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RESEARCH NOTE

A SINGLE-CHANNEL MODEL DOES NOT PREDICT VISIBILITY OF ASYNCHRONOUS GRATINGS

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INTRODUCTION

Recently, we reported three experiments which showed that the visibility of asynchronous compound gratings could not be predicted by a single channel model (Watson and Nachmias, 1980). Limb (1981) has considered one of these experiments, and has argued that with certain assumptions, a single-channel model can predict the results.* Here I point out that Limb's assumptions are quite improbable, and that under plausible assumptions, all three of our experiments reject the single-channel model.

Limb's predictions differ from ours in three respects. First, he predicts thresholds for a range of asynchronies, while we calculated the prediction only for that (unknown) asynchrony at which the peaks of the two component responses coincide in time. Second, Limb considers the effects of probability summation over time, while we did not. Both of these elaborations of our model are appropriate, particularly in view of the evidence for probabilistic effects (Watson, 1979).

The third difference is that in our predictions we have made use of the best available estimate of each model parameter, while Limb has assumed parameters that will minimize the difference between the data and the single channel predictions. Limb can predict the results of our experiment 2 only if he assumes a β of 2.9 and a 1.5 dB imbalance in the components of the compound grating. Both of these assumptions are improbable, their conjunction is very improbable.

Both we and Limb assume that β is constant under our experimental conditions. This is supported by Monte-Carlo simulations of our estimation procedure (Nachmias, 1981) which suggest that most of our variance in β is measurement error. Our mean estimate of β from 51 psychometric functions was 3.71 with a SE of 0.12. Limb assumes a value of 2.9, which is 6.73 SE away from the mean, well outside of any conventional confidence limits. Limb argues that our estimate of β may be biased upwards since we took the mean of a skewed distribution. The simulations show that the error is less than 5%. Even supposing a bias this large, *and* an overestimation by 2 SE, β is reduced only to 3.3, and the prediction lies only marginally below the uppermost curve in Limb's Fig. 3.

Consider next a possible imbalance in the amplitudes of the two components. Our predictions were for compounds in which the contrast of each component was an equal proportion of its threshold contrast. Limb assumes a constant or average imbalance of 1.5 dB between these proportions. He proposes three sources for this imbalance: measurement error, unequal sensitivity of the two eyes, and unequal sensitivity of different regions of retina. The latter two cannot, in fact, predict an imbalance for the observer, but only for one eye, or one region of retina. They are interesting (though very unlikely) hypotheses as to why a single channel fails, but are not sources of component imbalance.

The remaining potential source of imbalance mentioned by Limb is variability in measurement of thresholds, either between or within sessions. The overall average thresholds for the two components had SE of 0.17 and 0.15 dB. Based upon these averages, we can calculate directly the imbalance of the component contrasts used in each session. The average absolute imbalance was 0.53 dB (SE = 0.12). This is less than one third of the imbalance assumed by Limb, but even this small imbalance was explicitly compensated for by our method of estimating threshold reductions.

Limb's argument concerning within-session variability apparently neglects the fact that such variability is already explicitly incorporated in both his and our models: it is represented by the non-zero slope of the psychometric function. As noted above, Limb has already assumed a β that is well below the value estimated from the data. To add an additional variability with SD of 0.75 dB, as he recommends, would lower β still further. In short, trial-to-trial variability is already included in the model, it cannot be included twice.

* Limb in fact considers two models; but the second, described in the penultimate paragraph of his report, predicts a psychometric function quite unlike that of the human observer, and will not be considered further.

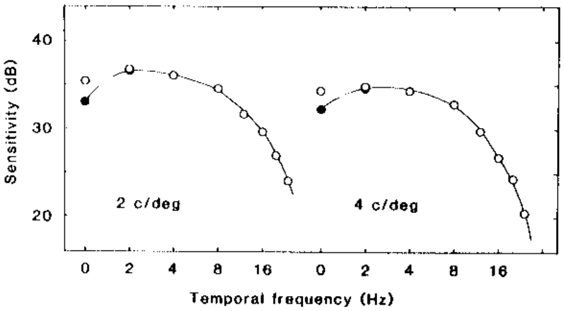

Fig. 1. Temporal sensitivity for the spatial stimuli of Experiment 3 from Watson and Nachmias (1980). Here the temporal waveform was the product of a sinusoid (at 0 Hz, a cosine) and a Gaussian which fell from 1 to 1/e in 250 msec. Open symbols are measured sensitivities; filled symbols are corrected for the effects of probability summation over time. Curves are the amplitude spectra of the hypothetical single channel.

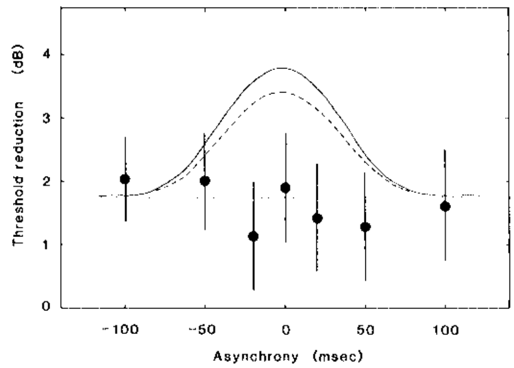

Fig. 2. Threshold reductions for compound gratings as a function of asynchrony. The solid symbols are the results of Experiment 3. The error bars show ±2SE. The solid curve is the single channel prediction with no imbalance and β equal to 3.5; the dashed curve is for a 0.5 dB imbalance and a β of 3.1. The dotted line is the prediction of the many channel model.

What of the other two experiments in our report? If, for the sake of argument, we accept an imbalance of 1.5 dB and a β of 2.9, then in Experiment 1 the single channel would predict a proportion correct of about 0.83, more than 2 SE above all of the proportions measured.

In view of his concern with retinal inhomogeneity, it is unfortunate that Limb did not consider the results of our third experiment. Retinal inhomogeneity was effectively eliminated by the use of small, peripheral patches of grating, and frequencies only an octave apart were used. How does it stand up to Limb's critique? To answer this, I measured temporal sensitivity for 2 and 4 c/deg grating patches under conditions identical to those in Experiment 3. The results are shown as open symbols in Fig. 1. Probability summation over time will slightly favor the lowest time frequencies. Correcting for this small effect, we obtain the presumed amplitude response of the single channel at the two spatial frequencies, as shown by the filled symbols.

The curve in each panel is the amplitude spectrum of an impulse response of the form

$$h(t) = u(t)\, t^{n-1}[\exp(-t/T1)/T1^{n} - r\exp(-t/T2)/T2^{n}$$

where $u(t)$ is the unit step function. This is a linear combination of two n-stage low-pass filters with time constants $T1$ and $T2$ (values used for 2 c/deg: $T1 = 6.67$ msec, $T2 = 50.3$ msec, $r = 0.297$; for 4 c/deg: $T1 = 7.43$ msec, $T2 = 41.2$ msec, $r = 0.252$; for both: $n = 4$).

These impulse responses are used, in the manner of Limb, to generate the predictions shown in Fig. 2. The data from Experiment 3 are also reproduced. The solid curve is the prediction for no imbalance and a β of 3.5. If we allow a β as low as 3.1, and an imbalance as large as 0.5 dB, the dashed curve results. Clearly, the data are not consistent with the single channel model. In summary, reasonable assumptions about imbalance and β generate single-channel predictions inconsistent with the results of all three of our experiments.

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