ular formation produces either inhibition or facilitation of the response of lateral geniculate units to visual stimulation (*6*). Also, a large proportion of visual cortical units are responsive to auditory stimuli (*7*). Thus, the auditory effect upon the visual response of lateral geniculate units might be mediated via either of these routes.

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Temporal Pattern Shifts in Singing Birds: A Critique

Ficken *et al.* (*1*) have hypothesized that the red-eyed vireo (*Vireo olivaceus*) and the least flycatcher (*Empidonax minimus*) change their patterns of singing to avoid acoustic interference when they are breeding in the same habitat. We believe, however, that the data and analysis presented do not necessarily constitute a complete test of the hypothesis.

Ficken *et al.* used data from five pairs of birds in which the recording sequences contained from 43 to 519 songs of the flycatcher and from 59 to 512 songs of the vireo. Song initiation for each species of each pair was scored as either an interruption or not, and a χ^2 value was obtained for each bird. This test is quite appropriate if the assumption is made that each song produced by a single bird is temporally independent of all other songs produced by that same bird. Our major criticism is that there is likely to be a lack of temporal independence among songs within an individual's singing. Birds appear to sing in bouts of song; that is, there would be two major categories of silences, long intervals between singing bouts (between the last song of a particular bout and the first song of the next bout) and short intervals between songs within a bout. It is known that these latter intervals are rather constant (*2*). Thus a test of the hypothesis presented by Ficken *et al.* should recognize the three potential states of an individual bird as (i) singing within a bout, (ii) silent within a bout, or (iii) silent between bouts.

If one bird happens to start a bout while the other is between songs (within a bout), this one episode may be sufficient to explain the phase displacement during the rest of the bout. Bout occurrences then should constitute the data rather than individual songs. Because of the chance displacement mentioned above, it is important to know how Ficken *et al.* "selected" the five vireo-flycatcher pairs at Lake Itasca, Minnesota. Some individuals may have been singing out of synchrony with an individual of the other species, others may have been singing in synchrony, and still others may not have been singing at all. The occurrence of bout singing does not negate the possibility of acoustic avoidance; however, it does demand a different approach to the analysis. It seems necessary therefore to suggest the tentative nature of the conclusions presented.

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Contrary to the assertion by Planck *et al.*, we did *not* attempt to test the hypothesis that the vireo and flycatcher "change their patterns of singing to avoid acoustic interference." To dismantle the straw man, we repeat that we recorded the species singing together and found that song overlap occurred less frequently than would have been expected from the simplest quantitative model of singing. The results suggested to us that some mechanism to avoid overlap has evolved, but we do not even agree among ourselves as to the most likely mechanism.

The other assertion by Planck *et al.*, that the data may have been "selected" by recording only when no song overlap occurred, is easily answered: of course not. This is so obvious a potential bias that we did not even bother to mention in the original report that tapes were made opportunistically by R.W.F. and M.S.F. whenever possible.

The substance of the technical comment by Planck *et al.* is thus not a "critique" but rather an additional suggestion on the mechanism of overlap avoidance. R.W.F. and M.S.F. have data to indicate that the proposal of phase-displacement at the beginning of a bout, although clever, is unlikely. Contrary to the assertion of Planck *et al.*, neither species sings in a truly regular fashion; birds do not stay out of phase or even begin out of phase and drift slowly into phase. We are still investigating the problem and will consider the phase-displacement possibility quantitatively when a more propitious occasion arises.

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Electrophysiological Correlates of Meaning: Vocalization Artifact

Johnston and Chesney (*1*) recorded the visual evoked potential from a frontal electrode in a choice reaction-time (RT) paradigm requiring a vocal response. They compared, by means of factor analysis, the wave forms evoked by a visual stimulus that was interpreted either as a letter ("B") or number ("13"), depending upon the context in which the stimulus appeared. Their results indicated a consistent factor (in three of four subjects) that differentially loaded on "B" and "13" in the interval from 160 to 240 msec after stimulus presentation (the maximum time sample in their evoked potential epoch). This led them to claim that "late components of the evoked potential wave form, recorded from the frontal areas of the brain, reflect neural activity correlated with the meaning of the stimulus" (*1*, p. 946). We feel, however, that this conclusion is premature without the addition of a necessary control condition and possibly further statistical analyses of their data. Specifically, it would be necessary to repeat their experiment with subjects refraining from giving a verbal response. As we demonstrate here, it is possible for specific patterns of activity preceding phonation of either a "B" or "13" response to "act backward" and thereby differentially contaminate late components of the sensory evoked potential (*2*). Such "prespeech" activity would thus constitute a serious confounding of the data reported by Johnston and Chesney.

