Dichoptic reading: The role of meaning in binocular rivalry

RANDOLPH BLAKE
Northwestern University, Evanston, Illinois

These experiments sought to determine whether meaning influences the predominance of one eye during binocular rivalry. In Experiment 1, observers tried to read meaningful text under conditions in which different text streams were viewed by the two eyes, a situation mimicking the classic dichotic listening paradigm. Dichoptic reading proved impossible even when the text streams were printed in different fonts or when one eye received a 5-sec advantage. Under non-rivalry conditions, the observers were able to read text presented at twice the rate used for dichoptic testing, indicating that cognitive overload does not limit performance under conditions of rivalry. In Experiment 2, observers were required to detect repeated presentations of a probe target within a string of characters presented to one eye. Although this task was easily performed under monocular viewing conditions, it proved difficult when the two eyes received dissimilar character strings. This was true regardless of whether the probed eye viewed nonsense strings, real words, or meaningful text. In a condition designed to encourage semantic processing of one eye's view, the observers were required to detect animal names as well as to detect the probe target. Performance remained inferior to that measured under monocular conditions. Even the observer's own name proved insufficient to influence the predominance of one eye under conditions of dichoptic stimulation. When two text strings were physically superimposed and viewed monocularly, essentially no probes were detected, indicating that the failure to see some probes during rivalry reflects a limitation unique to dichoptic viewing. These results contradict theories attributing binocular rivalry to an attentional process that operates on monocular inputs that have received refined analysis. This conclusion may be limited to rival stimuli whose meaning is defined linguistically, not structurally.

The idea that binocular rivalry involves some sort of attentional mechanism is deeply rooted within the literature on visual perception. In his classic treatise on physiological optics, Helmholtz (1866/1962) dealt at some length with the parallels between rivalry and attention, and James (1890), in his chapter on attention, used rivalry to illustrate the hallmarks of what he called "sensorial attention." This putative link between rivalry and attention also appears in contemporary writings. In one of the most recent reviews of the literature on binocular rivalry, Walker (1978) maintained this tradition by arguing that "rivalry reflects central selective processes . . . over and above the analysis of sensory information" (p. 387).

Several lines of evidence can be marshaled in support of the view that rivalry involves central attentional mechanisms. For one thing, rivalry occurs even when the provoking stimuli are afterimages (e.g., Breese, 1899), a condition that effectively eliminates such peripheral factors as eye movements, retinal adaptation, or changes in accommodation as causes of rivalry. It is also known that

pattern information continues to be registered even when the eye receiving that information is suppressed during rivalry (Blake & Fox, 1974; O'Shea & Crassini, 1981; Wade & Wenderoth, 1978). The continued effectiveness of a suppressed target places the site of rivalry suppression beyond at least the neural locus at which spatial-frequency and orientation information is initially registered. Finally, a number of papers have reported data indicating that predominance during rivalry is influenced by the semantic content of rival targets (see Walker, 1978, for a review of these studies). To give a few examples of the effect of meaning on rivalry, Engel (1956) reported that a familiar figure (an upright face) predominated over a less familiar figure (an upside down face) during rivalry. In a similar vein, Rommetveit, Toch, and Svendson (1968a, 1968b) found that semantic context influenced which word was seen when observers dichoptically viewed a pair of words differing in meaning.

Actually, this question of the influence of meaning on binocular rivalry is an important one, for the existence of such an influence would provide a very compelling argument that rivalry involves some form of attentional mechanism subject to cognitive control. This conclusion, if supported, would represent a serious challenge to more sensory-based theories of rivalry (e.g., Abadi, 1976; Fox & Rasche, 1969; Wade, 1974). However, the evidence for an influence of meaning on rivalry must be interpreted

cautiously. Simply asking observers to report which of two rival targets seems to predominate—the procedure employed in a number of these studies—introduces possible response biases and, at the least, requires observers to adopt some criterion for predominance. More preferable would be a procedure that employed an indirect measure to assess the predominance of an eye during rivalry.

