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CLASSICAL CONDITIONING OF AGGRESSIVE DISPLAY IN SIAMESE FIGHTING FISH[1]

TRAVIS THOMPSON AND THOMAS STURM

UNIVERSITY OF MINNESOTA

Unconditioned aggressive-display behavior elicited by the mirror image of a male Siamese Fighting Fish was brought under the control of a previously ineffective stimulus by classical conditioning. A stimulus light repeatedly paired with mirror presentation came to elicit the complex aggressive-behavior sequence. Relative rates of acquisition of four components of the display were compared. Fin erection and undulating movements were acquired most rapidly while gill-cover erection and frontal approach were acquired most slowly. A discriminative conditioning procedure revealed that the response was specifically elicited by the conditioned stimulus, and not a sensitization artifact.

Male Siamese Fighting Fish (*Betta splendens*) exhibit a complex unconditioned aggressive display in the presence of another male *Betta*, terminating in attack. The same behavior sequence is elicited by their own mirror image or a model of another male *Betta* (Lissmann, 1932). These fish will learn to emit an operant response when reinforced by a mirror image or the model of another male in aggressive display (Thompson, 1963). Thus, certain aspects of the visual image of another fish in aggressive display are reinforcing. Male *Bettas* exhibit aggressive display following an average of 97% of visual reinforcer presentations (Thompson and Sturm, 1965). Some subjects began to display following the emission of the operant before the reinforcing model was within view. This suggested that the display was elicited by stimuli which had been repeatedly paired with model presentation.

Adler and Hogan (1963) made a similar observation when they classically conditioned gill-cover erection, one component of this complex display. They used a 0.5 sec, 1.0 v electric shock as a conditioned stimulus, and a mirror as the unconditioned stimulus. The mirror was presented simultaneously with the shock and was available for 15 sec. The electric shock CS elicited a twitch response, which may account for the rather long latencies between CS presentation and conditioned gill-cover erection (some as long as 13 sec).

The present research studied relative rates of classical conditioning of four components of the unconditioned aggressive display sequence. In view of the possible confounding effects of shock, the first experiment sought to establish the feasibility of a light as a CS.

A discriminative conditioning procedure was used in the second experiment demonstrating that the four aggressive display components were specifically elicited by the CS. This eliminates the possibility that the results were the product of sensitization.

EXPERIMENT I

Subjects

Two male *Betta splendens* (Fish 1 and 2), 5.0 and 5.5 cm long, were purchased from a local aquarium supplier.

Apparatus

A red stimulus light was presented for 10 sec before and overlapping with a 15-sec mirror presentation along one wall of an aquarium tank. Two compartments, each enclosing two 100-w light bulbs, were placed 14 cm apart, allowing just enough space for the aquarium tank (12 by 25 by 23 cm) between the compartments (Fig. 1). The compartment walls adjacent to the aquarium were translucent onionskin paper, one of which was covered by a one-way mirror.

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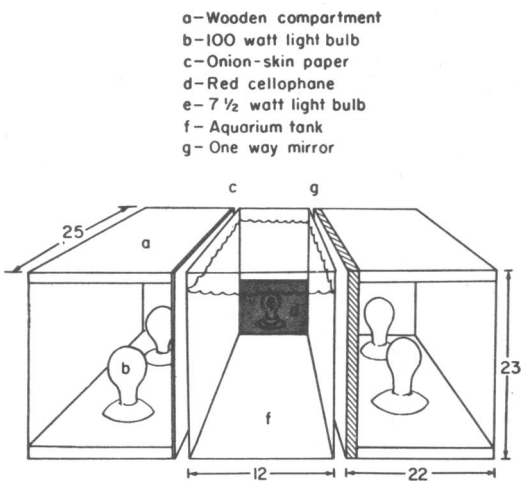

Fig. 1. Observer's view of apparatus for classically conditioning aggressive display in *Betta splendens*.

