Weak and Strong Phase Shifting in the Activity Rhythm of *Leucophaea maderae* (Blaberidae) after Light Pulses of High Intensity

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Activity, Circadian Rhythm, Cockroach, *Leucophaea*, Light Pulse, Phase Response Curve

In the running activity of the cockroach *Leucophaea maderae* a strong phase response curve is found when using high intensity light pulses (80 000 lx and about 12 hours duration). The phase response curve has an unsymmetric shape: delays are larger than advances. The phase jump lies about 2 hours after subjective midnight.

The cockroach *Leucophaea maderae* exhibits a clear circadian activity rhythm when recorded in a running wheel under constant conditions (28 ± 1 °C constant red light, further details see [1]). Compared with the eclosion rhythm of *Drosophila* only rather small phase shifts of 1–2 hours have been found so far in the activity rhythm of cockroaches by using light pulses of 2000 lx and 12 hours duration [2]. However, using high intensity light pulses larger phase shifts can be found. Fig. 1 shows a delay of about 12 hours and an advance of about 3.5 hours induced by light pulses of 80 000 lx and 150 angle degrees (because of the interindividual variability the free-running period has been standardized to 360 angle degrees; 150 angle degrees are equivalent to about 10 hours). Phase shifts brought about by pulses given at various phases of the cycle are shown in phase response curves (Fig. 2). Both types of phase response curves as known from the literature [3] exist also in *Leucophaea:* type 1 or weak type of phase response curve and type 0 or strong type of phase response curve. Pulses of 50 000 lx and 90 or 120 angle degrees duration (about 6 or 8 hours) evoke weak phase response curves in *Leucophaea*'s running activity rhythm. They are unsymmetric with maximal delays four to five-fold larger as compared to the maximal advances. These phase shifts are induced by light pulses during the subjective night (Fig. 2, hatched part of abscissa). Throughout the subjective day (white part of abscissa) the rhythm shows rather small phase shifts. There are two phases per cycle without phase shifting effects of light pulses, which separate delays from advances; the first in the subjective morning, the second shortly after subjective midnight. These features can be compared with those of weak phase response curves of *Drosophila* [4], *Kalanchoe* [5], and some noctural rodents [6].

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Pulses of 80 000 lx and 180 angle degrees duration (about 12 hours) evoke a strong phase re-

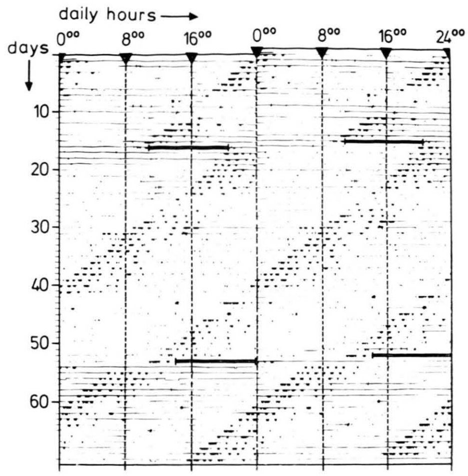

Fig. 1 a.

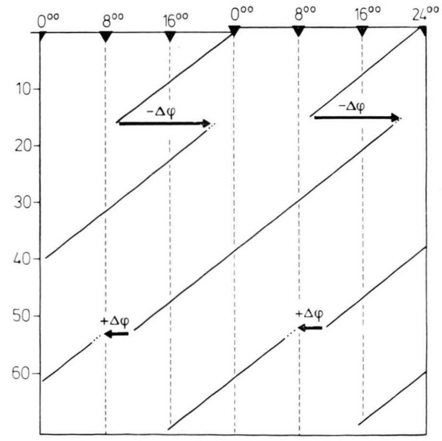

Fig. 1 b.

