STUDIORUM PROGRESSUS

Transmission of a Flight Reaction Amongst a School of Fish and the Underlying Sensory Mechanisms

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Introduction.–During experiments on sound localization in fish, a typical flight reaction of a school of minnows (*Phoxinus laevis*) was observed by v. FRISCH after one of the fishes had been injured. Elaborate studies demonstrated that the olfactory perception of some substance released from the skin of the injured fish (*"Schreckstoff"*) provokes this panicky reaction amongst the school[2]. There were some casual observations suggesting that fishes not exposed to this chemical stimulus might be carried away by the panic-stricken behaviour induced in the others. No further experiments were performed in this direction, however.

Flight reactions similar to those in the minnow were described in tadpoles[3]. During recent experiments with these animals, it was sometimes observed that the state of excitement seemed to pass from one aquarium to an adjacent one[4]. Transmission by optical stimuli was therefore envisaged. But during subsequent experiments it became obvious that the synchronization of the animal's reactions in the 2 aquaria must have been only coincidental. Optical stimuli are not involved in this flight reaction of tadpoles[4].

Although this may well be true in tadpoles, it remained to be seen whether it were true for fish, for it would still be a very useful thing if only some alarmists were necessary to warn the whole school of predatory danger, the more so as the chemical stimuli will spread only slowly from the centre where they are liberated. Little is known, however, about the schooling behaviour of fishes in general, to say nothing of more specific interactions between the individual members of the school[5].

A series of experiments were therefore set up, in an attempt to discover whether an alarming mechanism from fish to fish plays a role in the flight reaction and, if this should prove true, to determine which sense organs are involved.

The experimental animals used were freshly imported specimens of the small tropical teleost *Rasbora heteromorpha* collected in the waters around Singapore[6]. They were kept in the laboratory in stock tanks at 22°–24°C and fed daily on raw, finely minced or, still better, scraped meat.

Arrangement and Procedure.–The experiments were carried out in 2 small rectangular tanks (30 cm long, 20 cm wide and 23 cm deep) with transparent glass walls, placed side by side on rubber tubes to make sure that the fishes in one tank could exchange only visual stimuli with those in the other one. During control experiments, the visual stimuli were intercepted by a screen between the 2 tanks. The chemical stimulus could be administered to the fishes in one of them through tube ending in this tank. The arrangement is seen in the figures (film pictures).

The chemical stimulus was prepared by scaling one freshly killed fish into 5 cm^3 of water. The filtrate of the juice was used as stimulus. By adding Indian ink the spreading of the filtrate could be followed. Control experiments proved that the cloud of ink in itself did not evoke any visible reactions amongst the fishes.

About 60 unselected fishes averaging 25 mm in length were taken from the supply tank and distributed equally in the 2 observational tanks. The fishes were allowed to become accustomed to the more restricted space of these tanks for some days.

Then the experiments were run as follows: both groups of fishes were observed during 5 min. When the fishes were swimming around quietly and obviously undisturbed, the chemical stimulus was introduced into one tank (Fig. 1). The reactions of the 2 groups of fishes were recorded by observation and sometimes photographically or by motion pictures. The reaction times could be read from a chronometer unterneath the 2 tanks.

Results. The following sequence of reactions can be observed amongst the fishes in the tank where the chemical stimulus was applied. (a) As soon as some fishes happen to enter the cloud with the stimulus they make some agitated jerking movements while the fins are erected strongly. (b) While the agitation spreads among the other fishes that have not yet been in contact with the cloud, all fishes sink to the bottom (Fig. 2). (c) Within some tens of seconds, the rising agitation results in a general panic-stricken swimming hither and thither (Fig. 3). (d) After some time all the fishes are suddenly crowded tightly together in a corner of the tank (Fig. 4). Then the reaction types (c) and (d) occur alternating each other in succession for a considerable time.

The fishes in the other tank show a strikingly similar behaviour. They are subjected to the same wave of confusion, with the only difference that the respective reaction types in this second tank are some tens of seconds behind the events in the first tank. After some time the reaction types (c) and (d) are frequently synchronized in both tanks. After having darted around for some time, all the fishes would often pack tightly together into one visually coordinated cluster, with the 2 adjacent glass walls of both tanks forming a transparant partition right across (Fig. 5).

Calm is restored first among the fishes that were only optically aroused.

Discussion.–As appears from these experiments the question as to whether an alarming mechanism plays a part in this flight reaction can be answered in the affirmative. Sight is the primary sense involved, as it is in schooling in general. Moreover, mechanical stimuli to the tactile-auditory-lateral line group of sense organs may provide fishes with additional cues as to the state of alarm of other members of the school. (Experiments further analyzing the mode of action of this group of stimuli are still in progress.)

