

of type II and type III bursts are included in this account. Interpretation of these bursts in terms of plasma emission allows the determination of the electron density of the corona from near the Sun to near the Earth. Interpretation of millimetric and centimetric emissions in terms of thermal bremsstrahlung or gyro-synchrotron emission leads to estimates of electron temperatures, electron densities and magnetic field strengths in the chromosphere and low altitudes of the corona. Metric observations cover intermediate altitudes of the corona and give

information on electron density, and the direction and strength of the coronal magnetic field. Hence radio observations cover most of the Sun-Earth environment.

The other important aspect of radio observations is the evidence they provide for non-thermal populations of energetic particles released by solar flares. The fourth chapter deals with the theory of solar radio emission and is divided into primary emission processes, such as thermal bremsstrahlung and gyro-synchrotron emission from accelerated particles, and secondary emission

processes or wave-mode transformations such as Langmuir waves scattering into electromagnetic (plasma) radiation. Plasma instabilities such as the two-stream, velocity-anisotropy and tearing-mode instabilities are briefly discussed. The important question of amplification of radio waves is also mentioned but not considered in detail. The final chapter attempts to integrate solar radio astronomy with solar physics and solar terrestrial physics. The flare phenomenon is discussed, together with several possible mechanisms for the explanation of how particles are accelerated in the short time-scale of the flare and where the flare energy originates.

It is an ambitious undertaking to attempt to cover the entire span of the field in a single volume, but as an extensive review of the scientific literature the book is very successful and contains a useful list of references for the postgraduate student or research scientist. However, as an introduction to solar radio astronomy, it is less successful, being complicated by detail and lacking the highlights which give the reader an overall picture of an area of research. I feel that more emphasis could have been placed on the significant developments — instrumental, observational and theoretical — which have occurred in solar radio astronomy and that this would have led to a more readable account. However, I would recommend this book not only because of its uniqueness but also because it is an honest description of the work done in this field up until 1976. □

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Responses to arbitrary time schedules

J. T. Enright

Time in Animal Behaviour. By M. Richelle and H. Lejeune. Pp.273. (Pergamon: 1980.) Hardback £22, \$51; flexi £9.50, \$23.

DO NOT be misled by the title, the jacket and the forward of this book. It does not treat general features of behavioural adjustment to time, but instead deals almost exclusively with the key- and lever-pressing performances of hungry rats, pigeons and a small number of other species. The introductory chapter led me to hope for an integration of biological-clock research (circadian and similar studies) with other broader aspects of temporal regulation, but, as one finally discovers on p.135: "In the almost total absence of [relevant biological-clock] experimental work, we shall content ourselves with defining the type of research that is strongly needed to fill the gap. . .".

The real intent of the authors is to introduce certain sorts of temporally programmed operant-conditioning experiments to the uninitiated. These experiments centre around one of two basic designs. On the "fixed interval schedule", the animal learns not to "emit responses" (I shudder) continually or randomly, but to wait, after a given success, for a major fraction of the imposed unrewarded interval before trying again, and then to try persistently until success finally comes. At the other extreme is "differential reinforcement of low rates", a programme in which any unsuccessful keypress resets the timer to zero; following a reward, the animal is required to wait for *at least* the pre-programmed interval before trying again. Granted proper shaping regimes, most animals can apparently master these schedules, as well as many complex variants. True enough, mastery of the programme usually involves only relatively imprecise indications that the animal has some sort of expectation in the time domain. Nevertheless, the evidence presented in this book clearly demonstrates

that animals can evaluate and respond to arbitrarily chosen time intervals ranging from a few seconds to a few minutes.

The arbitrariness of the selected time intervals, based on their convenience in an operant-conditioning context, deserves emphasis. Most biologists are already familiar with certain other animal capacities to utilize time as a variable in an ecological context — matters of microseconds, as when an insectivorous bat uses sonar to home in on its prey, up to intervals of days, in time-training (*Zeitgedächtnis*) experiments with honeybees, and even weeks, in semi-lunar reproductive rhythms. Such aspects of temporal adaptation are presumably the intensely selected consequences of prolonged evolution. The animal skills considered in this book, on the other hand, seem to be completely devoid of any ecological relevance. To me, the impressive aspect of the results is that the animals show any capacity at all to deal appropriately with the arbitrary time schedules provided. These abilities are probably an evolutionary by-product, but the natural context in which they might originate remains obscure.

The general audience, for whom the book is intended, will encounter a number of stumbling blocks. It is easy to lose sight of the central questions when confronted with detailed results from yet another minor variant on the small number of standard experimental designs. A further difficulty lies in the authors' propensity for abbreviations which, once defined, the reader is expected to remember throughout subsequent chapters. The pages are peppered with FI, FR, FT, FI-FR, DRL 20s, DRL 60 LH 6, IRT, TO, RF/R and FRC, on through MULT FR 25 FI 7 min.

The authors emphasize (Chapter 6) that although brain lesions and certain drugs affect the response patterns, such results are fraught with ambiguity. I myself find the authors' attempts at overall interpretation (Chapter 9) to be equally ambiguous. For example, "We are dealing

here with a relaxation phenomenon, and not a pendulum-type oscillatory system. . . Temporal regulation involves the buildup of some sort of tension that is suddenly discharged. . ." (p.222). That sort of conclusion seems to me to be inextricably tied up with the experimental designs; if the imposed timing schedule contains major elements of a relaxation oscillation (sudden reset to zero), how could the animals behave otherwise? What we have here, then, is a large body of experimental data which seem, at present, to be begging for adequate explanation at both the evolutionary and the neurophysiological level. The authors deserve our thanks for making these results accessible in a compact form for those — like myself — who have been unfamiliar with this body of empirical knowledge. □

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