ditioning" auditory signal (sinusoidal sound of 0.5 s duration). In order not to impair the birds' learning disposition by neurosis shocks as weak as possible were applied, in both the "training phase" and the actual tests. Both phases merged since the accompanying computer program continuously indicated the reliability of the learning success achieved.

The limits of hearing as determined in 3 pigeons (Fig. 1) coincide rather well. The maximum discrepancy between individual curves is 15 dB, found at the frequencies of 8 and 10 kHz. It must be taken into account that each of the 48 measure points (Fig. 1) is statistically significant. The error probability (Student's t-test; s. [5], p. 109) was less than 2.5% in three cases, in the overwhelming majority 1% and less. Comparing the data of previous authors (Fig. 2), the correspondence in the general shape of the auditory thresholds has to be emphasized: high sensitivity around 1–2 kHz, a flat slope towards lower tones and a very steep rise of the curve up to 10 kHz, where the upper limit of hearing has to be defined. As well the comparison with several song birds (lit. s. [4]) and the parakeet [1] shows a clear similarity. While in these the area of maximal sensitivity is shifted upwards by about one octave, again no substantial auditory activity is found at a frequency above 10 kHz. Only the study of Harrison and Furumoto [2], gives the lowest thresholds of pigeons at frequencies between 2 and 3 kHz, that is by about 5 dB below the results determined here. According to the authors own interpretation, differences up to 10 dB in the sound intensity stated may have occurred, since the applied method of operant conditioning required free mobility of the pigeon within the sound field of the box.

Summarizing, pigeons do not stand back in their absolute hearing sensitivity behind other species of birds, though the behavioral meaning of vocal utterances of song birds and parrots must be rated considerably higher. The sounds involved in social contacts of pigeons are produced below 500 Hz. At most the offspring's "Nestpiepen" covers the range up to the frequency of best hearing, not requiring however, a sensitivity of such a marked degree. An explanation could be offered by analysing the sounds which are generated during flight. It is reasonable to assume that other bird species whose range of best hearing and of vocal utterances correspond, as well might use their hearing additionally for flight control.

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1. Dooling, R.J., in: Comparative Studies of Hearing in Vertebrates, p. 261 (A.N. Popper, F.R. Fay, eds.). New York-Heidelberg-Berlin: Springer 1980
2. Harrison, J.B., Furumoto, L.: J. Aud. Res. 11, 33 (1971)
3. Hienz, R.D., Sinnott, J.M., Sachs, M.B.: J. Comp. Physiol. Psychol. 91, 1365 (1977)
4. Kuhn, A., Müller, C., Leppelsack, H.J.: Naturwissenschaften 69, 245 (1982)
5. Sachs, L.: Statistische Auswertungsmethoden, S. 109. Berlin-Heidelberg-New York: Springer 1972
6. Shen, J., Hörster, W., Schwartzkopff, J.: Naturwissenschaften 70, 48 (1983)
7. Shen, J.: J. Comp. Physiol. 152, 251 (1983)
8. Trainer, J.E.: Ph. D. Thesis, Cornell Univ. 1946

Tranquillizer Reduces Electric Organ Discharge Frequency in a Teleost Fish

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One of the difficulties in the development of psychoactive drugs was the testing of their behavioural effects. Also, the involvement of specific neurotransmitter substances (the action of which can either be blocked or enhanced by centrally acting drugs) in the production of behaviour is still unclear (cf., e.g., [1]).

Therefore, a behavioural test was looked for which enabled a more precise measurement of the effects of psychoactive drugs. A necessary condition for this was a stable baseline of the chosen behaviour before drug administration. The most stable neuronally paced behaviour known is found among some weakly electric fishes such as Apteronotus albifrons (Gymnotiformes) with its electric organ discharge (EOD) [2].

Five fish, obtained from a tropical fish dealer, were placed in individual 45-l aquaria (26.0±0.1 °C). Frequency measurements were taken three times a day, during the light phase (700 to 1900 h) when the fish were hiding in their porous pot shelters.

In untreated fish, only small frequency fluctuations of unknown cause were observed (Fig. 1). On day 2, the tranquillizer chlorpromazine ("Megaphen" Bayer) was added to the aquarium water (0.125 mg/l). This concentration caused a significant decrease in the attack-, the sexual-, and the nest-building activity of the sunfish (Perciformes) [3].

Within about 3 h, there was a frequency drop by a mean of 26.2± s.e. 9.6 Hz. This significantly differs from each of the previous measurements (Fig. 1; $p < 0.05$; two-tailed paired t-test). No indication of anaesthesia (cf. [2]) was found.

The drug was removed on day 3, 24 h after administration, by totally exchanging the aquarium water. Another 24 h later, on day 4, the mean EOD frequency had nearly recovered.
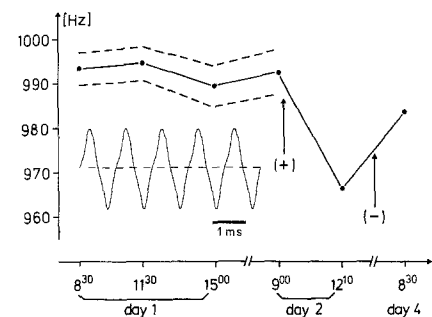

Fig. 1. EOD frequency of Apteronotus albifrons over time. Dashed lines represent ±1 standard error of the mean of paired differences for 5 individuals. Arrow (+): the tranquillizer chlorpromazine was added to the aquarium water; arrow (−): chlorpromazine was removed. Note the frequency drop following drug administration. Inset: electric organ discharge of A. albifrons

The observed frequency change may seem small, however, given the high baseline stability and the near impossibility to elicit any frequency change to all kinds of stimuli or disturbances in this fish [4], except temperature change and specific, jamming electric stimuli, the change is considerable [2]. In addition, jamming stimuli elicited only frequency *increase* (up to a few Hz), not decrease.

