.

Results

Errors were infrequent with an experiment-wide error rate of 3.5%. The only noticeable trend in the data was that fewer errors (5 in 400 trials) were committed in the picture-alone condition for right-visual-field stimuli than in any other condition (the range was from 11 to 20). This trend, however, was not significant.

The reaction time data which were analyzed were the medians of the correct response times to the 10 stimuli in each condition. These data were submitted to a 2 (visual field) × 3 (conditions) × 2 (blocks) within-subject ANOVA. Two main effects, blocks ($F(1, 19) = 95.24$, $p < .001$)[1] and conditions ($F(2, 38) = 44.71$, $p < .001$) were significant. The significant blocks effect and the lack of an interaction between this factor and any other simply mean that subjects improved with practice. The main effect of conditions was qualified by what is the major result of this study, a significant visual field × conditions interaction ($F(2, 38) = 4.60$, $p < .002$). These data appear in the top half of Table 1. No other effects approached significance ($p > .05$).

Interference scores. In order to analyze this interaction an analysis paralleling that presented by Wuillemin et al. was undertaken. Relative interference scores were calculated for each of the four picture–word conditions for each subject. This was accomplished by subtracting from the median reaction time for each condition the median reaction time for the appropriate picture-alone condition. A one-way ANOVA of these four sets of scores revealed a significant main effect of interference conditions ($F(3, 57) = 5.43$, $p < .005$). A subsequent Newman–Keuls analysis revealed that more interference was obtained in the same-semantic-category condition in right-visual-field presentations than in any other condition ($p < .05$). The differences among the other three conditions were not reliable ($p > .05$).

Discussion

There are two aspects of the data in Experiment 1 that deserve mention. First, more interference was observed in the same-semantic-category condition for right-field stimuli than for left-field stimuli. This result indicates that the trend in Wuillemin et al.'s data, although nonsignificant, was a real one. Further, it supports the analysis of hemispheric differences presented earlier. That is, words initially contacting the right hemisphere appear to receive less complete processing than those initially contacting the language-dominant left hemisphere and, thus, have less potential for interfering with picture processing.

The second aspect of the present data muddies up this conclusion considerably. That is, this visual-field difference appears to be entirely a semantic effect. When unrelated words appeared on the pictures equivalent interference was observed in the two visual fields. It is only when a relationship between the word and picture exists that right-field stimuli produce more interference than their left-field counterparts. Further, the existence of a semantic relationship in left-visual-field stimuli totally fails to produce even the hint of a semantic-category effect.

As mentioned previously, Lupker and Katz (1981) have suggested that

[1] Due to the arguments presented by Wike and Church (1976) and others, stimulus materials was not treated as a random factor as suggested by Clark (1973) in this or any subsequent analysis.

TABLE 1
MEAN REACTION TIMES[a] AS A FUNCTION OF STIMULUS CONDITION AND VISUAL FIELD

Stimulus condition	Right visual field	Left visual field
	Experiment 1	
Same-semantic-category words	899	852
Unrelated words	860	864
Pictures alone	760	783
	Experiment 2	
Same-semantic-category words	769	771
Unrelated words	744	765
Pronounceable nonwords	743	751
Consonant strings	718	758
Pictures alone	702	710

[a] In milliseconds.

the interference from an unrelated word arises because the phonetic code of that word is generated automatically and interferes with the output of the picture's name. The semantic-category effect derives from the automatic activation of semantic information which affects an earlier, decision process. The present pattern of results suggests then that words presented to either hemisphere undergo equivalent phonetic coding, thus, producing equivalent output problems. However, only words presented in the right visual field receive semantic processing and, thus, only they can produce a semantic-category effect.

These conclusions unfortunately are exactly the opposite of what one would expect based on our current knowledge about hemispheric differences in word processing. That is, it is the semantic processing capabilities of the two hemispheres which may be somewhat equivalent while there are clear and substantial differences in the two hemispheres' phonetic processing abilities. As such, a closer examination of the present effects seems in order. One hypothesis that might be entertained would be that Lupker and Katz's analysis is only appropriate for central and right-field stimuli, while the *nature* of the interference for left-field stimuli is quite different. As such, Experiment 2 was undertaken to examine the nature of the interference in the two visual fields.

