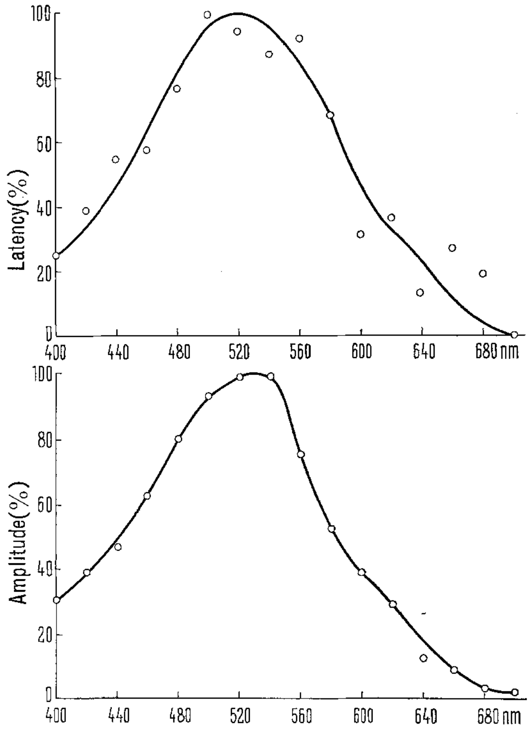
Spectral Efficiency as Function of Latency in the Visual Mechanism of Insect (*Tenebrio molitor* L.)

The range of spectral sensitivity and efficiency of the *T. molitor* eye has been reported in detail[1]. Energy-calibrated monochromatic light was used in addition to conventional optical and electronic systems. Exact amplitude and waveform of the ERG were determined with the aid of a computer of average transients (CAT 400B, TMC).

The percentage differences between the peak latency of the principal potential and minimum latency value was calculated. Since these bear an inverse relationship to amplitude values (as the stimulus become higher, the time necessary for obtaining maximal sensitivity is shorter[2]) they were subtracted from 100%. The peak was found to be between 510 and 530 nm, the curve decreasing to zero in long wavelengths and to about 25% efficiency in the short ones. This paralleled the results of amplitude studies (Figure). Latency at various wavelengths varied by 20–30%, in contrast to a 5–100% variation in amplitude; therefore, the latency factor is more stable. The relative variability among the latency values at each wavelength is greater than for amplitude values at corresponding wavelengths. Latency measurements can serve to confirm results based on calculations of amplitude.

When the response was tested at 10 nm, intervals between 500 and 560 nm, a plateau was obtained, decreasing slightly at both ends. Therefore, there is no clear-cut peak – indicating poor discrimination between wavelengths.

The amplitude is conventionally used as a measure of spectral sensitivity or efficiency; few data[3] are available on the rate of rise of the ERG in man in respect to monochromatic light, but it is of no importance in understanding the spectral sensitivity. The present work reveals the possibility of using latency as a measure of spectral sensitivity in insects.



Spectral efficiency curves for *T. molitor* based on latency and amplitude.

Zusammenfassung. Bei Untersuchungen der elektrophysiologischen Reaktion des Facettenauges beim Mehlkäfer *Tenebrio molitor* wurde die Maximalreaktion zwischen 510 und 530 nm gefunden. Latenz und Amplitude dienten als Kriterien der facettären Spektraleffizienz.

U. YINON

The Hebrew University of Jerusalem,
Department of Entomology and Venomous Animals,
Jerusalem (Israel), 18 February 1969.

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[1] U. YINON, Ph. D. Thesis, submitted to the Hebrew University of Jerusalem (1968).

[2] Y. LE GRAND, *Light, Colour and Vision* (J. Wiley, New York 1957).

