Book Reviews

Toward a More Rigorous Psychophysics

Signal Detection Theory and Psychophysics. DAVID M. GREEN and JOHN A. SWETS. Wiley, New York, 1966. 467 pp., illus. $12.95.

Detecting and deciding are ubiquitous acts of animals and men. A sudden rustling in a forest causes a doe to freeze for a few seconds, then run. Was it a signal (a predator) or a noise (a gust of wind)? Was running the right decision? What is the value of staying or running? What the cost? Signal-detection theorists think of the doe's behavior as having two independent and separable parts: sensitivity and criterion. These notions have put into question the very existence of the sensory threshold.

Fechner refined the ancient concept of sensory threshold in his *Elemente der Psychophysik* (1860) and set down *the* three psychophysical methods for assigning to the threshold (limen) a numerical value. A signal was either above or below the threshold. If above, it was always detected; if below, its presence was merely guessed at. The facts of behavior made necessary the assumption that the threshold varied randomly according, say, to a Gaussian probability law. The guessing rate was estimated from the proportion of false reports on trials when the signal was deliberately omitted ("catch" trials).

The threshold theory and its associated methods are still viable after 107 years. No event for almost 100 years seriously disturbed these notions, although the fixed threshold was implicitly called into question by L. L. Thurstone's "law of comparative judgment" (1927). Thurstone considered that stimuli gave rise to internalized "discriminal processes" and any given stimulus gave rise to a "discriminal dispersion" about a mean value. Thus two values of similar stimulus attributes (weight, brightness, beauty) could have overlapping discriminal dispersions, and one could be mistaken for the other. Thurstone's work on psychophysics was quite obviously related to Neyman and Pearson's (1928) use and interpretation of certain test criteria for purposes of statistical inference. His law provided a way of setting and measuring an observer's psychological scale value of sensation relative to the intensity of the physical stimulus. The law was neglected by psychophysicists for several reasons, but a concept essentially identical to the discriminal process lies at the heart of the book here reviewed.

In *Signal Detection Theory and Psychophysics*, Green and Swets have given us a most welcome book. It is the first systematic work on the methods and substance of psychophysics based on mathematical theories of decision and communication. Statistical decision theory is used in the analysis of detection whereby decision criteria (response biases) are separated from sensory variables. The "ideal detector" of communication theory provides the second basic aspect of signal-detection theory. The crucial feature is the interpretation of the parameters of the theory in terms of the measurable physical properties of electronic devices and several kinds of signals and noises. The theory thus specifies the ideal and a way of calculating the relative efficiency of real devices for which there exists an uncertainty or an inability to use a particular parameter (phase angle, for example). And by manipulating these parameters in experiments with observers it may be possible, say Green and Swets, to infer how much and what kinds of sensory information can be used or something about the structures and modes of sensory processes.

Detection theory was first applied in psychology about 1953 to criterion problems and has since then had much success in giving a descriptive account of a number of aspects of sensory performance. Part 1, Decision Processes in Detection, reviews the elements of statistical decision theory and applies them to psychophysical procedures. The main burden is showing how the receiver's operating characteristic (ROC) gives measures of his sensitivity and decision criterion independently of each other. Basic experiments (yes-no, forced-choice, and rating) for separating sensory and decision processes are detailed and shown to yield equal indices of sensitivity. Green and Swets say that such consistency "has been very rare, perhaps nonexistent, in the measurement of human behavior. This result gives promise of a rigorous, quantitative science of psychophysics." Is there a threshold? Evidence is adduced for and against a number of theories: classical, high-threshold, neural quantum, low-threshold, and detection. The latter two are favored, but the low-threshold theories have several disabilities to overcome before they can be adequate for sensory psychology. Detection theory needs no threshold. Rather, a given sensitivity constrains hit and false-alarm rates to lie in a region bounded by the ROC curve. Where in the region they lie depends upon the decision criterion, which is under the control of such factors as values and costs, instructions, "motivation," and the like. (It has recently been suggested by Treisman that the sensory performance parameter of signal-detection theory can be estimated from results given by the Fechnerian method of constant stimuli. It may not then be necessary to junk a century's accumulation of psychophysical threshold data.)

Part 2, Sensory Processes in Detection, treats the central concept of ideal (optimal) detectors. Device A will be ideal, that is, give the best possible performance, in one situation, but device B will be ideal in another. The ideal detector is defined by the kind and amount of information available to it about the signal waveform. For example, an envelope detector may be optimal for detecting a sinusoid in narrow-band noise if amplitude and frequency but not phase angle may be used. However, if the signal added to the noise is just more noise, the ideal detector uses in its decision only the energy of the waveform. Human performance is compared with explicit models based on cross-correlation and envelope-detection processes. There is an extensive discussion of the interesting, plausible, and rather simple energy-detection model for audition. The results of applying the model to diverse psychoacoustic data reveal the grave difficulties that beset signal-detection theory when something deeper than comparative performance indices is wished for.