To achieve this goal, in the present experiments I utilized a technique for assessing predominance that was modeled after the dichotic listening paradigm in hearing (e.g., Lewis, 1970).[1] In dichotic listening, a person hears two different passages of auditory material played over headphones, one passage to each ear. The listener may be asked to "shadow" (i.e., repeat) one ear's input or to detect probe targets embedded within the auditory stream presented to one ear or the other. Typically, listeners have no trouble attending to one ear's input, judging from their accuracy in shadowing. Yet listeners retain some degree of sensitivity to the unattended ear's input, judging from their abilities to respond to target words or sounds within that input (e.g., Corteen & Wood, 1972). In my visual adaptation of this procedure, observers viewed two different streams of letters, one seen by the left eye and the other seen by the right. By varying the semantic content of the letter streams, it was possible to determine whether meaningful text would predominate over nonsense. Two measures of predominance were used: the ability to read text seen by one eye and the detectability of probe characters embedded within one eye's view. Neither measure provided any evidence for an effect of meaning on binocular rivalry between dissimilar letter strings.
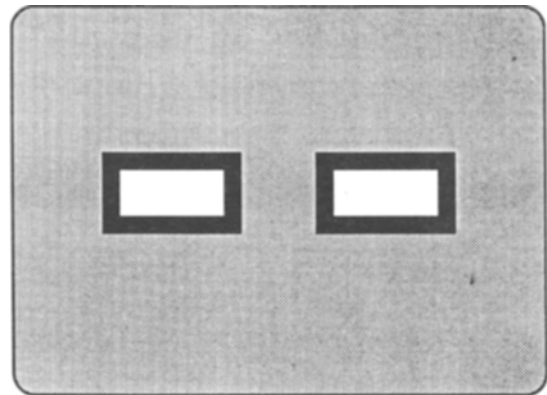
GENERAL METHOD

Apparatus

Stimuli were generated on the video screen of a Macintosh computer and were viewed through a modified Brewster stereoscope. Two white rectangular apertures, hereafter termed windows, were equally spaced on either side of the midline of the screen (see Figure 1); one window was viewed by the left eye and the other was viewed by the right eye. The dimensions of both windows were 4.5°×2.75° visual angle, and the outlines of the windows were drawn with thick (10′) black lines. The luminance of the white part of the windows was 23 fL, and the windows appeared against a 5-fL gray background. Observers had no problem maintaining these two displays in binocular coincidence.

A continuous stream of letters could be presented within either or both windows, and it was possible to present different letter streams to the two windows. The stream of letters passed from right to left through a window, moving at the rate of 13 characters per second (except where otherwise noted). The font style of letters could be varied independently for the two letter streams. As an alternative mode of presentation, successive sequences of letters could be briefly flashed within a window (a method referred to as the flash mode), with the flash rate under computer control. It was also possible to superimpose two text strings and present that composite to a single window.

Letter Strings

Letter strings lasting 1 min were created and stored as text files that could be assigned to either the left or the right window. Multiple instances of three different kinds of files were created: (1) text strings—excerpts from popular books transcribed verbatim, exclud-

Figure 1. Shown at the top is a schematic of the display viewed stereoscopically such that the left-hand window was seen by the left eye and the right-hand window was seen by the right eye. The black borders around each window served as effective fusion stimuli for maintenance of stable binocular alignment. The series of three windows (bottom of figure) depicts the direction in which text flowed through a given window. In the actual display, text appeared only within the window, not in the region outside the window frame. Different types of strings (text, words, or nonsense) could be displayed simultaneously in the two windows. Window size: 4.5° × 2.75° visual angle. Luminance: window, 23 fL; background, 5 fL. Text speed: 13 characters/sec. Trial duration: 1 min.

ing punctuation marks; (2) word strings—strings of unrelated words selected from Thorndike and Lorge (1944); (3) nonsense strings—letter sequences produced by typing words from Thorndike and Lorge with each hand misplaced by one key on the computer keyboard.

A modified version of every file was also constructed by inserting multiple replications of a specially designed character within

the 1-min letter string; this unique character (∴) was termed the *probe target*. Thus for each type of letter string, there existed a modified version differing only in that it contained from 10 to 13 repetitions of the probe character. The placement of probes within a file was random, with the stipulation that the interval between successive probes never be less than 3 sec.