EXPERIMENT 2

The results of Experiment 1 seem to suggest two conclusions: (1) that words presented to the right hemisphere are processed phonetically, just as those presented to the left hemisphere, but (2) they are not processed semantically. The first of these conclusions was examined by introducing two new conditions into Experiment 2, a pronounceable-nonword condition and a consonant-string condition. Previous research with centrally presented stimuli (Lupker, 1979; Rosinski, 1977) has indicated that orthographically regular, easily pronounceable nonwords, like words, also allow the rapid generation of a phonetic code, thus, producing measurable interference. The difference in reaction time between the pronounceable-nonword and unrelated-word conditions is typically small (e.g., 10–20 msec) and in some situations nonexistent (Rosinski, 1977). Consonant strings on the other hand do not allow the generation of a viable phonetic code and, thus, produce much less interference (Lupker, 1982; Rayner & Posnansky, 1978). This same pattern of results would be expected in the present study for right-visual-field stimuli. If, as suggested, left-visual-field letter strings are undergoing equivalent phonetic processing, similar results should be obtained for these stimuli.

The second conclusion was examined by introducing a secondary manipulation. As in Experiment 1, both same-semantic-category and unrelated-word conditions were included in Experiment 2. At the end of the experiment subjects were asked to do a surprise free recall of all the words appearing in these two conditions. As the reader may recall, the stimuli in Experiment 1 were constructed so that each word appeared with only one picture in one condition in one visual field. Thus, it is possible to determine in what situation any recalled word had been presented. Since the reaction time data from Experiment 1 clearly indicate that right-visual-field words underwent semantic processing, same-semantic-category words should be recalled better than unrelated words in the right visual field due to the context in which they appeared. If words in the left visual field do not undergo semantic processing a similar effect should not be obtained.

Finally, evidence has emerged in more recent years suggesting that males may have more pronounced hemispheric asymmetries than females (McGlone, 1980). Implications of these differences for the present investigation were examined by introducing sex as a blocking variable in Experiment 2.

Method

Subjects. Forty-eight University of Western Ontario undergraduate volunteers (24 males and 24 females) received course credit for appearing in this experiment. All reported that they were exclusively right-handed and that English was their first language. None had ever been in a picture–word interference experiment before.

Materials and equipment. The stimulus and presentation parameters were identical to those of Experiment 1. Also, as in Experiment 1, the subjects were divided into four groups with each group now consisting of six males and six females. These groups were delineated, as before, by the particular pairings of pictures and words in the same-semantic-category and unrelated-word conditions. As such, the exact same stimuli were used in the same-semantic-category, unrelated-word, and picture-alone conditions as had been used in Experiment 1. To create the pronounceable-nonword condition, for each group of subjects, the set of pictures that appeared in a particular visual field with same-semantic-category words also appeared in that same visual field with pronounceable nonwords. Twenty pronounceable nonwords were used so that each picture contained a different nonword. In addition, a given nonword always appeared on the same picture. To create the consonant-string condition, for each group of subjects, the set of pictures that appeared in a particular visual field with unrelated words also appeared in that same visual field with consonant strings. Twenty consonant strings were used so that each picture contained a different consonant string. Also, a given consonant string always appeared on the same picture. This procedure created a situation in which each subject saw a given set of pictures in three conditions in one visual field and in the remaining two conditions in the other visual field. However, over all the subjects each picture was seen equally often in each visual field. A complete list of the pictures, words, pronounceable nonwords, and consonant strings used is presented in the Appendix.

The tachistoscope, timer, microphone, and voice-activated relay were the same as those used in Experiment 1.

Procedure. The procedure was essentially identical to that of Experiment 1. There were two differences. There were now 100 stimuli per block and following the presentation of all 200 stimuli subjects were required to write down as many of the words as they could recall. As much time as was necessary was allotted for the memory task. The entire procedure took about 1 hr.

Results

As in Experiment 1 naming errors were few (less than 2% experiment-wide). No trends were evident in these data.

The data which were analyzed were the medians of the correct reaction times for each subject to the 10 stimuli in a given condition. These data were submitted to a 2 (sex) × 2 (visual field) × 5 (conditions) × 2 (blocks) ANOVA, with sex being the only between-subject variable. First of all, although females seemed to be faster than males, sex of subject neither yielded a main effect ($F(1, 46) < 1.0$) nor interacted with any of the other factors (all p's $> .05$). Thus, it will not be discussed further. The other three main effects, visual field ($F(1, 46) = 8.20$, $p < .01$), conditions ($F(4, 184) = 23.16$, $p < .001$), and blocks ($F(1, 46) = 142.06$, $p < .001$) were all significant. The significant blocks effect and the lack of an interaction between this factor and any other again simply mean that subjects improved with practice. The other two main effects cannot be explained so simply since they are qualified by what is essentially the major result of this study, a highly significant visual field × conditions interaction ($F(4, 184) = 4.46$, $p < .002$). These data appear in the lower half of Table 1.

