

Dichoptic and dichotic micropattern discrimination*

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Ss compared two rapidly successive, brief, discriminably different stimulus elements, called a micropattern, with a second micropattern composed of the same two stimulus elements presented in reverse temporal order. Discriminations could be made between two such micropatterns in the monaural (monocular) as well as in the dichotic (dichoptic) modes of presentation. Discrimination between micropatterns was based on the perceptual dominance of the temporally trailing stimulus element in both modalities and in both modes of presentation. While monaural (monocular) micropattern discrimination is significantly superior to dichotic (dichoptic) discrimination, the existence of dichotic (dichoptic) discrimination demonstrates that no essential peripheral process is required for micropattern discrimination.

Recent experiments in this laboratory in the visual, auditory, and vibratory modalities (Efron, 1973) have been concerned with the discrimination of brief, complex stimuli differing only in their fine temporal structure. In these experiments, Ss compared two consecutive, brief, discriminably different stimulus elements, called a micropattern, with a second micropattern composed of the same two stimulus elements presented in the *reverse* temporal order. Ss readily discriminated between micropatterns having reversed temporal order of stimulus elements in all three modalities, even when the temporal asynchrony between the stimulus elements was so far below the threshold for making temporal order judgments that each micropattern was experienced as a unitary perceptual event. The discriminations were based on the perceptual dominance of the second or trailing stimulus element. Additional studies revealed that the trailing stimulus element phenomenally dominated the perception of each micropattern by virtue of a retroactive degradation of the perceptual experience of the leading element. This perceptual degradation of the leading stimulus element by the trailing element did not have the properties of retroactive masking.

In all the previous experiments, the two stimulus elements of each micropattern were presented to the same eye, ear, or skin location—an experimental paradigm which did not permit any analysis of the neuroanatomical locus of the retroactive interaction. In the experiments to be described here (in the auditory and visual modalities), the same micropatterns were presented dichotically (dichoptically)—one stimulus element of the micropattern to each ear (eye). If there is an *essential* peripheral process involved in micropattern discrimination in the basilar membrane or in the retina, the phenomenon of perceptual dominance of the trailing stimulus element would not be expected in such dichotic (dichoptic) presentations. The purpose of the present experiments was to determine (1) whether dichotic and

dichoptic micropattern discriminations are possible, (2) whether the discriminations (if possible) are based on the perceptual dominance of the trailing stimulus element as was found in the monaural and monocular modes, and (3) whether these discriminations in the dichotic and dichoptic modes are affected in the same way by parametric manipulations as are those in the monaural and monocular modes.

METHODS

Instrumental

A complete description of the instrumentation and stimulus parameters employed in these experiments has been previously presented (Efron, 1973) and will only be summarized here. For the auditory experiments, the outputs of two oscillators of different frequency were passed through attenuators, and then through audio gates which generated brief tone bursts. The duration of each tone burst and the sequence of the two tone bursts were controlled with a digital logic system (Iconix 6257-6010-6171) accurate to ± 0.01 msec. For the monaural experiments, the output of the two audio gates was electrically added, passed through a bandpass filter, and delivered via calibrated earphones to a single ear. For the dichotic experiments, the output of each gate was passed through its own bandpass filter and then delivered via a reversing switch to either the right or left ear. For the visual experiments, the pulsed light output of two glow modulators was passed through neutral density filters and a Wratten colored filter. The colored beams from these two filters were optically combined using a Y-shaped two-channel fiberoptic bundle—the end of which was defocused to the plane of a circular aperture (5.5 deg), which was then observed in Maxwellian view. For the dichoptic experiments, two independent optical systems were used and the two apertures were viewed binocularly (visually superimposed). The timing sequence and duration of each of the two colored light flashes were controlled by the same digital logic system used for the auditory experiments.

Psychophysical

In the previous study of monaural and monocular micropattern discrimination (Efron, 1973), a two-alternative "same-different" paradigm was employed. This same method could not be used for the present experiments as a consequence of two confounding phenomenal cues in the dichotic mode—an ear asymmetry cue and a sound localization cue. The confounding nature of these cues and the experimental design employed to circumvent these difficulties is illustrated in Fig. 1.

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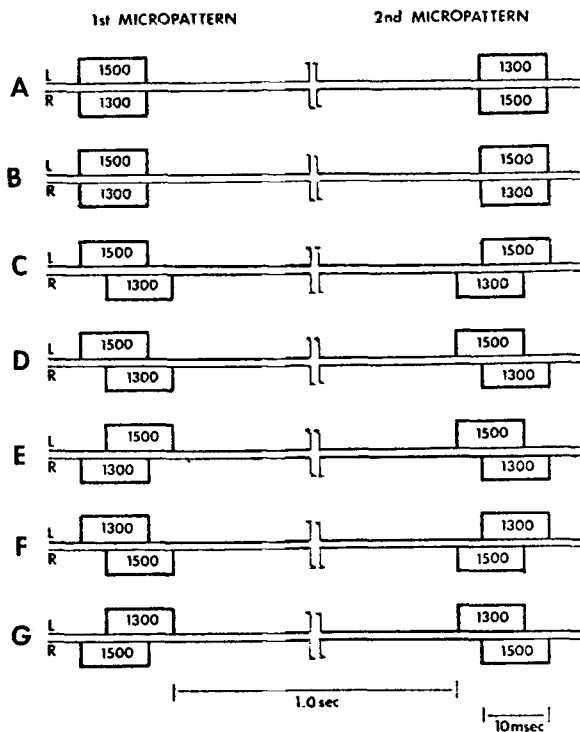


Fig. 1. Diagrammatic representation of experimental paradigm. See text for details.