Procedure

While comfortably seated in front of the Macintosh, the observer viewed the dichoptic windows through the stereoscope. Each 1-min trial was initiated by the observer's pressing the mouse button. In Experiment 1, the observer was simply asked to read aloud the text that was visible. The experimenter monitored the observer's reading to determine which of the two letter strings was being reported. In Experiment 2, the observer was instructed to tap the mouse button whenever the probe character was detected within a letter string. Each time the button was pressed, the computer captured and stored the letter strings appearing within the left and right windows, as well as the letter strings that had passed through the windows during the previous 1.5 sec. At the end of each 1-min trial, each letter string captured during that trial was printed on the screen, allowing the experimenter to tally the number of probes detected. It was also possible to compare left- and right-eye letter strings, to determine the letters appearing in one eye's view at the time the observer failed to detect a probe character appearing in the other eye's view.

Observers

For Experiment 1 (dichoptic reading), 12 volunteers were recruited from among the postgraduate, graduate, and undergraduate population of Cresap Neuroscience Laboratory. These individuals were not screened for visual acuity or stereopsis; anyone with refractive error wore his/her corrective lenses during testing.

The author plus 3 of the 12 observers (1 male and 2 females) participated in Experiment 2 (probe detection). All except 1 (the author) were naive about the hypothesis under test. All had normal or corrected-to-normal acuity and excellent stereopsis. Each observer was given practice on the probe detection task prior to formal data collection.

EXPERIMENT 1: DICHOPTIC READING

In this experiment, the observer was instructed simply to read the text to the best of his/her ability. To begin, each observer practiced reading text under nonrivalry conditions: a text string was presented to one eye only, with the other eye viewing a blank window. All observers could read accurately under this condition, which confirmed that the letter stream, although moving briskly through the window, was legible.

Next the observer was tested in a condition in which the two eyes received different stories composed of letters written in the identical font for the two eyes. In this condition, 10 of the 12 observers were unable to read text with a given eye for any extended period of time. Occasionally, an observer was able to pick up several words in a row from one eye's view followed by a couple of words from the other eye's view. Usually, however, the observer's verbalizations consisted of fragmentary sounds punctuated with laughter at the impossibility of the task. Two observers were able to read almost continuously from a particular eye, but neither could switch reading from that eye to the other upon request. In fact, when nonsense was presented to the preferred reading eye and the readable story was presented to the other eye, both observers

found reading impossible. Evidently these 2 individuals exhibited strong eye dominance on this modified rivalry task.

To try to facilitate segregation of the two stories, each observer was next tested on two new stories, this time with one eye's text written in large, bold letters (Venice 14 font) and the other's written in small, thin letters (Monaco 9 font). It is known that dichotic listening is made even easier when the separate voices heard by the two ears differ in pitch (e.g., male vs. female voices). No such facilitation was found, however, in the case of dichoptic reading. The observers still found the task virtually impossible, although there was now a tendency to report more words written in the large, bold type.

In a further attempt to promote selective attention to one eye's story, the text windows were designed so that the letters seen by one eye were red and the letters seen by the other eye were green.[2] This was achieved by reversing the contrast of the window and letters, so that the letters appeared as white against a black window. Small pieces of Kodak Wratten filter were placed over the windows, No. 25 (red) over one window and No. 58 (green) over the other; the background remained gray. The observers were asked to read the text passage printed in a particular color, with the designated color varying randomly across observers. Segregating inputs by color also failed to simplify dichoptic reading, a result that may not be so surprising in view of the putative independence of color and form rivalry (e.g., Creed, 1935).

Finally, the observers were tested in a condition designed to provide a possible initial advantage to one eye. For the first 5 sec of each trial, text was presented within one window only; the other window remained blank for 5 sec before text began streaming through it. The observers readily shadowed the head-start eye's text until the onset of the other text stream, at which time reading quickly deteriorated.

In summary, it was impossible to create stimulus conditions that allowed observers to read the text presented to one eye when the two eyes received discrepant text information. In this respect, the binocular visual system seems to behave quite differently from the binaural auditory system, with which listeners can successfully monitor one ear's input under conditions of dichotic stimulation.