Turning off the light behind the one-way mirror and turning on the light on the opposite side of the tank made the mirror highly reflective. Reversing the illumination terminated the mirror effect. A 7½-w bulb behind a sheet of red cellophane stretched across the end of the tank (12 by 12 cm), illuminated the tank interior with bright-red light during conditioned stimulus presentation. Behavior was observed through the opposite end of the tank. Red light and mirror presentation were programmed by automatic electronic switching and timing devices. Data were recorded by observing the four display components during red-light presentation.

Procedure

Each fish was tested daily for 10 trials programmed at random intervals varying from 30 to 240 sec, with a mean intertrial time of 120 sec. This aperiodic intertrial procedure was used to minimize development of temporal discrimination. Because aggressive display occurred occasionally in the absence of an eliciting stimulus, immediately after the home tank was moved, the home tank was transferred to the test apparatus 10 min before each session. The observer sat at the end of the tank and recorded the occurrence or nonoccurrence of the display for each trial on standard score sheets. The four following components could be distinguished: (1) frontal approach to the mirror and/or red stimulus light, (2) fin erection, (3) gill-cover erection, and (4) undulating movements (described in detail by Forselius, 1957).

Figure 2 presents four photographic views of a male *Betta* illustrating the four aggressive display components. Figure 2A shows the subject in frontal approach with the gill covers erected (GE). Figures 2B and 2C illustrate the undulating swimming movements, in which the fish first orients its head toward the opponent with its body curved slightly away (2B) then bends its body in the opposite direction with a rapid thrust of the tail (2C). Figure 2C also shows the gill covers erected, revealing the bright red gill membranes. The maximum fin erection as well as gill erection can be seen in Fig. 2D.

Two adaptation sessions of 10 trials each were run in which the red CS light, but not the mirror, was presented to establish that the light alone did not elicit display behavior. Conditioning was continued on this schedule using a 15-sec mirror presentation until the four components occurred on each of 10 consecutive trials in the presence of the CS. In extinction, the one-way mirror was removed, and the illumination changes occurred as before. Since illumination changes accompanied mirror presentation, it would not be adequate to discontinue mirror presentation by no longer switching the lights during extinction. Illumination changes may have become a CS for the conditioned response. Thus, in extinction the CS (red light) was presented and followed by illumination changes, but no mirror presentation. To control light intensity, the mirror was replaced by additional onionskin sheets until the light intensity of the two sides, as measured by a light meter, were equal. This procedure was continued until 10 consecutive trials without any occurrences of the four components had elapsed.

Results

Figure 3 presents the number of occurrences of each of the four aggressive display components during each block of 10 trials. During the adaptation sessions, neither fish displayed aggressively in the presence of the red light. Fin erection was clearly the most rapidly acquired response, while frontal approach required the greatest number of trials to reach criterion. There appears to be little difference between acquisition rates of undulating movements and gill-cover erection for Fish 1, while

