error of about 1/2%.

Gondeck's claim of increased computational efficiency is difficult to assess. Both algorithms must integrate the vector velocity in order to evaluate the ranges at each step. The trajectory diagram algorithm[2] can be made somewhat more efficient in the iteration of the scalar positions by integrating each step from the previous one rather than from time zero.

The advantage of the trajectory diagram approach is that it provides a graphic illustration of the time compression effect. If multiple scattering occurs, it can also be helpful in ascertaining signal interference effects.

[1] A. R. Gondeck, "Doppler Time Mapping," J. Acoust. Soc. Am. 73, 1863–1864 (1983).
[2] D. W. Ricker, "Echo Waveform Synthesis in a Rapidly Varying Geometry," J. Acoust. Soc. Am. 72, 1321–1323 (1982).

Reply to "Comments on 'ear dominance and sequential interactions' " by E. William Yund

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(Received 12 August 1982; accepted for publication 26 January 1983)

The author presents a reply to E. William Yund [J. Acoust. Soc. Am. 71, 1287–1290 (1982)].

PACS numbers: 43.66.Rq, 43.66.Mk, 43.66.Hg [FLW]

When two tones of different frequency are simultaneously presented, one to each ear, under certain conditions a fused sound is heard whose pitch tends to correspond to the frequency delivered to one ear rather than to the other (see Deutsch, 1982, for a detailed discussion). Deutsch (1980) noted that, in paradigms in which ear dominance was produced, the identical frequencies were presented to the two ears in succession. Further, when a dichotic sequence was presented in which this pattern of relationship did not hold, no ear dominance was obtained (Deutsch, 1975). It was therefore hypothesized that the effect depends on such sequential interactions. A study was therefore performed to obtain a better understanding of the sequential conditions giving rise to ear dominance. Yund (1982) has raised three main objections to this study: the first concerned experiments I and II; the second concerned experiment III; and the third concerned the use of the two alternate forced-choice (2AFC) method. These will be dealt with in order.

In his objections to experiments I and II, Yund focused primarily on experiment II. There were two conditions in this experiment. The basic stimulus configuration in condition 1 is illustrated in Aa and Ab of Fig. 1. This consisted of two presentations of the identical dichotic chord, whose components formed an octave, such that one ear received first the high tone and then the low tone, while simultaneously the other ear received first the low tone and then the high tone. Thus, here the two ears received the same frequencies in succession. The basic stimulus configuration in condition 2 is illustrated in Ac and Ad. This consisted of two dichotic chords, each of which formed an octave, but which were composed of different frequencies. Thus, here the two ears did not receive the same frequencies in succession.

Subjects were selected for the experiment on the basis of consistently hearing a pattern of pitches that corresponded to the frequencies presented to one (dominant) ear rather than to the other, with sequences configured as in condition 1. In other words, such sequences were clearly heard as a succession of two single tones that were spaced an octave apart.[1] Thus, for example, the right ear dominant subject obtained percepts corresponding to the black notes in Aa and Ab of Fig. 1. Accordingly, he or she reported a "high–low" sequence when presented with configuration Aa, and a "low–high" sequence when presented with configuration Ab. Now, if the same pattern of ear dominance held in condition 2 as in condition 1, the right ear dominant subject should have obtained percepts corresponding to the black notes in condition 2 also. That is, he or she should have reported a "high–low" sequence when presented with configuration Ac and a "low–high" sequence when presented with configuration Ad. However this pattern of results was never obtained; rather, all subjects reported "low–high" sequences for both configurations Ac and Ad, for all levels of amplitude relationship between the tones at the two ears. It was therefore concluded that ear dominance cannot be regarded simply in terms of simultaneous interactions, but depends on sequential relationships also.

Yund (1982) argued that this conclusion requires the "critical assumption" that "when ear dominance is present, *only* the tone delivered to the dominant ear is preceived; the tone delivered to the nondominant ear is *totally* suppressed" (p. 1288). This statement is erroneous. The only assumption required is that the pitch percept *approximates* that of the frequency presented to the dominant ear; in other words, that the pitch assignment is in the octave corresponding to

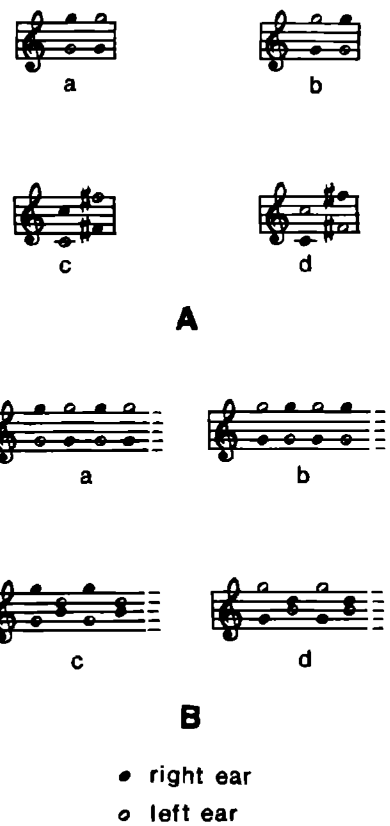

FIG. 1. (A) Stimulus configurations employed in experiment II of Deutsch (1980). Configurations a and b were employed in condition 1, and configurations c and d were employed in condition 2. (B) Stimulus configurations employed in experiment I of Deutsch (1980). Configurations a and b were employed in condition 1, and configurations c and d were employed in condition 2. Musical notation is approximate. See text for details.

the frequency delivered to the dominant ear. Such a pitch assignment could still occur with a minor contribution from the nondominant ear, and does not require total suppression of the information presented to the nondominant ear. This was unequivocally the case in condition 1, since listeners who did not obtain this type of percept were not employed in the experiment.