One could argue that the impossibility of reading one eye's text arises from some type of cognitive overload, whereby dichoptic stimulation doubles the number of characters to be processed per unit time. There are, however, several reasons to reject this cognitive overload argument. For one thing, the argument is tantamount to assuming that suppression of one eye's input occurs after the site where text information is processed, yet there is evidence that suppression occurs prior to this stage of processing (Zimba & Blake, 1983). The descriptions offered by the observers in the present experiment indicate that they were experiencing binocular rivalry, not two superimposed streams of text. Also, 2 observers with strong eye dominance *were* able to read one eye's text,

implying that the task itself imposed no insurmountable cognitive barriers. Still, to test this cognitive overload hypothesis, 5 of the observers were asked to inspect a monocular stream of text moving at 26 characters per second, that is, twice the rate used in the dichoptic reading experiment. In this nonrivalry control condition, the observers had no trouble comprehending the entire 60-sec episode, although the story line did move too quickly for them to verbalize the text as it appeared. (Note that this doubled presentation rate is equivalent to a reading rate of approximately 240 words per minute, a value easily realized by educated individuals reading nontechnical prose.)

All things considered, it seems most reasonable to attribute the difficulty of dichoptic reading not to cognitive overload but to a unique limitation within binocular vision. This conclusion was further supported by the results of Experiment 2, which was designed to answer the following question: To what extent does the semantic content of the stimulus viewed by one eye influence probe detectability by that eye under conditions of binocular rivalry?

EXPERIMENT 2: PROBE DETECTION

The observers were instructed to signal the detection of a probe target that appeared at irregular intervals within one of the dichoptically viewed letter streams. The observers were not told which eye's view would contain the probe target. The displays used in this experiment are illustrated in Figure 2.

Monocular (Nonrivalry) Control Condition

For each observer the experiment began by testing probe detectability in a nonrivalry condition in which only one eye was stimulated. The stimulated eye received a nonsense string in which the probe target was embedded; the nontested eye viewed a blank window. As summarized by histogram a in Figure 3, performance under this condition was perfect (i.e., 100% of the probes were detected), thus confirming that observers had no trouble picking out the probe from text strings—the basic task was easy.

Rivalry Between Nonsense Strings

Each observer was tested in a rivalry condition in which both eyes received nonsense strings, with different strings presented to the two eyes. Each string consisted of three to seven characters; strings were separated by blank spaces. During one of the two 1-min test periods the probe appeared with the left eye's string; during the other 1-min test period the probe appeared within the right eye's string. The order of these two trials was random for each observer.

The results for this condition are shown by histogram b in Figure 3; data were averaged across eyes and observers because the pattern of results was the same in all instances. The results show that probe detectability fell to around

Figure 2. These pairs of windows illustrate the kinds of dichoptic displays used to generate the data shown in Figure 3. For a given condition, the right eye viewed one member of the pair while the left eye viewed the other member of the pair. Window pair a represents a monocular (nonrivalry) control condition, pair b the condition in which the two eyes viewed different nonsense strings typed in the same font, pair c the condition in which the two eyes viewed different nonsense strings typed in different fonts, pair d the condition in which one eye (the probed eye) viewed words while the other eye viewed nonwords, pair e the condition in which one eye (the probed eye) viewed nonwords while the other eye viewed words, pair f the condition in which one eye (the probed eye) viewed text while the other eye viewed nonwords, and pair g the condition in which one eye (the probed eye) viewed nonwords while the other eye viewed text.

60%, indicating that almost half the probes went undetected when the two eyes viewed dissimilar nonsense strings. The difference between the nonrivalry and rivalry conditions is statistically significant [$\chi^2(1) = 25$, $p < .01$].