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Association and Motivation in the Establishment of Conditioned Reflexes in Rats

It is generally admitted that one of the basic requirements in the establishment of conditioned responses is the presence of a certain level of motivation, commonly obtained by reinforcing positively or negatively the conditioned stimulus. Without discussing the strict physiological meaning of this supposed temporary state of the organism and the wider acceptance often given to it in less controlled psychological stituations, it appears from quite a number of experiments that motivation is not an absolute requirement for the forming of a conditioned reflex. Thus, NARBUTOVICI and PODKOPAEV[1] and later ROKOTOVA[2,3] have shown that a simple association between neutral stimuli, e.g. light and sound, is efficient in obtaining a conditioned response. After such an association, a sound stimulus initially coupled with a light stimulus, is liable to provoke elaborate salivary responses previously elicited by light alone. The neurophysiological aspects of these purely associative conditioned reflexes have been studied by POPOV[4], GASTAUT et al.[5], GASTAUT[6],

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[2] N. A. ROKOTOVA, Jurn. Viss. Nervn. Deiat. *6*, 833 (1954a).

[3] N. A. ROKOTOVA, Jurn. Viss. Nervn. Deiat. *4*, 516 (1954b).

[4] C. POPOV, C. r. Acad. Sci., Paris, *241*, 1414 (1955).

[5] H. GASTAUT, A. JUS, F. MORRELL, W. STROM VAN LEEUWEN, S. DONGIER, R. NAQUET, H. REGIS, A. ROGER, D. BEKKERING, A. KAMP and J. WERRE, Etude topographique des réactions électroencéphalographiques conditionnées chez l'homme. Electroenceph. clin. Neurophysiol. *9*, 1 (1957).

[6] H. GASTAUT, in *Reticular Formation of the Brain* (Ed. LITTLE; Brown and Co, Boston 1958), p. 561.

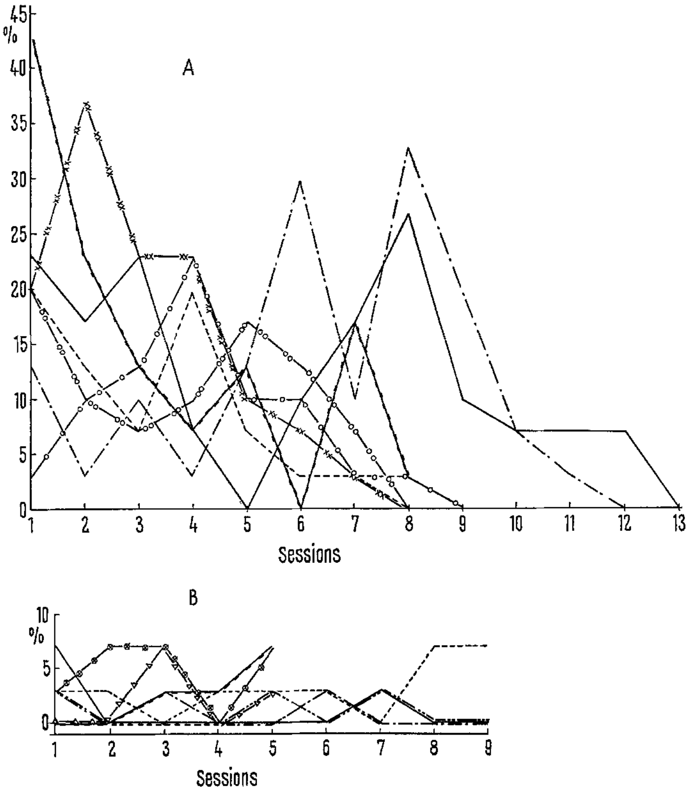
Michaux[7,8], Lelord and Rolland[9] and others. Similarly, Giurgea[10,11], Giurgea and Raiciulescu[12] and Doty and Giurgea[13] have established contrarily to Loucks[14] that an occipital stimulation initially coupled with a motor stimulation will elicit, after a sufficient number of trials, the movement provoked by the latter alone. In the present study, an attempt has been made to obtain these reflexes on a low vertebrate such as the rat, as these responses have only been clearly demonstrated until now on man and on high vertebrates (cat, dog, monkey).