To test for this possibility we replicated their recording and stimulation procedures as nearly as possible (*3*). However, instead of analyzing frontal electroencephalograms (EEG's) by triggering a computer of average transients (CAT) at flash onset, we triggered it at speech onset in order to assess the effects of the verbal response (*4*). The EEG activity occurring just prior to speech onset was processed by the simple technique of averaging, in real time, the signal derived from the playback channel of an FM tape recorder. When the CAT was triggered at speech onset and the frontal EEG was simultaneously recorded, it took 200 msec (at 38 cm/sec) for the frontal EEG occurring at the moment of speech onset to be entered into the computer. Thus, we were able to analyze frontal EEG activity occurring up to 200 msec prior to speech onset.

The results for two subjects are shown in Fig. 1. For the data shown in Fig. 1, A (subject 1) and E (subject 2), the task required either a "B" or "13" response depending upon whether the stimulus was in a letter or number context in an RT paradigm. Both subjects produced individually different but repeatable wave forms. Visible differences in the prespeech wave form patterns extended 145 msec (Fig. 1A) and 100 msec (Fig. 1E) prior to speech onset (*5*). Thus, the time frame within which Johnston and Chesney (*1*) found significant results (160 to 240 msec after stimulus onset) could be affected by any verbal response occurring within 305 to 385 msec for the first subject, and 260 to 340 msec for the second.

We found no significant difference between mean RT for "B" and "13" when each stimulus was presented within the appropriate context. Sample RT distributions associated with a single replication of "B" in Fig. 1, A and E, are shown for each subject in Fig. 1, B and F. Those trials that fall within the critical time period defined above appear as solid bars. For subject 1, who showed the greater prespeech effect, this amounts to 72 percent of all trials, and for subject 2, 45 percent. Some of the faster RT's for subject 1 (245 to 285 msec) could possibly affect the interval 100 to 140 msec after stimulus onset; Johnston and Chesney found significant effects for one subject in this interval, with similar trends for two other subjects. The summation of such wave form differences in the averaged evoked potential could be detected by a sensitive factor analysis (*6*).

Since the data presented in Fig. 1, A and E, represent a comparison between "B" and "13," it is necessary to show that these differences are not dependent upon context (number versus letter), but rather upon other factors. Figure 1C shows three differing wave forms obtained to the response "B" at differing mean intensities of verbalization (measured at 68, 78, and 88 ± 2 db by a sound pressure meter positioned at the microphone). Figure 1G shows varying