Presumably, presentation of different strings to the two eyes caused binocular rivalry, and the undetected probes were appearing within the letter string while that eye was suppressed. The observers were not asked to track the fluctuations of rivalry in this condition, and indeed this would have been very difficult, since both eyes viewed nonsense strings that were dissimilar but undistinctive. Phenomenal descriptions from the previous experiment confirmed, however, that the observers experienced genuine rivalry when the two eyes viewed dissimilar text strings. It is reasonable to assume, therefore, that the failure to detect probes in the present condition is attrib-
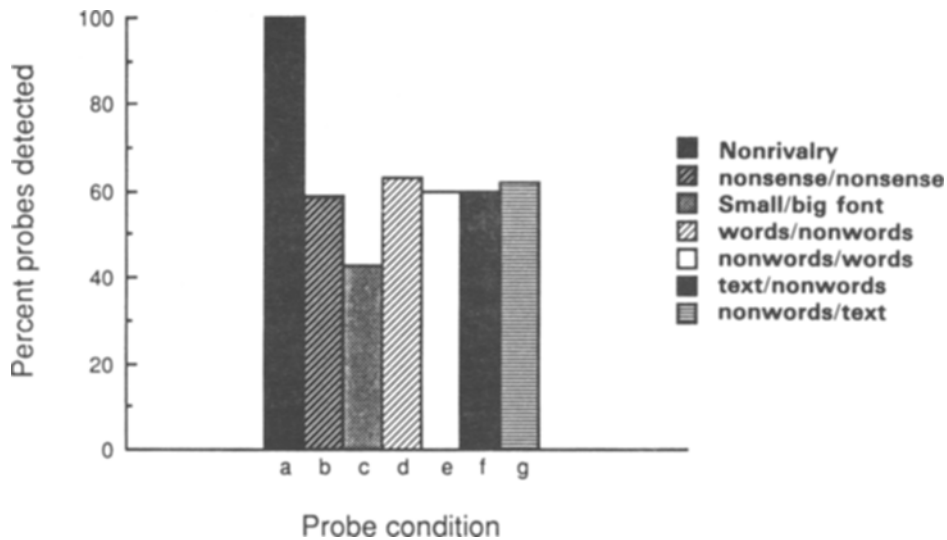
Figure 3. Histograms showing the percentage of probes detected under the various conditions illustrated in Figure 2. Data were averaged across observers, as the pattern of results was the same for all observers. Each data value is based on at least 50 probe trials. For each probe condition the eye receiving the probe was the one viewing the text string shown first in the legend (e.g., the eye viewing text received the probe in the text/nonword condition). The differences between Condition a and each of the other conditions are statistically significant ($p < .01$) as determined by chi-square.

utable to the transient appearance of those probes within a suppressed eye's view.

Of course, one could argue that the drop in probe detectability under conditions of dichoptic stimulation has nothing to do with binocular rivalry but, instead, stems from a general information processing limitation (recall the idea of cognitive overload from the previous experiment). More specifically, the two eyes' views, rather than engaging in rivalry, could simply be combined, thereby doubling the number of "noise" characters compared to the nonrivalry, monocular condition. The observers' descriptions of the dichoptic display certainly implied that they were seeing just a single string of letters, not a superimposition of letter strings. It is also noteworthy that the probe, on those occasions when it was detected, was just as visible as it was when seen under the nonrivalry, monocular control condition. This observation suggests that probes were not being camouflaged, or masked, by the characters presented to the other eye. Still, it seemed worthwhile to evaluate the level of performance expected when the signal-to-noise ratio was actually halved in a manner predicted by the superimposition hypothesis. To accomplish this, a double text monocular control condition was devised.

In this double text condition, one eye viewed a display composed of the superimposition of two separate strings of nonsense; the nontested eye viewed a blank window. The test probe appeared within the combined letter string, and the observer was again instructed to tap the mouse button whenever a probe was detected. All 3 observers tested found this task essentially impossible—only 5% of the probes were detected, a level of performance signifi-

cantly worse than the 60% detection level measured under conditions of rivalry [$\chi^2(1) = 22.1, p < .01$]. The impossibility of detecting the probes under this double text condition is perfectly understandable: the additional, superimposed characters literally obliterated the probe. To illustrate, imagine a string of typed characters that includes the probe target. Now take that string of typed characters and physically type another, unrelated, string of characters over the original; this is essentially the display viewed by observers in this monocular double text condition. Not only were the letters obscured, the probe itself was overwritten by the superimposed characters, rendering the probe entirely unrecognizable. During binocular rivalry, however, the two strings did not appear superimposed, strings of characters were not unrecognizable, and the test probe was not obliterated. Instead, the two dichoptic letter strings were reciprocally dominant, which is why roughly half the probes were detected under conditions of dichoptic viewing. This pronounced difference in performance between the rivalry condition and the monocular double text condition supports the conclusion stated previously; that is, the decrement in performance under conditions of rivalry results not from masking (i.e., a reduction in the ratio of signal to noise) but from a unique limitation inherent in binocular vision. To explore the generality of this conclusion, several other conditions of dichoptic stimulation were examined using the probe technique.