The two micropatterns illustrated in Fig. 1A (where no element asynchrony exists) are not discriminable when presented monaurally. They will be discriminable dichotically if any asymmetry exists between the two ears. Two types of ear asymmetry are known: (1) a difference in sensitivity of the two ears, and (2) a right or left ear "dominance" such as that described by Broadbent (1954), Kimura (1961, 1967), Lowe et al (1970), Efron and Yund (1974), and others in a wide variety of dichotic listening experiments. Both types of asymmetry will give rise to the same phenomenal cue. For example, if the left ear is more sensitive (or more dominant) than the right, then the 1,500-Hz tone in the left ear in the first micropattern of Fig. 1A will be louder than the 1,300-Hz tone burst in the right ear. The perceived dichotic chord will be dominated by the 1,500-Hz tone. For the same reason, the 1,300-Hz tone will perceptually dominate the second micropattern. The S will consequently report that the two micropatterns are discriminably different.

To circumvent any ear asymmetry cues, all dichotic micropatterns were presented so that the same frequency was delivered to the same ear for both micropatterns of a single trial (Fig. 1B). While this mode of presentation effectively eliminates any cues resulting from an ear asymmetry, it introduces a localization cue for all dichotic micropatterns with a nonzero element asynchrony. Thus, the first micropattern of Fig. 1C will be localized to the left of the midline, and the second will be localized to the right of the midline—and this would be readily detected by the S. However, when two identical micropatterns are presented, as in Fig. 1D, they would have the same intracranial localization. Even if no dichotic micropattern discrimination were possible, the use of a same-different method could still yield a 100% discrimination score merely on the fact that the micropatterns of Fig. 1D have the same localization, while those of Fig. 1C have a different localization. (The S could reply "same" when the localization of the two micropatterns did not alter within a trial and could reply "different" when the locus did alter within a trial.) In sum, same-different judgments

could not be employed since there was no way to present asynchronous dichotic micropatterns with the same frequency elements in the same ear for both micropatterns of a single trial without introducing the localization cue just described.

In the method employed for the present series of experiments, the S received only trials in which the first and second micropatterns were different with respect to the frequency of the trailing element (illustrated in Figs. 1C, 1E, 1F, and 1G). He was required to report if the first micropattern in each trial was of higher or lower pitch than the second. The validity of this form of report had already been established by the previous studies (Efron, 1973), which unequivocally showed that the basis for monaural micropattern discrimination was the perceptual dominance of the pitch of the trailing stimulus element.

If only Configurations 1C and 1E were employed (where the 1,500-Hz tone is always in the left ear in both micropatterns of a single trial), then the micropatterns in which the 1,500-Hz tone was the trailing element would always be localized to the right of the midline. Similarly, the micropattern in which the 1,300-Hz tone was the trailing element would always be localized to the left of the midline. If the S became aware of this cue, he might then base his reports on this localization difference. To circumvent the use of these localization cues, the Ss were also presented with trials having configurations illustrated in Figs. 1F and 1G. Configuration F is like Configuration C in that the first micropattern is heard on the left and the second is heard on the right—but, if there is a perceptual dominance of pitch of the trailing element, then Configuration C will be reported as having a low-high pitch sequence and F will be reported as having a high-low pitch sequence. Similarly, E and G have the same localizations, but would have opposite pitch sequence reports. An experimental session for a given stimulus element asynchrony consisted of 25 trials of Configurations C, E, F, and G in pseudorandom order.

Since this psychophysical method was mandatory in the dichotic experiments, identical procedures were used in the monaural experiments so that the data of the two modes of presentation would be comparable.

Essentially identical methods were employed in the visual modality. The Ss were presented with micropatterns consisting of brief flashes of light of different hue, i.e., red and green stimulus elements. In this case, both micropatterns of a trial are perceived as flashes of yellow light. The Ss were required to report if the first micropattern was more greenish yellow or more reddish yellow than the second. In the dichoptic experiments, it was not necessary to take the elaborate precautions to avoid localization-like phenomena, and thus the green flash was always delivered to the left eye and the red flash was always delivered to the right eye.

All three Ss used for these experiments had had extensive previous experience in other visual and auditory psychophysical studies.

Nontemporal Stimulus Parameters

For the auditory experiments, the two stimulus elements were tones 25 dB above the detection threshold determined for each S. This low intensity level was used to avoid any effects of bone conduction across the head in the dichotic presentations. The same intensity levels were used in the monaural condition. For Experiments 1 and 2 in the auditory modality, the frequencies of the tones were 1,300 and 1,500 Hz. For Experiment 3, which was concerned with the effect of the difference in frequency between the two stimulus elements, a variety of frequencies was employed (vide infra).