A similar type of flight reaction was observed amongst the fishes in the stock tanks after mechanical disturbance, for instance if one bangs on the table carying these tanks. Moreover, it was observed sometimes without any

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[2] K. v. FRISCH, Naturwissenschaften *25*, 601 (1938); *29*, 321 (1941); Z. vgl. Physiol. *29*, 46 (1942).

[3] I. EIBL-EIBESFELDT, Exper. *5*, 236 (1949). – J. HRBAČEK, Exper. *6*, 100 (1950).

[4] E. KULZER, Z. vgl. Physiol. *36*, 443 (1954).

[5] J. E. MORROW, Quart. Rev. biol. *23*, 27 (1948). – C. M. BREDER, Jr., Bull. Amer. Mus. nat. Hist. *98*, 1 (1951). – M. H. A. KEENLEYSIDE, Behaviour *8*, 183 (1955), and others.

[6] The author gratefully acknowledges the facilities received from the Royal Dutch Airlines K.L.M. in transporting the freshly collected fishes from Singapore.

apparent provocation. It is tempting to think of threshold lowering culminating in "vacuum activity"[7].

A rather unpleasant and complicating factor was met with in the waning of the responses which occurs after a number of tests. The mechanism of this waning still remains to be cleared up, since, after some weeks or months, a general damping down of responses became apparent even among stock fishes not yet used in the experiments. This phenomenon may be related to the fishes becoming more and more tame.

[7] K. LORENZ, Naturwissenschaften *25*, 289, 307, 324 (1937).

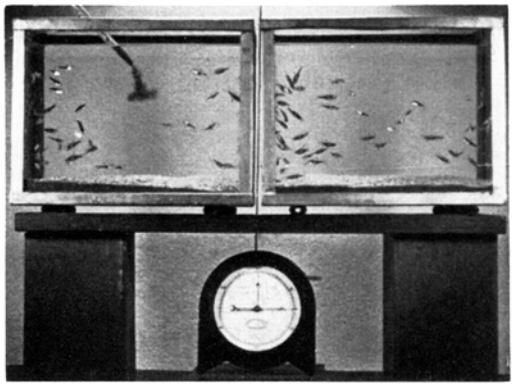

Fig. 1.

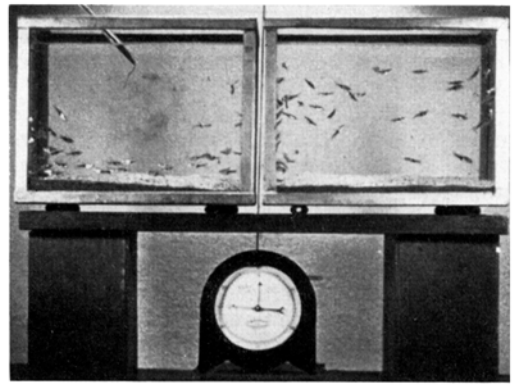

Fig. 2.

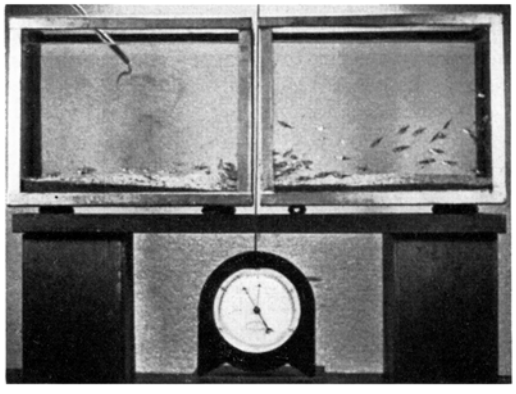

Fig. 3.

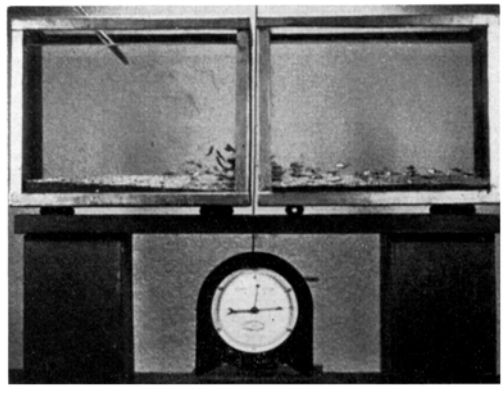

Fig. 4.

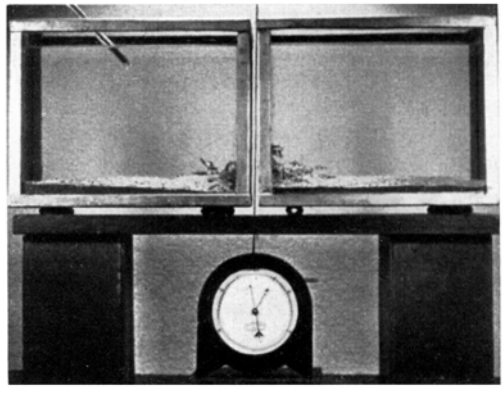

Fig. 5.