Small Versus Long Font

The nonsense rivalry condition was repeated, except that now the nontested eye viewed large, high-contrast

letters while the tested eye viewed letters printed in the usual, smaller font. In this condition, probe detectability deteriorated even further, with only 42% of probes being detected on average (Figure 3, histogram c). This finding is not surprising—it merely indicates that large, high-contrast letters predominated in rivalry over smaller letters, thereby increasing the probability that the probe target would briefly appear within the letter string viewed by the suppressed eye.

For all remaining conditions, the two eyes received identical fonts; only the meaningfulness of the messages was varied.

Words Versus Nonwords

For the next rivalry condition, one eye viewed strings of letters that spelled common real words while the other eye viewed nonsense strings like those used in the previous condition. The real words were drawn from those with an average word frequency of 100 per million within Thorndike and Lorge's (1944) lists, with the stipulation that no word exceed seven characters in length. Individual words and individual nonsense strings were separated by blank spaces. For a given 1-min trial, the repeated presentations of the probe target occurred within only one eye's string, with the string containing the probe (nonword vs. word) varied over trials. Four trials were administered in this condition, so that the right eye and the left eye each received the probe in both types of string (word vs. nonword).

Under this monocular word-versus-nonword condition, probe detectability was once again 60%, regardless of whether the probe was embedded within the nonword string or the word string (Figure 3, histograms d and e). This indicates that words alone enjoy no dominance over nonwords in rivalry. Incidentally, content analysis of the words appearing in the windows on occasions when the probe was detected revealed no tendency for certain types of words (e.g., nouns) to accompany detected probes. The words associated with undetected probes were also analyzed, and no such tendencies were found. Whether a probe was detected or undetected was apparently unrelated to the nature of the word in which it was embedded (probe within word string) or to the nature of the word appearing simultaneously in the other eye's view (probe within nonword string).

Text Versus Nonwords

What happens when an eye receives letter strings that constitute meaningful text? In this condition, one eye viewed text excerpts while the other eye viewed nonword strings. The eye receiving the probe (left vs. right) and the type of string in which the probe was embedded (text vs. nonword) were tested in all four combinations, randomly ordered.

Averaged data appear in histograms f and g of Figure 3. Note that probe detectability remained around 60%, regardless of whether the probe was presented to the eye receiving text or to the eye receiving nonwords. This result indicates that meaningful text enjoys no predominance over nonwords.

Forced Reading of Text

In the previous conditions, nothing about the task forced observers actually to read the material—their instructions were simply to signal the appearance of the probe target. Given this task, one could argue that observers effectively processed the letter strings only to a level necessary to discriminate the probe target from other characters. Perhaps, according to this argument, letter strings were not processed to the level of semantic content, which explains why meaning had no influence on probe detectability and, by inference, on rivalry dominance. To address this concern, the task was modified in a way that required observers actually to read the meaningful material.

In this revised condition, the names of common animals were randomly interspersed among the strings of words, with from 8 to 10 animal names appearing within each 1-min test sequence. The observers were instructed to tap the mouse button whenever an animal name appeared as well as whenever the probe character was detected.

Each observer was first tested in a nonrivalry, monocular control condition, wherein word strings containing the probe target were presented to one eye while the other eye viewed a blank window. The results from this condition (see Figure 4) revealed that the modified task was somewhat more difficult than the task involving probe detection only—on average, the observers detected 85% of the probes and 80% of the animal names. False-alarm rates were negligible.