For the visual modality, experiments were designed to test performance with two opponent-color pairs. For the red-green stimulus pair, Wratten No. 29 (red) and Wratten No. 58 (green) filters were used. For the monocular experiments, the luminances were approximately 110 and 300 fL, respectively. This value gave rise to a well-saturated yellow flash when the two

stimulus elements were both 10 msec and simultaneous. For the dichoptic experiments, the red flash was 7.1 fL and the green flash was 300 fL. This ratio yielded a yellow flash closely resembling that used in the monocular mode.

For the blue-yellow stimulus pair, Wratten No. 47 (blue) and Wratten No. 15 (yellow) were used. In the monocular experiments, the luminances were approximately 17 and 620 fL, respectively. This ratio of luminances gave rise to a white flash when the two stimulus elements were both 10 msec and simultaneous. For the dichoptic experiments, the luminances were 27 and 478 fL, respectively—which resulted in a white flash of closely similar appearance.

[It will be observed that different ratios of luminances for the two colors had to be used in the dichoptic mode compared to the monocular. These values were determined by adjustment of the dichoptic intensities to produce a hue similar to the corresponding monocular stimulus. The requirement for more red, in the red-green case, and more blue, in the blue-yellow case, is in agreement with the work of Thomas, Dimmick, and Luria (1961) on binocular color mixing.]

Only one of the three Ss was able to achieve dichoptic color mixing—a finding not surprising in view of the well-known difficulties associated with binocular color mixing. The S who could perform the dichoptic experiments was one of the authors (B.Y.), who had had previous experience with dichoptic visual stimuli.

Temporal Parameters

The temporal relationship between the stimulus elements of the micropatterns was the independent variable in Experiments 1 and 2. Figures 2A, 2B, and 2C illustrate the three types of temporal relationships that were explored for both modalities. Figure 2A illustrates the dichotic (or dichoptic) condition in which both stimulus elements of each micropattern are of equal (10-msec) duration, and the onset and offset asynchronies also have equal durations. Figure 2A only illustrates the configuration seen in Fig. 1C; configurations seen in Figs. 1E, 1F, and 1G, while presented to the S, are not illustrated. For the

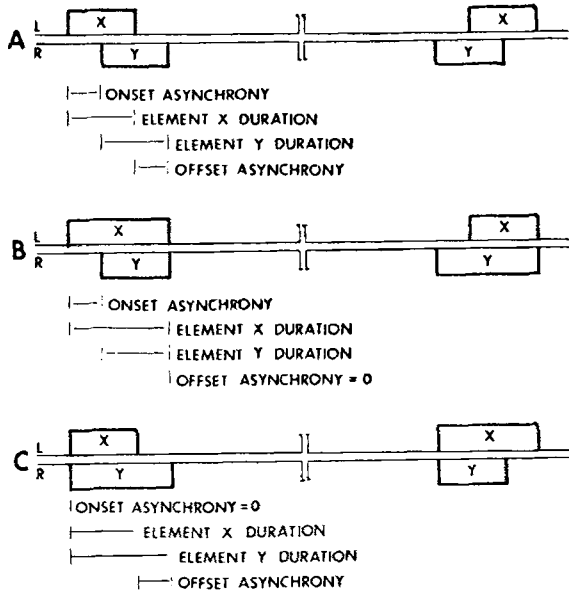


Fig. 2. Diagrammatic representation of the three types of stimulus element asynchronies employed in these experiments. Only the dichotic (dichoptic) forms of these micropatterns are illustrated. In A, the onset and offset asynchronies are both present and equal. In B, only onset asynchronies are present. In C, only offset asynchronies are present.

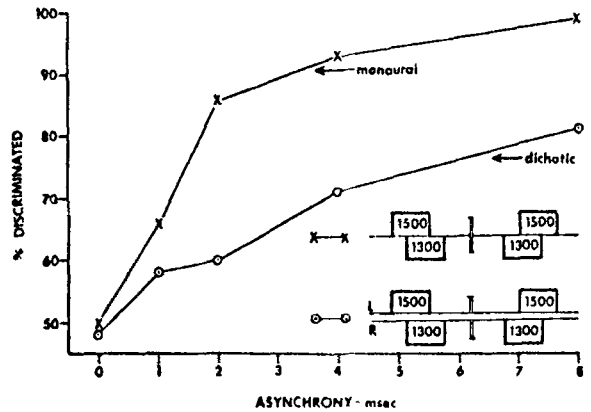


Fig. 3. Comparison of dichotic and monaural micropattern discrimination as a function of element asynchrony. As indicated by the inserted schematics, the onset and offset asynchronies were always equal. Their absolute values are indicated on the abscissa. The percent discriminated is plotted on the ordinate.

auditory modality, X was 1,500 Hz and Y was 1,300 Hz. For the visual modality, X was red and Y was green in one experiment, while X was blue and Y was yellow in a second experiment. These same experiments were repeated in the monaural and monocular modes in which the two stimulus elements of each micropattern were presented to the same ear (eye). The temporal relationships, however, were identical.