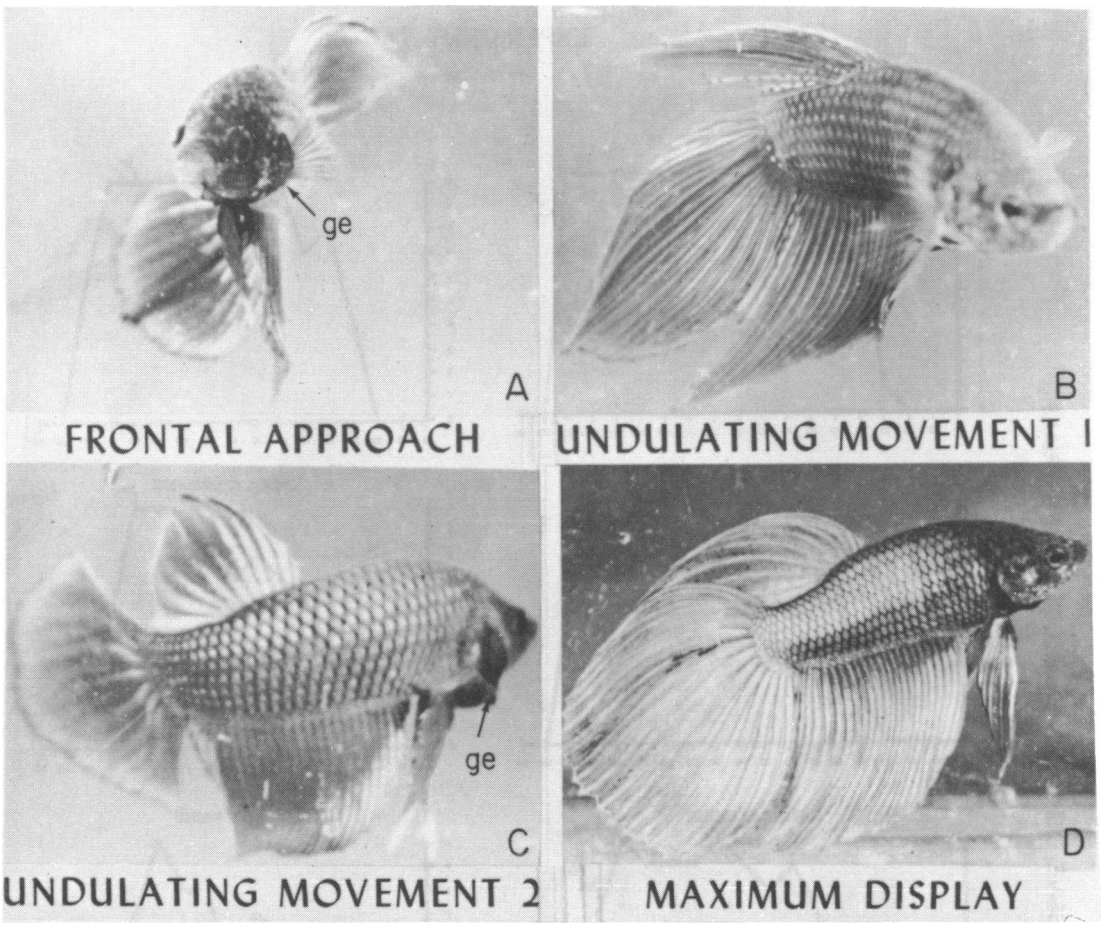

Fig. 2. Four photographic views of a single male *Betta splendens* illustrating four components of the complex aggressive display sequence from different observational positions. A. Frontal approach viewed head-on, revealing fin erection and gill erection (GE). B. and C. Two successive views of the fish exhibiting rapidly undulating body movements. D. The maximum display in frontal approach viewed laterally. Notice that all fins and the gill covers are erected.

Fish 2 acquired undulating movements more rapidly than gill-cover erection. Extinction of all four responses required 30 to 40 trials for both fish.

The regularity of the accelerated acquisition curves is much more apparent in the cumulated data in Fig. 4 and comparisons among the four components is facilitated. The marked difference in acquisition rates of fin erection and frontal approach for Fish 1 can be seen in relation to the very similar functions for undulating movements and gill-cover erection. By contrast, the four acquisition curves for Fish 2 are more clearly separated. Extinction of all four responses required from 30 to 40 trials for both fish, but the form of extinction curves is clarified when expressed cumulatively. The precipitous drop in number of displays per block of 10 trials during extinction seen in Fig. 3 obscures the orderliness of the process. Figure 4 reveals that extinction of each conditioned response is the reverse of the conditioning process, rather than a sharply defined new process as might be concluded from Fig. 3.

EXPERIMENT II

The results of the first experiment indicate that four components of the unconditioned aggressive display of male *Bettas* can be elicited by a previously neutral stimulus light due to classical conditioning. The possibility remains, however, that these conditioned responses may