Fig. 1–5 are taken from a 16 mm film. The long hand of the chronometer indicates one s for each of the 60 scale units, the short hand indicates 1 min for each scale unit. Figure 1 was taken 15 s after the chemical stimulus was introduced into the left tank, Figure 2 about 30 s after Figure 1, etc. For further explanation see text.

A search of the literature revealed a wide-spread interest in the reactions of fish to chemical substances such as pollutants from the industry[8]. The results of a great number of experiments indicate that substances probably perceived as odours and tastes do not arouse biologically typical fright reactions amongst fishes or schools of fishes. Strong poisons and irritants, however, do evoke violent reactions, as is to be expected. Apparently only one out of the many experiments on these lines has yielded results germane to the problem in question. During a study, undertaken to find whether migrating Pacific salmon can be repelled from polluted river locations, it was found by accident that dilute water rinses of human and, more generally, mammalian skin had a distinct, repellent action. Dilute solutions of some tens of substances failed to change the rate of migration. Obviously an acute olfactory sense enables Pacific salmon to detect predators like bears, sea-lions and seals[9].

It might be imagined that during these types of fright reactions fishes are interacting in a similar way as described before. Interaction of this kind, however, was not envisaged in the experiments just mentioned. The distribution of a number of fishes in gradient fields was mostly evaluated as being the result of individual responses to the applied chemical stimulus. It follows from the above considerations that the possibility of mutual interaction should be borne in mind when reviewing the conclusions from these experiments.

Zusammenfassung

Beim kleinen tropischen Schwarmfisch *Rasbora heteromorpha* löst ein Schreckstoff aus verletzter Haut chemisch Alarm- und Fluchtverhalten aus. Es zeigte sich, dass das rasche Übergreifen der Schreckwirkung auf alle Schwarmmitglieder durch optische (und wohl auch mechanische) Reize bedingt ist, die von den bereits alarmierten Individuen ausgehen.

[8] J. R. E. JONES, J. exper. Biol. *28*, 261 (1951). – R. W. HIATT, J. J. NAUGHTON, and D. C. MATTHEWS, Biol. Bull. *104*, 28 (1953), and others.

[9] J. R. BRETT and D. MAC KINNON, Fish. Res. Bd. Canada, Pac. Prog. Rept. No. *90*, 21 (1952); J. Fish. Res. Bd. Canada *11*, 310 (1954).

Corrigendum

Z. SUPEK and S. MILKOVIČ: *Quantitative Biological Determination of 5-Hydroxytryptamine*, Experientia, vol. XII, fasc. 2, p. 71 (1956).

The last paragraph on page 72 reads: 87 μg/ml and 26 μg/ml, but it should read: ng/ml, i.e. "nanogram", which is $^1/_{1000}$ of μg (see C. SMITH, *Biomathematics*, London 1954, p. 438).

CONGRESSUS

U.S.A.

First International Congress on Developmental Biology

Rhode Island, July 23–26, 1956

Under the auspices of the Institut International d'Embryologie a congress on developmental biology will be held in Brown University, Providence, R. I., USA.

It will be followed by a conference on Cytodifferentiation, sponsored by the I.U.B.S. (July 27–31).

The registration fee for the congress will be $5.00. Accommodation can be provided at a flat rate of $7.00 per day for room and board to those who remain for the duration of the congress or the conference or both. Applications must be sent as soon as possible to Prof. J. WALTER WILSON, Department of Biology, Brown University, Providence 12, R. I., USA. Correspondence about the congress and conference can be sent to Mr. G. A. NORTON, Administrative Assistant, Developmental Biology Conference Series 1956, National Academy of Sciences, National Research Council, Division of Biology, 2101 Constitution Avenue, Washington 25, D.C., USA.

BELGIQUE

Congrès international de cybernétique

26 au 29 juin 1956

La Province de Namur organise, sous le Haut Patronage du Ministère de l'instruction publique et de l'UNESCO, et sous la Présidence d'Honneur de Monsieur le Gouverneur de la Province de Namur, un congrès international de cybernétique qui se tiendra à Namur (Belgique).

Les personnes qui auraient l'intention de participer au congrès au titre d'auditeur, d'auteur de communication ou d'exposant de matériel, sont priées de se faire connaître en écrivant au Secrétariat du congrès international de cybernétique, 13, rue Basse-Marcelle, *Namur* (Belgique). Des informations détaillées leur seront envoyées.

E. STIEFEL