Material and methods. 14 Wistar female rats, weighing 180–200 g and 3 months old at the beginning of the experiments, were randomly divided in 2 equivalent groups of 7 (control group and experimental group), and trained in an avoidance-reflex program. In a standard session, the experimental group received at irregular intervals varying from 30–120 sec, a light-stimulus (L) lasting 5 sec followed immediately by a buzzer noise (S) lasting 3 sec. In each experimental session, 30 such L–S couples were presented. During this initial phase, an orientation reflex directed to the sound-source established itself progressively, the result of which being that, as soon as the light went on, the rat made for the loudspeaker as if it expected the sound. After completing 15 such sessions, the light stimulus was suppressed and the same sound stimulus was used as the signal of an electrical stimulus (0.6 mA). In this second phase, the sound was also given at irregular intervals varying from 30–120 sec and lasted 15 sec. Pressing the pedal during the sound avoided the shock and stopped the sound altogether. After 7 sessions, 90% of the shocks were avoided. When this level of performance was attained, the light stimulus was presented again, always without reinforcement, in order to establish whether the formerly neutral light signal would elicit the same response as the sound. During this third phase, the light-signal was presented randomly 30 times in each session.

The standard sessions of the control group were identical to those of the experimental group, except that the animals were not submitted to the initial association phase, and began directly with the shock avoidance experiment.

Results. The individual percentages of responses to the light stimulus during the third phase are given for both groups in the Figure. From the first presentations of the light stimulus on, 5 out of the 7 animals of the experimental group reacted by pressing the avoidance pedal at a rate varying from 20–45% of the total number of stimulations. This phenomenon lasted in average during 5 or 6 sessions, after which extinction occurred in the normal way as a consequence of non-reinforcement. In 2 animals, extinction was first obtained after 10 sessions.

In the control group, on the other hand, the responses elicited by the light stimulus do not distribute along an



Bar-pressing rates after light-stimulation per block of 30 trials for the 2 groups. (A) Experimental group; (B) control group.

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[7] L. Michaux, J. D. Duche, C. Koupernik, G. Lelord and M. Rolland, Revue Neuropsychiat. infant *2–3*, 171 (1966).

[8] L. Michaux, J. D. Duche, H. Flavigny, G. Lelord and M. Rolland, Revue Neuropsychiat. infant *2–3*, 183 (1966).

[9] G. Lelord and M. Rolland, Le Concours Médical *89*, 1485 (1967).

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[13] R. W. Doty and C. Giurgea, *Brain Mechanisms and Learning* (Ed. J. F. Delafresnoy; Blackwell Scientific Publications, Oxford 1961), p. 133.

[14] R. B. Loucks, J. comp. Psychol. *2*, 415 (1938).

extinction curve. Their rates oscillate between 0% and 7% of the total number of stimulations for all animals, which means that none of them developed a successful response to light. The calculation of the level of significance of the differences found between the results of both groups, shows that the initial association of light and sound has systematically affected the behaviour of the experimental group ($P < 0.001$; Fisher exact probability test for the 6 initial sessions of the third phase).

Discussion. It can be concluded from the results obtained in these experiments, that an 'associative' conditioned reflex can be obtained on the rat. One could nevertheless object that the identity of reaction to sound and light can be simply interpreted as a case of response-generalization. This amounts to saying that no true association was formed in the experimental group, in other words that the light stimulus never acted as an authentic signal for the electrical shock. The absence of an efficient response to the light-stimulus in the control group seems, however, to establish the opposite. For the animals of this group, indeed, the situation presented called for a discrimination between a non-reinforced stimulus (L) and a reinforced stimulus (S). The results obtained for the controls show that the light did not play the role of a signal as the sound had done before. In the case of the animals of the experimental group, on the contrary, the percentages of pedal-pressing for light show that this stimulus acted, at least up to a certain level, as a signal for the sound, the latter acting in its turn as a signal for the shock. This means that, in so far as the animals reacted in the same manner for light and for sound, light acted as a signal for the shock. It can therefore be concluded that the temporal contiguity of 2 neutral stimuli has in itself enabled the rats to establish a functional relation between them, without the aid of any specific motivation factor.