Due to the different nature of the question being asked in Experiment 2 this interaction was analyzed in a slightly different fashion than in Experiment 1. Newman–Keuls analyses at the .05 level were undertaken to evaluate the data within a given visual-field condition. The analysis of the right-visual-field data indicates that these conditions can be partitioned into four groups. Reaction times in the consonant-string condition were slightly but significantly longer than reaction times in the picture-alone condition. Unrelated words and pronounceable nonwords produced equivalent amounts of interference which were significantly larger than that obtained in the consonant-string condition. Finally, same-semantic-category words produced an additional 25 msec of interference with respect to the unrelated-word condition, also a significant difference.

A Newman–Keuls analysis of the left-visual-field presentations revealed that although each condition produced a significant amount of interference with respect to the picture-alone condition, there was essentially no differentiation among the four letter string conditions. The only difference among these four conditions was the marginally significant difference ($p < .06$) between the same-semantic-category and pronounceable-nonword conditions. Thus, it appears that for left-visual-field presentations the amount of interference seems to be independent of the linguistic nature of the superimposed letter string.

The free-recall data which were analyzed were simply the number of words recalled in each combination of visual-field and semantic-category relationship. These data were submitted to a 2 (sex) × 2 (visual field) × 2 (conditions) ANOVA. As with the reaction time data there neither was a main effect of sex ($F(1, 46) = 2.33$, $p > .10$) nor did it interact with any of the other factors (all p's $> .05$). However, there were significant main effects of both visual field ($F(1, 46) = 34.42$, $p < .001$) and conditions ($F(1, 46) = 99.21$, $p < .001$). These results are shown in Table 2. As is obvious more words were recalled that had been presented in the right visual field and more words were recalled that had appeared on same-semantic-category pictures. In addition, it appears that these two effects are additive, since the interaction of the two variables was not significant ($F(1, 46) = 3.06$, $p > .08$) even though the effect of a semantic-category relationship was, most likely, somewhat attenuated in the left visual field by the floor effect in the unrelated-word condition.

Discussion

The results for the right-visual-field presentations were as anticipated. Consonant strings which cannot provide a viable phonetic code produced only a small amount of interference. Pronounceable nonwords and unrelated words, both of which are quite viable phonetically, produced significantly

TABLE 2
MEAN NUMBER OF WORDS RECALLED AS A FUNCTION OF VISUAL-FIELD AND SEMANTIC-CATEGORY RELATIONSHIP IN EXPERIMENT 2

	Right visual field	Left visual field	Total
Same semantic category	3.10	1.83	4.93
Unrelated	1.29	.54	1.83
Total	4.39	2.37	6.76

more interference. The fact that these two conditions led to equivalent amounts of interference might, at first, seem a bit surprising. However, the observed difference between the unrelated-word and pronounceable-nonword conditions is inevitably dependent on how pronounceable the nonwords are. Apparently, generating the pronunciation of the nonwords used in the present study was relatively easy, allowing these pronunciations to be just as available to the motor-output channel as the name codes of the unrelated words. Thus, essentially equivalent response tendencies were evoked, leading to essentially equivalent amounts of interference. Finally, the same-semantic-category words, which are also quite viable phonetically and, in addition, can provide interfering semantic information, led to an additional 25 msec of interference in comparison to the unrelated words. Thus, for picture–word stimuli presented in the right visual field, just as for stimuli presented centrally, both phonetic and semantic factors are important determinants of the amount of interference observed.

The explanation of these results follows directly from the initial analysis of the processing capabilities of the left hemisphere. Linguistic stimuli, like words, seem to be processed much more efficiently by the left hemisphere, although some processing of these stimuli may be accomplished by the right hemisphere, and the ability to generate verbal outputs seems to be totally controlled by the left hemisphere. As such, it was anticipated that the automatic processing of words presented in the right visual field would parallel that for centrally presented words, with both phonetic and semantic information becoming available and being important to the responding process. The difference between the consonant-string condition and the unrelated-word and pronounceable-nonword conditions supports the assertion that phonetic information was automatically retrieved and produced response competition. The difference between the unrelated-word and same-semantic-category conditions supports the assertion that words presented in the right visual field also allowed the automatic retrieval of certain semantic information which further prolonged picture naming. This final assertion also received support from the recall data. Same-semantic-category words presented in the right visual field were recalled better than unrelated words presented in the same visual field. If semantic information were not being automatically retrieved these two conditions should have yielded equivalent recall scores. The fact that this difference exists suggests that not only is the semantic information retrieved but, as anticipated, it receives additional processing in the context of a picture supplying semantically similar information.