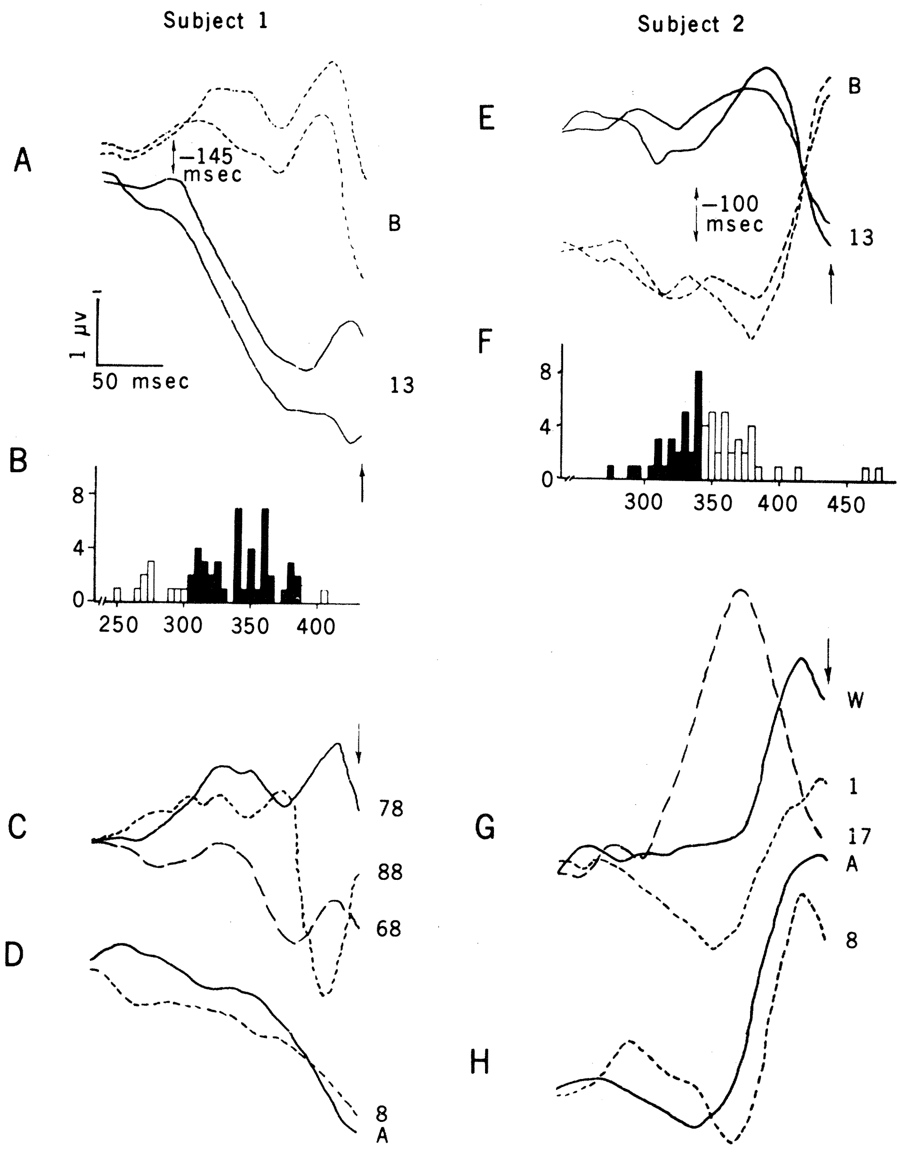

Fig. 1. Prespeech activity and reaction time data for two subjects. Evoked potential traces are averages of 50 recordings free of gross artifact. The vertical arrow at right edge of evoked potential plots represents speech onset; the origin at left is 200 msec prior to speech onset. (A and E) Two replications of responses to "B" and "13." Visual inspection shows consistent wave form differences that extend 145 msec prior to speech onset for subject 1 (A), and 100 msec for subject 2 (E). (B and F) Reaction-time distributions. The mean RT's are 333 ± 36 msec for subject 1 (B) and 353 ± 50 msec for subject 2 (F). Solid bars represent trials in which a prespeech effect of 145 msec (in B) or 100 msec (in F) would occur within the interval 160 to 240 msec after stimulus onset. (C) Comparison of activity preceding "B" response produced at an average of 68, 78, and 88 db. (D and H) Comparison of similar prespeech wave forms for "8" and "A." (G) Different prespeech wave forms for numbers "1" and "17" and the letter "W."

wave forms to the numbers "1" and "17" and the letter "W" (many other wave forms also had different patterns). Finally, Fig. 1, D and H, show very similar wave forms to the "8" and the "A" for each subject (this combination was selected since both have similar gross movement patterns for their vocalization). Such data indicate that prespeech wave forms of numbers and letters can be either similar or dissimilar, and can vary according to loudness and patterns of jaw, tongue, and lip movement involved in vocalization. In short, such wave forms are a function of the verbal response, and not the visual stimulus.

