The unique criterion constraint: a false alarm?

TO THE EDITOR—In a recent paper in *Nature Neuroscience*, Gorea and Sagi[1] proposed a novel method for estimation of the separate signal and noise components of the contrast transducer in humans. Their experimental task requires detection, simultaneously, in two locations of contrast increments differing by either increment value (see their Fig. 3b) or baseline contrast (their Fig. 4a). In this mixed task, observers adopt a common false alarm rate (FA) for both locations[2] to provide separate estimates of the transducer exponents for the signal and the noise, which took the form of a compressive signal nonlinearity and an almost constant noise.

In the Gorea and Sagi task, however, the only independent quantities are FA and the discriminability (d') derived through signal detection theory. These quantities both depend on the signal-to-noise ratio governing performance rather than on the signal transducer alone. To overcome these basic limitations of psychophysics, Gorea and Sagi[1] introduce a "unique criterion constraint" for all attended stimuli that is critical for their subsequent analysis of mixed-stimulus situations. They show that the assumption of a single criterion is appropriate for same-baseline conditions and then generalize this assumption to mixed-pedestal situations where the properties of the noise sources are at issue.

Formally, the criterion c is linked to the false alarm rate through the expression

$$z(FA) = \Phi^{-1}\left(1 - p(FA)\right) = \frac{c}{\sigma} \quad (1)$$

where z is the probability z-score, Φ^{-1} is the inverse Gaussian cumulative distribution function with unity standard deviation, and σ is the noise standard deviation. Gorea and Sagi[1] argue that the mixed task enforces the constraint that

$$c_1 = c_2$$

and hence

$$z(FA)_1 \cdot \sigma_1 = z(FA)_2 \cdot \sigma_2 \quad (2)$$

However, the only property they established was that the false alarm rates were found experimentally to be equal:

$$p(FA)_1 = p(FA)_2 \quad (3)$$

It therefore follows only that

$$c_1 \cdot \sigma_2 = c_2 \cdot \sigma_1 \quad (4)$$

and nothing is independently known about the equality of either the criteria or the noise levels. All one can say is that, if the noise levels are equal, the criteria are equal. Previous studies[3–5] would suggest that these different baseline contrasts should evoke different noise levels σ_1 and σ_2. Consequently, the mixed-baseline stimuli could be judged by different criteria (eq. 4), while the false alarm rates could still conform to eq. 3. There is no evidence from Gorea and Sagi[1], therefore, that the different baseline stimuli were judged by a single criterion. Invoking the unique criterion constraint in this situation is just an arbitrary choice. Given that the observers were cued to which stimulus was to be presented on each trial, however, the simplest (most parsimonious) assumption is that the observers equated the false-alarm rates by adopting appropriate criteria for each stimulus condition. For example, if you are asked to detect a bird against a scene containing both a blue sky and choppy waves, you will respond to a faint motion against the sky, but require a much stronger stimulus before accepting a motion in front of the moving waves as a flying bird.

The lack of evidence for unique criterion constraint leaves the transition from their Eq. 4 to Eq. 5 unjustified, because the σ-ratio cannot be related to the $z(FA)$ ratio as asserted in their Eq. 3. In fact, their Eq. 5 can be expressed as a power function of the baseline contrast ratio

$$\frac{d'_2 \Delta C_1}{d'_1 \Delta C_2} = \left(\frac{C_1}{C_2}\right)^{1-\gamma+\gamma\beta} \quad (5)$$

whose exponent is the slope of the threshold contrast (TvC) function (0.57 ± 0.02 for their two-alternative forced-choice task), and whose remainder is the empirical ratio from their Fig. 4

$$\frac{z(FA)_1}{z(FA)_2} \approx \left(\frac{C_1}{C_2}\right)^{-0.1\pm 0.08} \quad (6)$$

Therefore, the full ratio in their Eq. 5 should be

$$\frac{d'_2 \Delta C_1 z(FA)_1}{d'_1 \Delta C_2 z(FA)_2} \approx \left(\frac{C_1}{C_2}\right)^{-0.47\pm 0.08} \quad (7)$$

which is consistent with the Gorea and Sagi estimate of 0.42 ± 0.07 of the same ratio exponent. Their measurements thus confirm the already-known value of the slope of the TvC function and validate the applicability of signal detection theory to contrast discrimination data. Nevertheless, their data are inadequate for disentangling the separate signal and noise exponents.

Indeed, the Gorea and Sagi results are consistent with any combination of signal and noise nonlinearities that predicts the correct TvC slope. In particular, they are consistent with our recent estimates[6] of the accelerating signal transducer $\gamma = 2.3$ and almost multiplicative noise $\beta = 0.83$. These values predict a TvC slope of $1 - \gamma + \gamma\beta = 0.61$, which is indistinguishable from the experimental value of 0.57 measured by Gorea and Sagi.

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REPLY—In our view, the criticism of our work[1] from Kontsevich *et al.* bears on the following two points. First, the observed equality of the false alarm z-scores (zFA) across paired conditions (i,j) does not guarantee our claim of a unique criterion constraint expressed by the equality $c_i = c_j$, with $c_k = zFA_k\sigma_k$ (with c the criterion and σ the standard deviation of the noise). Rather, it necessarily implies