Figure 2B illustrates the dichotic (or dichoptic) condition in which the stimulus elements of each micropattern have asynchronous onsets but synchronous offsets. Trials illustrated in Figs. 1C, 1E, 1F, and 1G were presented, but only Configuration 1C is illustrated in Fig. 2B. Experiments with this temporal configuration were performed monaurally (monocularly) as well as dichotically (dichoptically).

Figure 2C illustrates the dichotic (or dichoptic) condition in which the stimulus elements of each micropattern have synchronous onsets but asynchronous offsets—once again illustrating only the configuration seen in Fig. 1C. These experiments were also performed monaurally and monocularly.

In all these experiments (Figs. 2A, 2B, and 2C), the independent variable was the element asynchrony, the specific values of which will be described separately for each experiment.

RESULTS

Experiment 1A—Monaural and Dichotic Micropattern Discrimination

The temporal configuration of the auditory micropatterns employed in this experiment are illustrated in the schematic diagram of Fig. 2A. The duration of each stimulus element was 10 msec, with an exponential rise-decay time of 5.0 msec. The onset and offset asynchronies were 8, 4, 2, 1, and 0 msec in five different experimental sessions—the last serving as a control determination where the performance would be expected to be at the chance (50%) level. The frequencies of the two elements were 1,300 and 1,500 Hz.

Both the monaural and dichotic results are presented in Fig. 3, averaged across the three Ss. The element asynchrony is plotted on the abscissa. The ordinate represents the percentage of trials in which the Ss gave

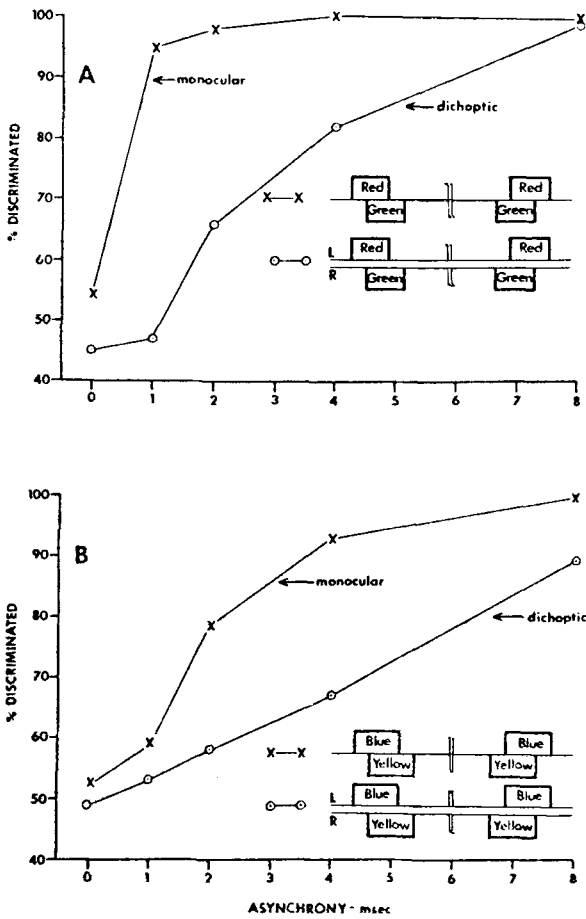


Fig. 4. A comparison of dichoptic and monocular micropattern discrimination for red and green (Fig. 4A) and for blue and yellow (Fig. 4B). As indicated by the inserted schematics, the onset and offset asynchronies were always equal. Their absolute values are indicated on the abscissae. The percent discriminated is plotted on the ordinates.

the expected response, i.e., reporting that the pitch of the trailing element dominated the pitch of the micropattern. It can be seen in Fig. 3 that the Ss consistently gave the expected response except where the asynchronies were small and consequently the performance was near the chance level.

The most significant aspect of the results seen in Fig. 3 is the demonstration that dichoptic micropattern discrimination is possible. All of the dichoptic nonzero asynchrony points are significantly different from the zero asynchrony point ($p < .05$ for 1, 2, and 4 msec, $p < .005$ for 8 msec; paired values t , paired by Ss). As in the monaural case, dichoptic micropattern discrimination improves as asynchrony increases. Presumably, larger asynchronies would lead to even better dichoptic performance. However, asynchronies exceeding 8 msec might enable the S to judge the temporal order of the stimulus elements within the micropattern (Hirsh & Sherrick, 1961) and were not employed for this reason.

It is also clear from the results of Fig. 3 that monaural

micropattern discrimination is superior to the dichoptic for all nonzero asynchronies. This difference between the monaural and dichoptic values for the nonzero asynchronies is significant at the .0005 level (paired values t test with values paired for Ss and asynchronies).

In summary, dichoptic micropattern discrimination is possible throughout the range of asynchronies from 1 to 8 msec. Throughout this range, dichoptic performance is inferior to monaural performance.

Experiment 1B—Monocular and Dichoptic Micropattern Discrimination

The temporal configuration of the chromatic micropatterns employed in this experiment are illustrated in the schematic diagram of Fig. 2A. The duration of each stimulus element was 10 msec, with a rise-decay time of less than 0.4 msec. The asynchronies between the two elements were identical to those employed in Experiment 1A.