The present results demonstrate a tranquillizing effect of chlorpromazine also for the EOD of high-frequency, high-precision electric fish. Interestingly, formaldehyde-induced fluorescence histochemistry (Falck-Hillarp technique) combined with microspectrofluorometry showed that, among many other structures, the neurons of the medullary pacemaker nucleus which commands the electric organ contain biogenic amines (catecholamines) in the brain of *Eigenmannia*, a related gymnotiform fish [5].

The animal model presented here appears suitable for the investigation of the behavioural effects of psychoactive drugs. It offers speed, accuracy and simplicity over the more complex ethological methods, as employed in [3].

1. Burgen, A.S.V., Mitchell, J.F.: Gaddum's Pharmacology. London-New York-Toronto: Oxford Univ. Press 1978
2. Bullock, T.H., Hamstra, R.H., Scheich, H.: J. Comp. Physiol. 77, 1 (1972)
3. Kramer, B.: Z. Tierpsychol. 32, 353 (1973)
4. Kramer, B., Tautz, J., Markl, H.: J. Comp. Physiol. 143, 435 (1981)
5. Bonn, U., Kramer, B.: Neurosci. Lett., Suppl. 7, 363 (1981); Bonn, U.: Diss. Univ. Regensburg 1983; Bonn, U.: submitted

Magnetic Field Induced Temperature Change in Mice

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The motivation for the present study came from the recent observation by Gremmel et al. [1]. They found that magnetic fields as commonly used in NMR tomography cause sizeable temperature changes ($\Delta T \approx 5$ °C) in the human body. While performing similar experiments on mice we also detected magnetic field induced temperature changes. In addition to the results by Gremmel et al. we found a clear relationship between the magnetic field gradient relative to the mouse and the *sign* of induced temperature change. Furthermore we investigated the saturation of the temperature change in magnetic fields up to 8 *T*.

Horizontal magnetic fields were produced by a superconducting coil containing a coaxial cylindrical sample chamber (diameter 5 cm, length 29 cm). The magnetic field was parallel

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to the axis of the sample chamber. It was nearly homogeneous in the center of the chamber and showed a field gradient towards either side of the center (Fig. 1, top). The air temperature inside the sample chamber was kept at 23 ± 0.2 °C during all experiments. Experiments were performed on both nude mice (nu/nu mouse, BALB/c) and coated mice (BALB/c). A mouse was mechanically fixed with two plastic belts on a plastic ruler. The surface temperature of the mouse was measured ventrally, dorsally, and at the tail using platinum resistance thermometers (Pt 100). The rectal temperature was measured using a thermistor (YSI, model 520). All temperature values were continuously recorded. After fixing the mouse and attaching the thermoresistors, the mouse was located at one of the positions A, B or C inside the sample chamber as shown in Fig. 1. In order to keep the mouse as calm as possible the sample chamber was darkened and protected from draft. To

reduce the influence of vibrations and acoustic noise the experiments were always performed during the night between 8 p.m. and 6 a.m.

Due to the handling and preparation before an experiment, the mouse usually became excited and its temperature increased. After the mouse was located inside the sample chamber it took about 3 h for the temperature to reach its normal value. Afterwards the temperature of the mouse stayed constant within 0.1 °C for several hours (in Fig. 2 from 3 to 5 h for example). Then the magnetic field was raised by increasing the current through the coil. A field of 3 T (all given field strengths quoted were measured at the center of the sample chamber) was reached in 5 min.

The result of an experiment performed with the mouse in position B is shown in Fig. 2. About 4 min (not visible on the time scale in Fig. 2) after the magnetic field started to increase the *rectal* and *dorsal* surface temperature of the mouse also started to rise. Although the magnetic field was kept constant at a value of 3 T the temperature continued to increase and reached saturation only 3 h later. On switching off the magnetic field (switch-off time 5 min) it took 2 h for the temperature to return to its normal value. No matter where the temperature was measured (see caption of Fig. 1) they all varied with time in nearly the same way. The temperature change at the *ventral* side of the mouse and at the *tail* was measured between the two curves given in Fig. 2.

All mice already react to relatively weak fields. A magnetic field of only 0.4 T induces a detectable increase of temperature of 0.45 °C. But the temperature increase begins to reach saturation in a magnetic field of 2 T. A further increase of the field from 2 to 8 T leads only to a small temperature increase of about 0.2 °C.

In all our experiments with the mouse kept in position A or B, we observed a field-induced *increase* of temperature. However, if the experiment was performed with the mouse in position C we observed a *decrease* of temperature when the magnetic field was moved up. In this case, decreasing the field to zero led to an increase of temperature until the normal level was reached again within about 2 h.