Although our data show consistent differences up to 145 msec before speech onset, the largest artifacts actually occurred during the verbal response (not shown). If Johnston and Chesney (*1*) had presented evoked potential wave forms that extended beyond 240 msec after stimulus presentation, it would have been possible to visually judge the extent of such artifacts in their data. More important, they should have included a condition in which the verbal response was either eliminated or delayed well beyond the time when speech artifacts could confound the data. As a further test of the possible confounding of prespeech activity, it would have been useful to do factor analyses of wave forms for fast versus slow RT trials. If our arguments are valid, then there should be marked differences between fast and slow RT wave forms in the interval within which differences in "B" and "13" wave forms are found (significant differences should occur in earlier time intervals for faster RT trials). In this regard, it would be interesting to know whether the one subject whose wave forms for "B" and "13" were not significantly different had slow RT's or lesser amounts of prespeech activity (or both), which could confound the data.

Until such controls and further analyses are performed, it is impossible to accept the conclusions reported by Johnston and Chesney. However, if their data stand the test of further scrutiny, then their results represent a significant contribution to the evoked potential literature.

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3. We could not replicate the light intensity used by Johnston and Chesney (*1*) since quantitative data were not reported. The light intensity used in our study was 0.91 mlam.
4. Thus, the stimulus-locked evoked potential was effectively ignored. However, this did not make any appreciable difference, since we obtained similar results whether the verbal reaction was in response to the appropriate visual stimulus in an RT paradigm, to a homogeneous light flash, or was obtained during repetitive vocalization in the absence of a visual stimulus.
5. Our analysis is limited by the fact that differences between wave forms were judged visually. Although the data show marked differences in slopes, peaks, and polarity within the identified time intervals, we do not claim that the particular time intervals are the same as those that would be selected by factor analysis.
6. Even if prespeech activities in the two contexts were not markedly dissimilar and mean RT's were identical, it is still possible that a systematic bias could be introduced into the data. If, for example, RT for numbers was more variable than that for letters, then the prespeech activity for numbers would be confounded earlier on some trials, and with less uniformity, than is the case for letters. This fact alone could result in systematic differences in late evoked potential components in the two conditions.
7. Supported in part by NIH grants HD 06650, RR 05632, and HD 4612.

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There is other evidence in the literature that better supports the conclusions drawn by Johnston and Chesney (*1*). They failed to cite reports by Brown *et al.* (*2*), Teyler *et al.* (*3*), and Chapman (*4*) which demonstrate correlates of linguistic meaning in the wave form of the average evoked potential to words. Brown *et al.*, for example, demonstrated differences in evoked potential wave forms when the same word was given different contextual meaning; specifically, differences were demonstrated in the wave form to the word "fire" in the phrases "sit by the fire" and "ready, aim, fire." Since it appears to be the policy of *Science* to publish reports that demonstrate or markedly clarify new relationships, the omission of these references is particularly significant.

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It is a routine procedure in our laboratory to collect response-locked potentials, for periods both before and after response, in all of our evoked potential studies. Using a boxcar procedure (*1*), we have demonstrated that (i) the response-locked electrooculogram is almost entirely eliminated by the balancing procedure employed in our previous experiment (*2*) and (ii) the response-locked electromyogram is maximal 20 msec before contact closure of the voice-operated relay and can be detected no more than 70 msec before the response. Our data on response-locked preverbal electroencephalogram potentials, however, are of questionable validity since "the faithful presentation of response-related potentials and especially of the slowest rp [readiness potential] component requires employing stable, nonpolarizing electrodes and direct coupled amplification" (*3*, p. 248). In the absence of these precautions, a preverbal negative or positive shift, such as those detected by McAdam and Whitaker (*4*), is not only attenuated, but can be distorted into a negative-positive ensemble. We do not believe, therefore, that either our observations or those of Galbraith and Glidden (*5*), who replicated our recording procedure, represent reliable measures of either the nature or the extent of the preverbal response. With these reservations in mind, our data indicate that differential preverbal responses as early as 200 msec before the response can be detected from vertex recordings, but we have been unable to observe such effects from our frontal electrode recording site (2.5 cm above the inion).

These observations, together with subsequent reports (*6*) of meaning-correlated changes in the absence of differential preresponse waves, have led us to the conclusion that our original interpretation is still valid. We thank Galbraith and Glidden, however, for their constructive suggestions for improving our methodology.

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