The astonishing variety of Other Applications of Detection Theory (part 3) includes tasks involving multiple or repeated stimulus presentation, temporal structure, and signals of uncertain frequency. Some of these data are used to explicate the notion of the "critical band" of the ear. There is a chapter on applications to speech recognition. The final chapter covers preliminary applications to various substantive problems bordering on psychophysics, including animal psychophysics, sensory physiology, reaction time, time discrimination, vigilance, attention, subliminal perception, and recognition memory.

The authors' aim of providing a source book and a textbook is realized in the appendixes and the problem sets (with even a few solutions) at the end of the first eight chapters. Appendix 1 gives the elements and only the elements of probability theory required to follow the development of statistical decision theory. It is compact and admirably done. Appendix 2 presents some basic concepts of waveform analysis. It is quite uneven in level of difficulty. Appendix 3 is a compendium of techniques both useful and necessary to supplement the discussion of the book.

Signal Detection and Psychophysics is very nearly the most important single monograph on psychophysics published yet in this century. It will be and deserves to be widely influential, because it is a lucid presentation of the not quite revolutionary ideas of the new psychophysics. Since this is so, a few cautionary words are in order. The theory has not been reinterpreted very far in terms appropriate to human behavior, being still tightly bound to electrical systems. A consequence is that most applications are mere analogs, or are far-fetched, and some depend on outrageous assumptions. The ideal-observer theory is a normative theory and could have the effect of delaying rather than inducing a search for actual mechanisms. Because the human observer may and no doubt does introduce unknown noises, an appropriate ideal observer may never be found. Few if any serious tests have been made of the crucial, almost certainly wrong, assumptions that noise and signal trials are independent and that sequential effects hardly matter. Data are fitted by eye to theoretical ROC curves because optimal tests "have not yet been devised," though such fits are widely interpreted as being favorable to the theory.

Whatever the degree to which one can accept the psychophysical signal-detection theory, it is a seminal theory and has already revitalized psychophysics and its applications. It will be seen 25 years hence as a major influence, if only because of having made a clear distinction between sensitivity and criterion. *Signal Detection and Psychophysics* is an excellent source book and is highly recommended for use as a text, though it is far more than a textbook.

EDWARD C. CARTERETTE
Department of Psychology,
University of California, Los Angeles

Hepaticology

The Hepaticae and Anthocerotae of North America—East of the Hundredth Meridian. Vol. 1. RUDOLF M. SCHUSTER. Columbia University Press, New York, 1966. 822 pp., illus. $20.

Rudolph Schuster's latest contribution to hepaticology is indeed impressive in its dimensions, and the abundant illustrations are very well executed. The bibliography is extensive, and the historical outline is interesting and instructive. Unfortunately, the quality of the work progressively deteriorates after the historical outline until, in the systematic section, the text has become so encumbered with technical errors, both of omission and of commission, as to render it of little value.

The extensive coverage of evolution in the Hepaticae is included under seven subheadings in four chapters and involves much redundancy and numerous cross-references. This material is notably slanted in favor of the author's concepts. A misleading footnote on page xi notwithstanding, the bibliography contains references through 1965 and the text itself contains abundant references up to and including 1966. Such important works as those of Church (1919), Fulford (1951, 1964, 1965), Proskauer (1960), and Mehra (1957), however, are given irrelevant or merely incidental mention or none at all.

Little of the adequately documented material included in the voluminous section on morphology will be new to the professional, while much of it is badly confused and contains numerous, often startling errors. The poor quality of the writing, coupled with the author's repeated allusions to exotic genera and species and the frequent untranslated quotations from German, Latin, and French sources, will quickly discourage the casually interested professional as well as the beginning student.

The final section of the book, devoted to systematics, is poorly organized and written, and established rules of nomenclature are disregarded. For example, pages 726–37 are devoted to an elaborate discussion of the genus *Lophochaete* Schust (December 1960). This name exists only as a synonym of the genus *Pseudolepicolea* Fulford & Taylor (February 1960).

In conclusion, I must say that the nonspecialist will find little of value in this book aside, possibly, from the illustrations, while the experienced professional will have need for it merely in the interest of documentation. Finally, in view of the quality of the text and the fact that the National Science Foundation "undertook most of the cost of publication" (p. x), I consider the price of the book to be exorbitant.

RAYMOND E. HATCHER
Department of Botany,
University of Wisconsin, Milwaukee

Extracellular Fluids

Brain Tissue Electrolytes. A. VAN HARREVELD. Butterworth, Washington, D.C., 1966. 183 pp., illus. $7.95.

This small volume deals with an extensive and widely scattered literature on a subject that has generated considerable interest and controversy during the past decade. Because Van Harreveld has been an imaginative and resourceful contributor to investigations of the composition and volume of extracellular fluid his book is of special interest. A most useful aspect of the book is the discussion of specific impedance of central nervous tissue and its relationship to the phenomenon of spreading depression, and of the relationship between tissue resistance and the size of the extracellular fluid compartment. It was these questions that initially stimulated Van Harreveld's interest in the general subject of brain electrolytes. His discussion leads to a description of the work he has done, using histochemical methods, on the anatomical locus of chloride and the movement of this ion to an intracellular site during asphyxia and spreading depression. The section on electron microscopy deals primarily with Van Harreveld's important work in applying the technique of freeze-