The analogous argument holds for Yund's objections to experiment I. Here two conditions were again employed. The basic stimulus configuration in condition 1 is illustrated in Ba and Bb of Fig. 1, and the basic configuration in condition 2 is illustrated in Bc and Bd. Subjects were again selected who consistently heard a single sequence of tones whose pitches corresponded to the frequencies presented to one (dominant) ear in condition 1. Thus the right ear dominant subject perceived a "high–low" sequence when presented with configuration Ba, and a "low–high" sequence when presented with configuration Bb. If sequential interactions were irrelevent to ear dominance, such a subject should have reported a "high–low" sequence for configuration Bc, and a "low–high" sequence for configuration Bd also. However, this result was never obtained. Subjects either reported "high–low" for both configurations Bc and Bd, or "low–high" for both these configurations, for all levels of amplitude relationship between the tones at the two ears. Such a finding is inconsistent with a maintenance of the ear dominance effect obtained in condition 1.[2]

Experiment III also consisted of two conditions. In condition 1, the identical dichotic chord was twice presented, whose components formed an octave, such that one ear received first the high tone and then the low tone, while simultaneously the other ear received first the low tone and then the high tone. The two presentations were separated by a 750-msec silent interval. Condition 2 was identical to condition 1, except that a binaural tone at 599 Hz was interpolated during the pause between the two dichotic chords. In both conditions, subjects judged for each chord pair whether it was of the "high–low" type or the "low–high" type. They were asked to ignore the interpolated tone in condition 2.

When the strength of ear dominance was plotted as a function of the amplitude relationships between the tones at the two ears, the effect was found to be significantly weaker in condition 2 than in condition 1. This was manifest as a leftwise shift in the function displayed in Figs. 10 and 11 of Deutsch (1980). Yund argued against this conclusion on the grounds that the difference in conditions could have been due to a general degradation of performance in condition 2. His main argument here is that the individual plots appeared more variable for condition 2 than for condition 1. This argument is also erroneous. In condition 1 there was a substantial ceiling effect for the subconditions in which the signal to the dominant ear was higher in amplitude than the signal to the nondominant ear, and in which this signal was equal to or 3 dB lower in amplitude than the signal to the nondominant ear. Since following of the dominant ear was virtually complete in these subconditions, they necessarily exhibited minimal variability. The critical issue then is whether there was also less variability in condition 1 than in condition 2, taking those subconditions in which such a ceiling effect was not present. In fact, the data were significantly *more* variable in condition 1 than in condition 2, when the signal to the dominant ear was 6 dB lower than the signal to the nondominant ear [$F = 5.80$, $df = (15,15)$, $p < 0.01$]. At the 9-dB level, the variability was again greater in condition 1 than in condition 2, though this effect was not statistically significant. At the two remaining levels, in which the signal to the dominant ear was 12 and 15 dB lower than the signal to the nondominant ear, a ceiling effect was again present. Furthermore, there was a significantly greater following of the nondominant ear than the dominant ear in condition 1 than in condition 2 at both the 6-dB level [$F = 11.12$, $df = (1,15)$, $p < 0.01$] and also at the 9-dB level [$F = 10.14$, $df = (1,15)$, $p < 0.01$]. These patterns of significance demonstrate that the interpolated tone acted specifically to reduce the strength of ear dominance in condition 2, and therefore that the results cannot be attributed to a simple degradation of performance in this condition.

Finally, Yund raised some general objections to the use of the 2AFC measure in the study. First, Efron and Yund (1976) employed a paradigm in which a dichotic chord was followed by a binaural chord, and subjects adjusted the relative amplitudes of the components of the binaural chord until its pitch matched as well as possible the pitch of the dichotic chord. They found that smaller amplitude differences were required to produce a match than were required to produce a balanced pitch response with the 2AFC method. However, this result is exactly as expected on the hypothesis that ear dominance depends on sequential interactions in the manner outlined in Deutsch (1980, 1982). Yet it cannot be explained on the hypothesized basis for ear dominance proposed by Yund and Efron (1977), which takes no account of sequential interactions. This apparent inconsistency has led Yund to opt for one method as more "valid" than the other. Yet rather than a genuine inconsistency, this difference poses a further difficulty for the Yund–Efron hypothesis. It should also be noted that Efron and Yund (1975) have themselves remarked that the binaural matching method contains a "possible source of error," due to the presence of a difference tone in the binaural chord.

A second argument raised by Yund is that Efron and Yund (1976) report that the function relating ear dominance to amplitude relationships appears in certain rare instances to depart from monotonicity (though since they give no significance values for their data this statement should be treated with caution). A third argument is that the function relating ear dominance to amplitude relationships varies when different ΔF's are employed. Both these arguments are irrelevant to the present study. In condition 2 of experiments I and II, a complete absence of ear dominance was obtained; the difference between conditions was not simply one of degree. In experiment III, highly significant differences were found between conditions 1 and 2, though the identical dichotic chord was presented in both cases. The question of monotonicity was not at issue, and the identical ΔF was employed in both conditions. There is therefore no valid basis for Yund's objection to the use of the 2AFC method.

[1]This was shown by the following: (a) the subjects all reported hearing an octave difference between successive tones, and (b) when asked to match the succession of pitches in this dichotic configuration to those of a single binaural sequence, their matches all approximated to a succession of tones that were spaced an octave apart.

[2]In Footnote 3, Yund (1982) argues that "an alternate explanation of experiment I and II results can easily be formulated." All that he suggests, however, is that an "additional factor" could have been concealing the ear dominance effect in conditions 2 of these experiments. Yet he gives the reader no clue as to what this "additional factor" might be.

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