Although all three Ss could perform monocular micropattern discriminations with both the red-green and blue-yellow color combinations, only one S could achieve sufficiently stable binocular color mixing to perform these same discriminations in the dichoptic mode. Therefore, only the data from this one S will be presented here in detail. The results for this S for the red-green and blue-yellow color combinations are given in Figs. 4A and 4B, respectively. The element asynchrony is plotted on the abscissae. The ordinates represent the percentage of trials in which the S gave the expected response, indicating that the color of the trailing element dominated the color of the micropattern. Again, as in the auditory case, the S always gave the expected report except for the smallest asynchronies where he was near chance.

Dichoptic micropattern discrimination was obtained for both color combinations (note the open circles of Figs. 4A and 4B). To test the significance of these results, the 100 trial sessions were divided into 4 subsessions of 25 trials each; then t statistics were computed on these subsession results. For the case of the red and green elements, Fig. 4A, the 8-, 4-, and 2-msec asynchrony discriminations are significantly better than 0-msec asynchrony ($p < .0005$, .0005, and .05, respectively). For the blue-yellow case, Fig. 4B, the 8- and 2-msec asynchrony discriminations are significantly better than 0-msec asynchrony ($p < .005$ and .05) and the 4-msec values just miss significance at the .05 level.

For both color combinations, it is apparent that the monocular performance is superior to the dichoptic. Of all the nonzero asynchronies, only the results for 8-msec red-green and 1-msec blue-yellow fail to yield a significant monocular superiority. This statistical result at these two points is to be expected, since both monocular and dichoptic performances are essentially perfect for the first and chance for the second.

A comparison of Figs. 4A and 4B also demonstrates

that changing the colors of the stimulus elements from red-green (Fig. 4A) to blue-yellow (Fig. 4B) has a similar effect upon the monocular and dichoptic discrimination functions. The monocular red-green monotonic function rises more steeply than the monocular blue-yellow. This same difference between red-green and blue-yellow functions occurred for the other two Ss who were unable to participate in the dichoptic experiments. In like manner, the dichoptic red-green curve rises more steeply than the dichoptic blue-yellow. Thus, for both the monocular and dichoptic modes, the discrimination improves more rapidly as asynchrony increases when red and green elements are used than when blue and yellow elements made up the micropatterns. Whatever may be the cause of the superior red-green performance compared to the blue-yellow, the fact that the monocular and dichoptic results both show this effect is an important finding.

Experiment 2A—Effects of On- and Off-Asynchrony in the Monaural and Dichotic Modes

The temporal configurations of the stimuli employed in this experiment are illustrated in Figs. 2B and 2C. There are two major parts to the experiment. In the first, the ability to discriminate monaural micropatterns with elements having asynchronous onsets (Fig. 2A) is compared with that for micropatterns with elements having asynchronous offsets (Fig. 2B). This part of the experiment is a more extensive repetition (using different stimulus parameters and psychophysical procedures) of an experiment reported previously by Efron (1973). In the second part of the experiment, the same stimuli were presented in the dichotic mode. For all micropatterns in this experiment, the shorter stimulus element was 10 msec, with the same 5.0-msec exponential rise and decay times as used previously. The longer element was 10, 11, 12, 14, or 18 msec (with the same rise-decay times). These durations for the longer element yielded asynchronies of 0, 1, 2, 4, and 8 msec. The frequencies of the tone bursts were 1,300 and 1,500 Hz.

The results for the monaural part of the experiment are presented in Fig. 5A. The average percent discriminated for the three Ss is plotted as a function of the element asynchrony. The results for both types of stimuli, those with asynchronous element onsets (crosses and solid line) and those with asynchronous element offsets (circles and dashed line), indicate that discrimination performance was a monotonically increasing function of the element asynchrony. Such monotonic functions are to be expected in this experiment, since one of the stimulus elements is longer and thus has greater energy in the first micropattern, while the other stimulus element is longer and has a greater energy in the second micropattern. As the asynchrony is increased, a monotonic increasing function is inevitable. Thus, either curve, in Fig. 5A, *taken by itself*, is not of great interest with respect to an

