AN INFORMATIONAL APPROACH TO REACTION TIMES

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Simple reaction time is the minimum time required to respond to a signal such as a steady light or tone. Such a reaction time is taken to be the time required for transmission of a fixed quantity of information, $\Delta H$, from stimulus to subject. That is, information summation replaces energy summation. This information is calculated from consideration of the quantum nature of the stimulus. The theoretically derived equation for reaction time is fitted to experimental data. Piéron's empirical law for reaction time is obtained as an approximation from a proposed informational equation. The exponent in Piéron's law is found to be the same as the exponent in the power law of sensation. Threshold appears to be the smallest stimulus capable of transmitting the quantity of information $\Delta H$.

Introduction. Reaction time is defined as the time between the onset of stimulus and the beginning of an overt response (Coren et al., 1984). Simple reaction time involves a subject's pressing a key or button immediately upon detection of a stimulus such as a flash of light or a tone. It has been known for more than a century (Cattell, 1886) that simple reaction time grows shorter with increasing stimulus intensity; for example, a subject requires less time to react to a bright light than to a dim light. However, the reason why this is so has not been apparent.

The most common way of accounting for this relationship between simple reaction time and stimulus intensity is by invoking a principle of energy summation or integration; that is, a subject may react only when the integral of stimulus power with time (energy) reaches a critical level. Therefore, a stimulus of lower intensity must be applied for a longer time than a stimulus of higher intensity before a subject can react. Speaking very approximately, the product of stimulus intensity with reaction time is constant.

The study of reaction time is not the only one where the concept of energy integration has been invoked. For brief flashes of light near the threshold, the product of intensity with duration of flash is constant for detection of the flash. That is, a subject can detect a bright flash applied for a brief time period, or a dim flash applied for a longer time period. Mathematically:

$$It \approx \text{constant},$$

(1)
where \( I \) is the stimulus intensity and \( t \) is time. This law is known as Bloch's law or the Bloch–Charpentier law. The law does not hold precisely, but is an approximation (Williams and Allen, 1971).

Because of the similarity between the two phenomena, threshold detection and reaction times, it might be expected that Bloch's law would also hold for reaction times; however, this is not quite the case. As Piéron demonstrated (1952), and empirical rule that better describes the relationship between reaction time and intensity is the power law:

\[
I_{r} - I_{r_{\text{min}}} = CI^{-n}, \tag{2}
\]

where \( I_{r} \) and \( I_{r_{\text{min}}} \) are reaction time and minimum observable reaction time respectively, \( C \) and \( n \) are constants greater than zero. It has been shown by a number of investigators (e.g. Ueno, 1976; Doma and Hallett, 1988) that if \( I_{r_{\text{min}}} \) is small compared to \( I_{r} \), and if the constant, \( n \), is equal to unity, then Piéron's law becomes:

\[
I_{r_{\text{min}}} = C, \tag{3}
\]

which is identical to Bloch's law. Therefore, the suggestion is, perhaps both phenomena are examples of energy integration: Bloch's law for near-threshold intensities, Piéron's law for intensities above threshold. However, there are theoretical problems with the energy integration interpretation, particularly above threshold (Boynton, 1961), and there are numerical problems as well: \( I_{r_{\text{min}}} \) is not always negligible in comparison with \( I_{r} \), and the exponent \( n \) is usually of the order of 0.3 rather than 1.0 for both audition and vision. Therefore, perhaps it is not energy which is being integrated or summated but some other quantity.

We shall argue here that the quantity summed, both near and above threshold, is not energy but information. In the case of simple reaction time, the subject cannot react until he/she has received a critical quantity of information, which we shall represent by \( \Delta H \) [bits or natural units]. The advantages of this approach are several. It is not necessary for us to construct ad hoc an informational theory for application to reaction times. We can utilize an existing informational theory of neural coding that has accounted for many other neurophysiological and psychophysical phenomena, and adapt this theory to the study of reaction times. From this theory we can readily derive an equation that gives the observed reciprocal relationship between stimulus intensity and reaction time. The derived equation yields Piéron's law as an approximation. The exponent \( n \) emerges as the same exponent that appears in the psychophysical power law, or the law of sensation ("Stevens' exponent"). That is, \( n \) takes on a value near 0.3 rather than near unity. However, before