Next the observers were tested under a rivalry condition, wherein the word string, including animal names, was presented to one eye while the nonword string was presented to the other eye. Within a given 1-min test period, the probe target was presented within the word string or within the nonword string, with the order of these trials randomly ordered. Under this rivalry condition, probe detectability plunged to 50%, regardless of whether the probe was contained within the word string (which also contained the animal names) or within the nonword string. This difference in percent correct performance between nonrivalry and rivalry conditions is statistically significant [$\chi^2(1) = 13.07, p < .01$]. The number of animal names successfully detected also fell sharply, to just below 50%.

Thus, even when the observers were encouraged to process individual words to the level of meaning, probe detection was impaired during rivalry. In effect, the observers were unable to hold their attention on one eye's letter string. In another condition, the eye receiving words (including animal names) was given a head start: at the beginning of each 1-min test period, the words were presented to that eye for 5 sec, during which time the other eye's window was blank. This manipulation provided no assistance to the eye receiving the probe: once the nonword string began streaming through the other eye's win-
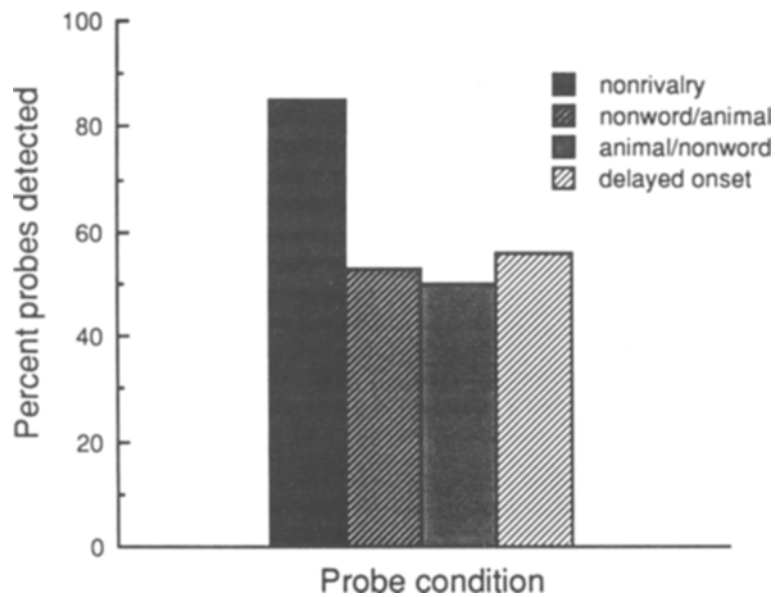
Figure 4. Histograms showing the percentage of probes detected under conditions of forced reading. In all conditions one eye viewed a string of words that included names of common animals. In the nonrivalry condition, probes and word strings were presented to one eye only, with the other eye viewing a blank window. In another condition the words (including animal names) and probes were paired dichoptically with nonwords. In a third condition, the probe was presented within the string of nonwords. In the last condition, the probe appeared within the string of words, and this string was presented for 5 sec alone before the string of nonwords was presented in the other eye's window.

dow, animal names were frequently missed and probe detectability was impaired.

Finally, 2 of the observers were tested in a modified version of this condition, wherein each of the animal names was replaced with the observer's own name. The observer was required to tap the mouse button whenever she detected her name or the probe target. Both observers performed just as they did in the original condition—almost half the probes and half the name occurrences went undetected. Evidently, even a stimulus as unique and familiar as one's own name is insufficient to influence rivalry dominance.

DISCUSSION

The present results indicate that binocular vision, unlike binaural hearing, fails to deploy selective attention strategies when confronted with dissimilar input. When the two ears receive different messages, people can successfully monitor one ear's input more or less continuously, and they can detect highly familiar messages (such as their names) presented within the nonattended channel. In contrast, the observers in the present study found it impossible to attend selectively to one eye's input even when that input consisted of meaningful text, including their own names. These results, therefore, contradict theories (e.g., Walker, 1978) positing that rivalry involves some form of high-level attentional process.