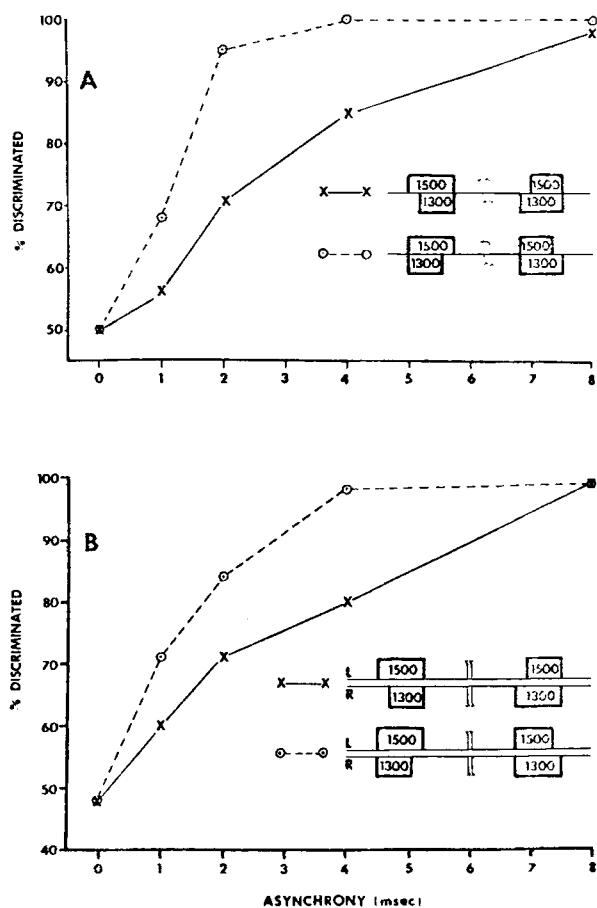


Fig. 5. (A) A comparison of monaural micropattern discriminations employing only onset or offset asynchronies. (B) A comparison of dichotic micropattern discriminations employing only onset or offset asynchronies. For both Figs. 5A and 5B, the abscissae represent the absolute values of the onset or offset asynchronies. The ordinates represent the percent discriminated. The inserted schematics illustrate the temporal configurations.

understanding of the processes involved in micropattern discrimination.

What is important about these results, however, is that the two curves are different. Stimulus pairs with asynchronous element offsets were more readily discriminated than were pairs where the same asynchrony occurred at the onset ($p < .0005$, paired values t test with values paired for Ss and asynchronies using all nonzero asynchronies). Some factor other than the energy difference between the stimulus elements—a difference which is identical for each asynchrony for these two curves—must account for this difference between these curves. The only possible factor is the fine temporal structure of the micropatterns which makes the discrimination easier to perform in the second experiment, where the element offsets were asynchronous, as was reported by Efron (1973). If dichotic micropattern discrimination is achieved by means of the same mechanisms as the monaural

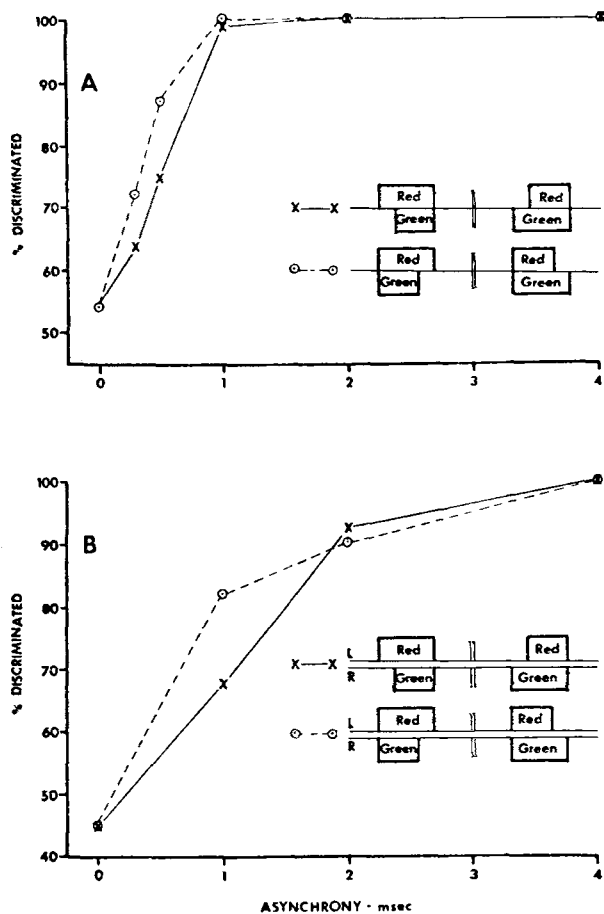


Fig. 6. (A) A comparison of monocular micropattern discriminations employing only onset or offset asynchronies with red-green stimulus elements. (B) A comparison of dichoptic micropattern discriminations employing only onset or offset asynchronies with red-green stimulus elements. For both Figs. 5A and 5B, the abscissae represent the absolute values of the onset or offset asynchronies. The ordinates represent the percent discriminated. The inserted schematics illustrate the temporal configurations.

discrimination, the same discrepancy between the onset and offset asynchrony performances would be expected when such stimuli are delivered in the dichotic mode.

The results for the dichotic part of the experiment are presented in Fig. 5B and confirm this expectation. Again, the average percent discriminated is plotted as a function of the element asynchrony. The similarity of these dichotic results to the monaural results of Fig. 5A is obvious. Both onset and offset asynchronies produced monotonically increasing functions, but, more importantly, the offset asynchronies lead to significantly higher average discrimination scores than were obtained with onset asynchronies ($p < .0005$, paired values t as in the monaural case).

Experiment 2B—Effect of On and Off-Asynchrony in the Monocular and Dichoptic Modes

The temporal configurations employed in the visual

experiments of this series were the same as those in the auditory experiments (2A) and are illustrated in Figs. 2B and 2C. The red-green monocular results for the S who was able to perform dichoptically are shown in Fig. 6A. Since the visual system is apparently very sensitive to relatively small energy differences in the micropatterns, it was necessary to expand the scale on the abscissa and to include two values of asynchrony shorter than 1 msec (0.5 and 0.3 msec) to demonstrate the difference between on and off asynchronies. Micropatterns with offset asynchronies were easier to discriminate than were those with onset asynchronies. The difference in discrimination performance reaches significance ($p < .05$) at 0.5-msec asynchrony.