Fig. 1. Recording of an activity rhythm of *Leucophaea maderae* under continous dim red light (free-running period $\tau = 23.1$ hrs) disturbed by light pulses (80 000 lx, 150 angle degrees duration). For better recognition of the slope of onsets of activity the actogram has been doublicated and the right part displaced upwards one day. a: raw data, produced by glueing the paper strip of an event recorder on a paper chart day by day, so that the same daily hours are directly under that of the previous day. Pulses are indicated by a double lined interruption of the recording. The pulse on day 16 evokes a delay of 185 angle degrees (about 12 hrs), the second pulse on day 53 an advance of 54 angle degrees (about 3.5 hrs). b: the same actogram as a, however, only connections between daily onsets of activity are shown. Phase shifts are calculated by measuring the distance from the slope of activity onsets *before* the pulse to the extrapolated trend of onsets *following* the pulse.

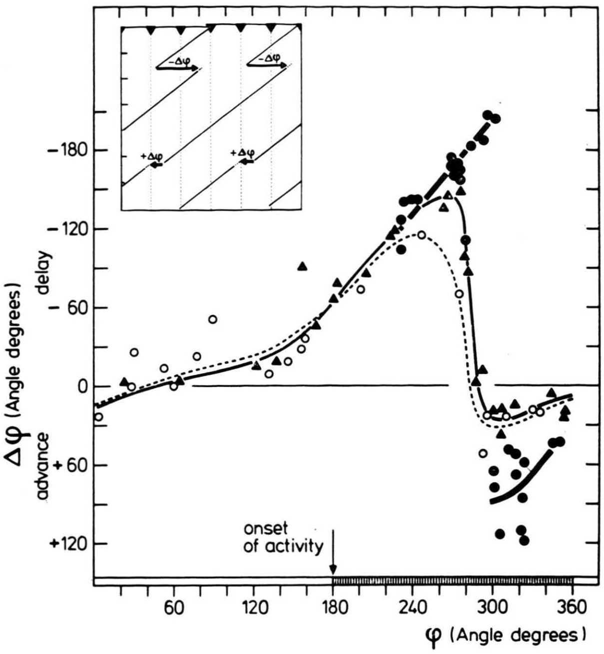

Fig. 2. Phase response curves of the running activity rhythm of *Leucophaea maderae* after high intensity light pulses. Ordinate: phase shifts derived from actograms of the type as shown in the insert at upper left. Abscissa: phase position of the *midpoint* of the light pulses. ○— — —○: 50 000 lx, 90 angle degrees; ▲———▲: 50 000 lx, 120 angle degrees; ●———●: 80 000 lx, 180 angle degrees. Each point represents the result of one phase shifting experiment as exemplified in Fig. 1. Subjective day and night are indicated by white and hatched bars at the abscissa.

sponse curve. Maximal delays of 205 angle degrees (about 14 hours) and maximal advances of 120 angle degrees (about 8 hours) are found. Although delays of more than 180 angle degrees could be plotted in the phase response curve as advances, the resulting uncontinuity and the asymmetry of the weak response curves would strongly speak against such a way of interpreting the phase shifts. It is therefore more likely, that the phase jump lies after subjective midnight at about 300 angle degrees, which is about 1.2 hours later compared to the phase jump in the standard phase response curve of *Drosophila* (1000 lx and 15 min duration) [7]. The time of jump in the *strong* phase response curve in *Leucophaea* is about 1 hour later than the unresponsive phase of the subjective night in the *weak* phase response curve, a feature which has been found in phase response curves for light pulses of different duration in *Kalanchoe*, too [5].

Details of this study and further results will be presented elsewhere.

[1] G. Wiedenmann, J. Interdisc. Cycle Res., in print.
[2] S. K. Roberts, J. Cell. Comp. Physiol. **59,** 2, 175–186 [1962].
[3] A. T. Winfree, J. Theor. Biol. **28,** 327–374 [1970].
[4] C. S. Pittendrigh, Cold Spring Harb. Symp. quant. Biol. **25,** 159–184 [1960].
[5] W. Engelmann, H. G. Karlsson, and A Johnsson, Intern. J. Chronobiol. **1,** 147–156 [1973].
[6] S. Daan and C. S. Pittendrigh, J. Comp. Physiol. **106,** 253–266 [1976].
[7] C. S. Pittendrigh and D. H. Minis, Amer. Naturalist **98,** 261–294 [1964].

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