In earlier studies, naive observers reported that familiar rival targets predominated over unfamiliar ones (Engel, 1956); moreover, observers were able to attend selectively to either of two complex, dichoptically viewed scenes (Neisser & Becklen, 1975). How can one reconcile these findings with the present results, which show no evidence for selective attention and no influence of meaning on rivalry? Let me offer two possible explanations for these apparently contradictory results. First, it can be argued that expectations and/or subtle demand characteristics make it impossible for naive observers to report rivalry dominance in an unbiased fashion. In this regard, the test probe technique used in the present experiments should be relatively immune to bias effects, since the technique requires only that the observer indicate detection of a neutral probe target.

A second possible explanation turns on the distinction between linguistic meaning and image meaning. In the present experiments, meaning was defined in terms of the semantic content of letter strings. Of course, there is nothing inherently meaningful in words themselves—their meaning is derived from the associations they engender. To the individual unfamiliar with the English language, the word *whale* carries no more meaning than the nonword *rlopa*. So the present results and their attendant conclusion may pertain only to meaning defined in a linguistic sense. Perhaps, according to this explanation, rivalry dominance *can* be influenced when it is the structure of

the image itself that conveys meaning. To illustrate, suppose that one eye views a patch composed of randomly scattered dots while the corresponding area of the other eye views a patch of dots that form a familiar object, such as a person's body. Would this kind of structurally meaningful stimulus predominate in rivalry? This remains an entirely reasonable possibility (see Ono, Hastorf, & Osgood, 1966), the present results notwithstanding. Of course to answer the question of meaning from image structure will require appropriate control conditions to evaluate alternative interpretations (e.g., response bias) of positive results, but devising such conditions is not an insurmountable challenge.

Finally, in light of the present results it is instructive to reconsider the findings of Rommetveit et al. (1968a, 1968b), who purported to find evidence for an effect of semantics on binocular rivalry between dissimilar words. These investigators very briefly presented a pair of typographically similar words (e.g., *wine* and *nine*) separately to the two eyes and asked observers which of the two rival words was perceived. Prior to some presentations, the observers saw a word (e.g., *beer*) or series of words that was related to one of the two rival words; these so-called context words were seen under conditions of fusion, not rivalry. Following dichoptic presentation of the pair of typographically similar words, the observers tended to report seeing the word that was related to the previously presented context words. This outcome implies that semantic context can influence perception under conditions of dichoptic stimulation. In attempting to reconcile Rommetveit et al.'s findings with the present results, it is important to note that target words in Rommetveit et al.'s study were presented in a single flash that lasted less than 400 msec. From other work, it is known that binocular rivalry is not experienced at durations this brief (Anderson, Bechtoldt, & Dunlap, 1978; Goldstein, 1970). Hence, instead of studying binocular rivalry, Rommetveit may have been measuring the effects of semantic priming on dichoptic masking (e.g., Holender, 1986). It would be informative to perform a version of Rommetveit's experiment in which the pair of rival targets are viewed for an extended period of time.

CONCLUSION

It is generally recognized that rivalry predominance depends strongly upon feature primitives such as orientation (Wade, 1974), spatial frequency (Fahle, 1982; Hollins, 1980), contrast (Blake, 1977), and motion (Breese, 1909; Wade, de Weert, & Swanston, 1984). In contrast, the present results indicate that the informational content of rival targets, linguistically defined, has essentially no influence on rivalry dominance. These properties of binocular rivalry imply that the underlying neural events transpire at a fairly early level of visual processing, prior to the stage where semantic information has been extracted (see also Zimba & Blake, 1983).

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NOTES

1. The visual analogue of dichotic listening developed for this study is not novel. In their study of visual memory, Sampson and Horrocks (1967) devised a projection system that made it possible to present sequences of numerals separately to the two eyes, on either corresponding or noncorresponding retinal areas. In their studies, recall of the order of numerals was the measure of interest. More recently, Lack (1979) used a motion picture projector to present sequences of alphanumeric characters separately to the two eyes. He used this dichoptic display to study the extent to which observers could attend to one eye's display exclusively. Lack's results showed that for naive observers the degree of voluntary control during dichoptic stimulation was not great compared to that characteristic of dichotic listening (e.g., Moray, 1969).

2. I am grateful to Anne Treisman for suggesting this condition.