The dichoptic results for these stimuli are given in Fig. 6B. The dichoptic performance is degraded, but otherwise similar to the monocular. Off-asynchrony performance was significantly ($p < .05$) better than on-asynchrony performance at 1.0 msec.

In sum, in both the auditory and visual systems, discrimination performance is superior when an element offset asynchrony is employed rather than an onset asynchrony. The same characteristic applies to the dichotic (dichoptic) as well as to the monaural (monocular) mode.

Experiment 3

In Experiment 1B, it was shown that changing the colors of the stimulus elements from red and green to blue and yellow had the same effects on both monocular and dichoptic micropattern discrimination. An analogous experiment was performed in addition to demonstrate that monaural and dichotic performance varies in the same way with changes in tone frequencies.

It has been previously reported (Efron, 1973) that in the monaural mode the perceptual dominance of the trailing stimulus element increased as the difference in frequency (Δf) between the two elements of the micropattern increased. This experiment was repeated in the monaural mode (using the present psychophysical methods and different stimulus parameters) and was performed in the dichotic mode for comparison. The temporal configuration seen in Fig. 2A was employed with both stimulus elements having a duration of 10 msec and an asynchrony of 8 msec. The frequencies of Elements X and Y (see Fig. 2A) were 1,600 and 1,200 Hz, 1,500 and 1,300 Hz, 1,450 and 1,350 Hz, 1,425 and 1,375 Hz, and 1,400 and 1,400 Hz in five different sessions. These values yield frequency differences of 400, 200, 100, 50, and 0 Hz, respectively—the last serving as a control—where chance levels of discriminatory performance were expected if all other relevant cues had been eliminated.

The results of Experiment 3 are seen in Fig. 7, where, as in all previous experiments, the dichotic performance is inferior to the monaural. However, the more significant aspect of these results is that both the monaural as well as the dichotic discrimination

performance increase as the frequency difference between the two elements of the micropattern increases.

DISCUSSION

Previous experiments using monaural and monocular presentations have shown that micropatterns can be discriminated even when the asynchrony between the two stimulus elements is as small as 2 msec. In all of the monaural and monocular experiments, the discriminations were achieved as a consequence of the perceptual dominance of the trailing stimulus element in each micropattern (Efron, 1973). In the present monocular and monaural experiments, performed with different stimulus parameters and with a different psychophysical method, the same findings were obtained. The results of the present experiments show that a perceptual dominance of the trailing stimulus element of the micropattern also occurs when the elements of the micropattern are presented to opposite ears or eyes in the dichotic or dichoptical modes.

Is the perceptual dominance effect observed in the dichotic (dichoptical) presentations the *same* phenomenon as that produced by monaural (monocular) presentations or is it a consequence of two essentially different processes having only a superficial resemblance?

Despite the fact that the Ss reported that the two dominance effects were indistinguishable, their performance in the dichotic mode was always inferior to their performance monaurally. The one S who could perform the dichoptical experiment also had an inferior level of performance dichoptically compared to the monocular performance. This difference in performance can be interpreted in either of two ways. On the one hand, it could be an indication that the two perceptual dominance effects are essentially different in the two modes of presentation. On the other hand, the performance differences could simply be an indication that the same phenomenon in the dichotic (dichoptical) mode is less powerful or that there is some interfering factor which is present in the dichotic (dichoptical) mode which reduces the apparent strength of the dominance effect.

A reexamination of the results of these experiments (Figs. 4A, 4B, 5A, 5B, 6A, 6B, and 7) strongly supports the view that the two dominance effects are identical in nature but different only in degree. In Figs. 4A and 4B, the monocular red-green monotonic function rises more steeply than the monocular blue-yellow function. In the dichoptical experiments, a parallel result was obtained—suggesting that the same factors which made the red-green micropatterns easier to discriminate monocularly were also operating dichoptically. In Fig. 5A, the monaural micropatterns were easier to discriminate when the elements had asynchronous offsets than when they had asynchronous onsets. In the dichotic experiments (Fig. 5B), a parallel result was obtained—indicating that the more powerful dominance

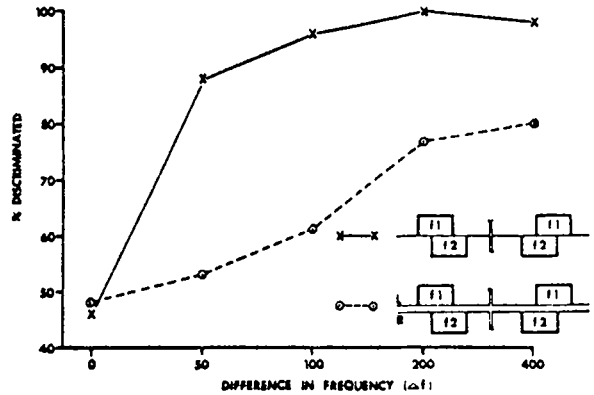


Fig. 7. A comparison of monaural and dichotic micropattern discriminations as a function of the difference in frequency of the two stimulus elements. The inserted schematics illustrate the temporal configurations employed. The onset and offset asynchronies were always equal (8 msec). The abscissa indicates the difference in frequency between f_1 and f_2 . The center frequency was 1,400 Hz.

