Note on Crozier's Neural-Availability theory[1]

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Two implications of Crozier's Availability theory are developed. First, the population of elements of neural effect is shown to have a minimum size. Second, intensity discrimination must be mediated by progressively smaller increments in neural effect as stimulus intensity is increased—an improbable state of affairs.

Although 30 years have passed since Crozier first began to write about the neurology of intensity discrimination, his Neural-Availability theory continues to receive attention (see Brown & Mueller, 1965; Hurvich & Jameson, 1966). Modern experimental (Jacobs, 1965; Kiang, 1965; Werner & Mountcastle, 1963, 1965) and theoretical (Blackwell, 1963; Siebert, 1965; Treisman, 1966) analyses of sensory coding and intensity discrimination have many origins in one or another of Crozier's notions. Seventy-five years before Crozier, Fechner (cf. Boring, 1950, pp. 291-292) had distinguished between "outer psychophysics" and "inner psychophysics"—in acknowledgement of the fact that we discriminate between stimuli by means of the neural effects they evoke. Nevertheless, it remained for Crozier to develop one of the first quantitative theories relating psychophysical data to neural effects.

Although Crozier focused attention on neural events and their statistics, two deductions permitted by his theory and pertaining to neural events seem to have escaped mention by critics of Crozier. It is the purpose of this note to describe these two deductions.

As applied to intensity discrimination, Crozier's Availability Theory (Crozier, 1940) develops from two principal assumptions:

(1) Stimuli evoke neural effects. The function relating neural effect, E, to stimulus intensity, I, is a log-normal ogive. Thus, the neural effect, E_1, evoked by intensity I_1 is given by Equation (1).

$$E_1 = \int_{-\infty}^{\log I_1} \phi(\log I)\, d(\log I) \tag{1}$$

(2) Intensity I_1 evokes an average neural effect, E_1. Excitability with respect to an increase in intensity is proportional to the number of elements not excited by I_1 and *available*, therefore, for activation by the increment. With excitability measured by the reciprocal of the JND, $(1/\Delta I)$, and with $E_{max} = 1$, the relation between ΔI and availability is as follows:

$$\Delta I = \frac{k}{1 - E_1} \tag{2}$$

Crozier preferred not to identify the "elements of neural effect" with particular cells or impulses. Nevertheless, the theory summarized in Equations (1) and (2) implies that the population of elements of effect has a minimum size. A second implication concerns ΔE, the increment in neural effect that accompanies the addition of ΔI to I_1. Discussion of these two consequences of the theory follows.

The relation between excitability and availability (Equation (2) specifies that ΔI increases as neural availability $(E_{max} - E_1)$ decreases. If, for example, ΔI increased (as I_1 increased from absolute threshold to maximum) by a factor of 10^6, then $(E_{max} - E_1)$ would decrease by the same factor of 10^6. Were E_{min} as small as one element, E_{max} would have to be as large as 10^6. The total number of elements of neural effect must be at least as large as $\Delta I_{max}/\Delta I_{min}$.

Equations (1) and (2) permit us to compute I_1 and ΔI for each value of E_1. Let I_2 be just-noticeably more intense than I_1 (i.e., $I_2 = I_1 + \Delta I$). The neural effect, E_2, evoked by I_2 can then be determined, and ΔE,

$$E_2 - E_1 = \int_{-\infty}^{\log\left(I_1 + \frac{k}{1 - E_1}\right)} \phi(\log I)\, d(\log I) - \int_{-\infty}^{\log(I_1)} \phi(\log I)\, d(\log I), \tag{3}$$

turns out to be a *decreasing* function of E_1. (This is easily seen by assigning some numerical value to the constant, K, and then evaluating the two integrals in Equation (3) for various values of E_1.)

Of interest is the implication that ΔE is not constant at all levels of stimulation—JNDs are not neurally equal. Crozier is said to have stated that

$$\Delta E = C \tag{4}$$

—that JNDs are mediated by the addition or subtraction of a fixed number of elements of neural effect (cf. Bartley, 1951, p. 971; Morgan, 1943, pp. 304-305). But the fact is that Crozier (1936) considered that ΔEs are not all equal. We have seen, moreover, that Equations (1), (2), and (4) cannot be simultaneously true. In fact, Equations (1) and (2) imply that intensity discrimination is based on progressively smaller changes in neural effect as E_1 increases. This is a most unlikely situation.

Blackwell (1963) has recently dealt with possible E-I transforms and with their relations to ΔE and

ΔI. The Weber function for stimuli, $\Delta I/I$—for a given sensory system—may not be paralleled by the underlying Weber function for neural events, $\Delta E/E$. There is no evidence, however, to suggest that ΔE decreases as E increases.

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Notes

1. Preparation of this paper was supported by National Science Foundation Grant GB 3451. H. R. Blackwell read and criticized a first draft of this note.

2. In this equation and in the discussion that follows, the unit normal distribution, $\phi(x)$, is used. As a result, the maximum neural effect, E_{max}, equals one, and half the "elements of neural effect" are excited by a stimulus whose intensity equals one (log $I = 0$). If stimulus intensity is increased by three log units (to $I = 1000$), 0.9987 of the elements of neural effect are excited.

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Erratum

Ueno, T. Visual search time based on stochastic serial and parallel processings. *Percept. & Psychophys.*, 1968, 3 (3B), 229-232. The η in Equations (8), (10), and (11) should be corrected to read n.