Résumé. Les expériences discutées ont porté sur le rôle de la motivation – sous la forme d'un renforcement – dans l'établissement de réponses conditionnées instrumentales chez le rat. Les résultats obtenus sur un groupe expérimental et un groupe de contrôle comprenant chacun 7 animaux, montrent que la contiguité temporelle de 2 stimuli neutres (son-lumière) permet aux animaux d'établir entre ceux-ci une relation fonctionnelle sans intervention d'un facteur spécifique de motivation.

M. DAVID-REMACLE, M. C. LESCRENIER
and C. GIURGEA

Centre de Psychologie Expérimentale et Comparée de l'Université de Louvain (Belgium), 10 March 1969.

The Constituents of Arterial Pressure Change

The hemodynamic determinants of arterial pressure are mainly cardiac output and systemic peripheral resistance. When a change in arterial pressure is observed in a cardiovascular reflex or response, one might be interested in the relative degrees of contribution of the 2 factors, cardiac output and peripheral resistance, to the arterial pressure change. This is a question of the constituents of the arterial pressure change. Formulation of equations for quantifying the constituents from experimental data would be useful for the analytical study of cardiovascular regulation.

Mathematical formulation. If we denote mean arterial pressure by P, cardiac output by I and systemic peripheral resistance by R, since P is a monotonically increasing function of I and R, it may be expressed as

$$P = f(I, R)\,; \quad \frac{\partial P}{\partial I} > 0\,, \quad \frac{\partial P}{\partial R} > 0\,. \tag{1}$$

Assuming that a law analogous to Ohm's law of electricity holds good approximately among P, I and R, then

$$P = I\,R\,. \tag{2}$$

In total differential form

$$dP = R\,dI + I\,\mathrm{d}R\,. \tag{3}$$

If we use increments instead of differentials, approximately,

$$\Delta P = R\,\Delta I + I\,\Delta R\,. \tag{4}$$

This equation means that any change in arterial pressure consists in the 2 parts: one due to a change in cardiac output and the other due to that in systemic peripheral resistance. The relative magnitude of contribution of each part to the arterial pressure change may be expressed by the ratio of each term of the right hand side of equation (4) to the total change, left hand side. Let us call these 2 ratios 'constituents' of the arterial pressure change and denote by C_I and C_R, i.e.

$$C_I = \frac{R\,\Delta R}{\Delta P} \tag{5}$$

and

$$C_R = \frac{I\,\Delta I}{\Delta P}\,. \tag{6}$$

C's refer to 'constituents', suffix I to cardiac output and suffix R to peripheral resistance. Obviously,

$$C_I + C_R = 1\,. \tag{7}$$

For actual computation, since R is not directly measurable, substituting the so-called total peripheral resistance, P/I, for R in equations (5) and (6),

$$C_I = \frac{P}{\Delta P} \cdot \frac{\Delta I}{I} \tag{8}$$

and

$$C_R = 1 - \frac{P}{\Delta P} \cdot \frac{\Delta I}{I}\,. \tag{9}$$

In a previous study[1] an index, β, was proposed for the degree of contribution of one particular region to a change in total peripheral resistance; i.e.

$$\beta = \frac{\Delta g}{\Delta G} = \frac{i\,\Delta P - P\,\Delta i}{I\,\Delta P - P\,\Delta I}\,, \tag{10}$$

where i = regional flow rate, g = regional conductance (= i/P), G = total conductance (= $I/P = 1/R$), and Δ's refer to their changes in a cardiovascular reflex or respon-