effect produced by the offset asynchrony operates on monaural and dichotic micropatterns in the same way. This same parallelism is observed in the monocular and dichoptical presentations of Figs. 6A and 6B. Finally, the improvement in discriminatory performance as Δf is increased is observed for both monaural and dichotic modes in Fig. 7. In sum, the fact that monaural (monocular) and dichotic (dichoptical) discrimination performance varies in the same way with changes in temporal parameters (Experiments 2A and 2B) and with changes in frequency-hue parameters (Experiments 3 and 1B) strongly indicates that the perceptual dominance effect seen in the two modes of presentation is essentially the same phenomenon.

If the two dominance effects are of the same type, then an explanation must be sought for the inferior performance levels in the dichotic (dichoptical) mode. As mentioned earlier, this inferior performance could come about either because the dichotic (dichoptical) dominance effect is less powerful or because of some interfering factor present in the dichotic (dichoptical) mode which reduces efficiency of discrimination.

Perceptual interference between two different stimuli delivered to the two ears or eyes is already known under circumstances similar to the one of the dichotic (dichoptical) micropattern experiments. In the auditory modality, dichotic listening experiments (Broadbent, 1954; Kimura, 1961, 1967; and Lowe et al, 1970, among others) have demonstrated a significant interference with digit, word, or nonsense syllable recognition presented to the left ear (of right-handed Ss) when different words or nonsense syllables are simultaneously presented to the right ear. More directly related to the experiments reported here are the results of Efron and Yund (1974), showing an ear advantage for the pitch of pure tone stimuli presented dichotically. (The three Ss employed for the present dichotic

experiments are now known to have a strong ear advantage. See Ss M.B., M.C., and B.Y. in Efron & Yund, 1974.)

In the paradigm used for the present experiments, the same frequency element was delivered to one ear in both micropatterns of a trial. This procedure, it will be recalled, was adopted so that any ear asymmetry did not make the dominant pitch of the two micropatterns of each trial discriminably different when there was no element asynchrony. It must be stressed that this procedure did not eliminate the ear asymmetry—it merely ensured that any existing asymmetry affected both micropatterns of each trial equally. The ear asymmetry, which nonetheless existed in each trial, would tend to *degrade* the salience of the perceptual dominance of the trailing stimulus element in all dichotic experiments. The reason for this can be seen by an inspection of Fig. 1C. In a S having a left-ear advantage, the 1,500-Hz tone would sound louder than the 1,300-Hz tone in both micropatterns—thus making them more similar, i.e., harder to discriminate. The perceptual dominance of the trailing stimulus element, however, has an *opposite* effect, making the two micropatterns more dissimilar and more discriminable. The trailing 1,300-Hz tone in the first micropattern of Fig. 1C will perceptually dominate the 1,500-Hz tone; the trailing 1,500-Hz tone in the second micropattern will dominate the 1,300-Hz tone. Thus, any ear advantage will act to degrade the dichoptic micropattern discrimination performance and will make the difference between the monaural and dichotic performance greater than might be the case if no ear advantage were present. Thus, the fact that dichotic micropattern discrimination performance is inferior to the monaural performance (Figs. 3, 5, and 7) might be merely a consequence of the strong ear advantage effect which would tend to make micropattern discrimination more difficult.

In the visual system, the best known example of dichoptic competition is binocular rivalry. Also well known are the related difficulties associated with dichoptic color mixing; indeed, many Ss (the most notable being von Helmholtz) cannot perform this task at all. Of the three Ss studied, only one could achieve adequate color mixing to discriminate dichoptic micropatterns. Given the strength of binocular rivalry and the difficulty of dichoptic color mixing, it is perhaps surprising that any dichoptic micropattern discrimination was possible. The fact that dichoptic micropattern discrimination performance is inferior to

the monocular performance (Figs. 4 and 6) might be merely a consequence of binocular rivalry—a phenomenon which would strongly interfere with whatever perceptual dominance was imparted by the trailing stimulus element. Binocular rivalry is analogous, in this sense, to a changing (unstable) ear-advantage effect, and would degrade dichoptic micropattern discrimination performance in the same way that an ear advantage would degrade dichotic performance.

In conclusion, the dominance of the trailing stimulus element may actually be as powerful in the dichotic (dichoptic) mode as in the monaural (monocular) mode—the difference in performance characteristics in the present experiments being merely due to the interfering effects of ear advantage and binocular rivalry.

The phenomenon of perceptual dominance of the trailing element of micropatterns and the associated degradation of the perception of the first element (as described in Efron, 1973) remains unexplained. The present results, however, indicate that a peripheral interaction between the two stimulus elements in the retina or basilar membrane is not essential to produce the perceptual dominance of the trailing element which underlies the capacity for micropattern discrimination. The ability of Ss to perform dichotic and dichoptic micropattern discrimination in these experiments indicates the existence of an important central process in this perceptual task.

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