The results for the left-visual-field presentations present an entirely different picture. In particular, again there was significant interference for left-visual-field stimuli. However, there was essentially no differentiation among the four letter string conditions. Unrelated words led to no more interference than consonant strings and, as in Experiment 1, there was little evidence of a semantic-category effect. Apparently, simply the presence of a letter string, and not its linguistic nature, is the crucial determinant of interference for left-visual-field stimuli.

These results, particularly the lack of a difference between the word conditions and the consonant-string condition, imply that left-visual-field interference is not phonetic in nature. That is, in tasks of this sort output interference produced by phonetic factors is, typically, a pervasive problem. As was demonstrated with right-visual-field presentations, it is a much larger problem when the letter string is phonetically viable. Thus, if the letter strings presented in the left visual field were being processed phonetically they should have produced response competition at output leading to a difference between the consonant-string condition and the pronounceable-nonword and word conditions. The fact that this difference did not occur implies that little phonetic processing of these letter strings was being accomplished.

The visual-field effect in the recall data would follow from this interpretation. To begin with, these data indicate that the linguistic nature of these letter strings was not simply being ignored, since the words clearly underwent semantic processing. Just as with right-visual-field presentations, same-semantic-category words presented in the left visual field were recalled better than unrelated words. Thus, same-semantic-category words were presumably being processed to a deeper semantic level than unrelated words, due to the context in which they appeared. In addition, this semantic-category effect was essentially the same in the two visual fields as indicated by the nonsignificant visual-field × semantic-category relationship interaction. Now, as Sternberg (1969) has pointed out a nonsignificant interaction does not prove independence. However, a finding like this at least suggests that the semantic-category effect and the visual-field effect arose from different sources. Since the semantic-category effect was obviously due to semantic processing the visual-field difference may very well have been due to differences in phonetic processing. Thus, the suggestion is that although words presented in the left visual field were processed semantically, they apparently received little phonetic processing. As such, memory for these words was reduced and there was no evidence of phonetic interference in the reaction time data.[2]

The conclusion that the left-visual-field letter strings receive semantic, but not phonetic, processing is, of course, quite compatible with the

[2] It, perhaps, should be noted at this point that when subjects are forced to process words phonetically no visual-field differences are obtained in a surprise free-recall task (Sanders, Note 1). Subjects in this task were simply required to name words presented in one of the two visual fields. The words were the same as those used in the present experiment. While a large right-visual-field superiority was obtained in the naming time data ($t(19) = 4.33$, $p < .001$), no visual-field difference was observed on the memory task ($t(19) = .71$, n.s.).

current view of the processing capabilities of the right hemisphere (Day, 1977; Gazzaniga & Sperry, 1967; Zaidel, 1978). However, the question remains as to why these stimuli did not produce a semantic-category effect in the reaction time data. It appears that simply the availability of potentially interfering semantic information is not sufficient to produce semantic interference, a conclusion also reached by Lupker and Katz (1981). When picture–word stimuli are presented centrally, or in the right visual field, at some point subjects will have available both the name of the word and whatever semantic information its processing has automatically produced. At the same time they will have available whatever pictorial information picture processing has produced. When the word and the picture are unrelated the information from these two sources will be quite dissimilar and determining that the word's name is not appropriate for the picture will be an easy matter. However, when the concept represented by the word is from the picture's semantic category, the available semantic information will promote the word's name as a legitimate name for the picture. Thus, additional processing will be necessary before the subject can decide that the word's name is not an appropriate name for the picture, producing the semantic-category effect. However, when the picture–word stimuli are presented in the left visual field, since automatic phonetic processing is much less likely, the word's name generally will not become available. As such, no decision problems will be created and no semantic-category effect will result. Thus, the explanation of the lack of a semantic-category effect for left-visual-field presentations is that this effect is based on the availability of *both* semantic and phonetic information, and these words were generally not receiving the necessary phonetic processing.

The essential conclusion to be drawn then from Experiment 2 is simply that the nature of the interference for left- and right-field stimuli is qualitatively different. For right-field stimuli, the interference is to a large degree phonetically, as well as semantically, based, while for left-field stimuli, it is not. The question remains, of course, as to how to characterize the interference for the left-field stimuli. Although a number of mechanisms may be proposed the fact that phonetic factors are unimportant suggests that it is an input rather than an output problem.

One such mechanism would be based on the notion that the left hemisphere is an analytic processor while the right hemisphere processes stimuli in a more holistic manner (Klatzky & Atkinson, 1971; Levy, Trevarthen, & Sperry, 1972; Levy-Agresti & Sperry, 1968; Springer & Deutsch, 1981; Zaidel, 1973). This conceptualization is, of course, a bit of an overgeneralization but it probably captures many of the features of hemispheric asymmetries. Its implications are that for picture–word stimuli presented either centrally or in the right visual field the two components may be segregated quite rapidly allowing picture processing to be carried out as independently as possible. Thus, stimuli like consonant strings, which have little phonetic viability, produce little interference. However, when picture–word stimuli are presented in the left visual field, at least initially, the amalgamation of lines and features created by a picture with a superimposed letter string will tend to be processed together. Thus, a situation is created in which either (1) the right hemisphere must expend extra processing effort to break the two components apart, or (2) the entire amalgamation is processed together breaking apart only when a picture identification is finally made (see Hellige, 1980). In either case, the processing of picture–word stimuli presented in the left visual field will be slowed down in comparison to a picture-alone condition, producing interference. In addition, because this interference is based solely on the fact that the letter strings are composed of lines and features, the amount of interference should be independent of the linguistic nature of the letter string, as was observed.

An alternate mechanism would be based on the perceptual/encoding model of Hock and Egeth (1970). In their conceptualization, originally proposed to explain color–word interference, subjects must divide perceptual resources between the two stimulus components (here the word and the picture). Processing the relevant component, the picture, is slowed due to a limitation of perceptual resources. Although there is little evidence for perceptual contributions to color–word interference (Dyer, 1973) or to picture–word interference for central (Lupker & Katz, 1981) or right-visual-field (consider the consonant-string condition in Experiment 2) presentations, it does not follow that the same can be said for left-visual-field stimuli.

On the basis of results reported by Day (1977) and others the right hemisphere appears to be capable of processing words to the level of meaning. However, it may only rarely be called upon to perform this task. As such, the processes involved in handling a string of letters may be somewhat less automatized than they would be for the left hemisphere. One of the characteristics of automatic processing is that it demands little, if any, attention (Posner & Snyder, 1975; Shiffrin & Schneider, 1977). Thus, it would follow that encoding a letter string would delay picture processing very little for right-visual-field stimuli. However, for left-visual-field stimuli, the encoding of letter strings may require enough attentional resources that a delay in picture naming would be evident. In addition, because this interference would be due to processing which takes place before any lexical access, it should be independent of the linguistic nature of the letter string, as was observed.

The present data do not allow a determination of which, if any, of these models best describes the interference for left-visual-field stimuli. However, they do indicate that the nature of this interference is perceptual and, thus, different from that for right-visual-field stimuli. As such, the point should be made that if, for example, only the unrelated-word and picture-alone conditions had been used in the present experiments, very different conclusions about hemispheric asymmetries in picture–word interference would have been reached. In particular, since the unrelated-word condition showed essentially the same amount of interference in the two visual fields in both experiments, arguing for any asymmetries at all would have been difficult. However, due to the inclusion of the semantic-category condition in Experiment 1 and the other two conditions, as well as the memory task, in Experiment 2, it was possible to detect that the interference in the two visual fields was not due to the same source. This fact nicely underlines Hellige's (1980) final conclusion. That is, the complexity of the cerebral hemispheres is such that unless the experimental techniques used allow for the separation of information processing stages the interpretation of laterality effects will be extremely difficult, it not impossible.

APPENDIX: STIMULI

Pictures	Words	Words	Pronounceable nonwords	Consonant strings
Set A	Group 1	Group 2		
BANANA	APPLE	PEAR	DIDA	HRSN
CAR	BUS	TRAIN	TEKA	RNPLM
CARROT	PEAS	BEANS	TALU	DGNTL
HAMMER	SAW	NAILS	SYDA	LRPST
LEG	ARM	NOSE	LORIM	TRBNS
LION	COW	TIGER	DERA	TCRSP
NURSE	LAWYER	TEACHER	AMEG	LNYG
PANTS	SHIRT	COAT	FETOL	MZTRS
SWORD	GUN	RIFLE	VORM	PSTLN
WAGON	DOLL	BALL	BOSUT	NLSRT
Set B				
BED	DESK	DRESSER	BOYER	TCDRP
CHAIR	TABLE	SOFA	VARUS	MSTR
DOG	CAT	FOX	VOMER	SCNRV
DOOR	WALL	WINDOW	SEZA	LRTCR
FOOT	HAND	EAR	PATEK	TCPSR
FORK	KNIFE	SPOON	PILAS	SYLNR
GUITAR	PIANO	DRUM	NARES	PRNTC
HAT	SHOES	DRESS	MENAL	NDTRS
MOUSE	HORSE	PIG	CALID	GNYL
PLANE	TRUCK	BOAT	KOKEM	RLMSD

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