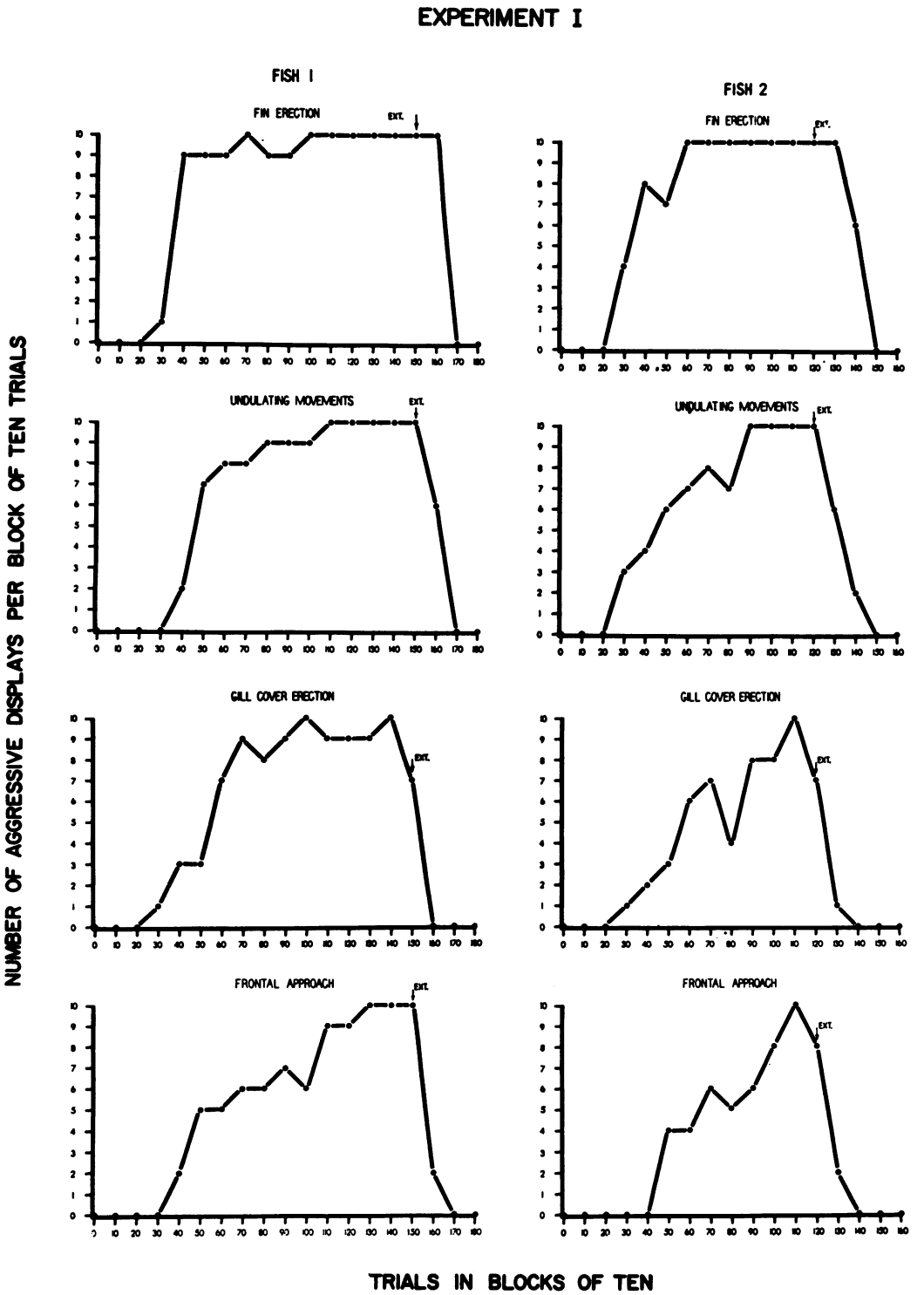

Fig. 3. The number of occurrences of each of the four aggressive display components during each successive block of 10 trials exhibited by Fish 1 and 2 during Exp I. Extinction began at the arrow (Ext).

be partly the product of sensitization. Through repeated presentation of the unconditioned stimulus (the mirror) within this environment, novel or similar stimuli may be capable of eliciting the aggressive display behaviors. To eliminate this possibility, a positive conditioned stimulus light was repeatedly paired with mirror presentation while a negative conditioned stimulus light was repeatedly presented alone. If the aggressive display behaviors occurred in the presence of the positive CS, and not the negative CS, the results must reflect discriminative classical conditioning rather than sensitization.

Subjects

Two experimentally naive male *Bettas* (Fish 3 and 4), measuring 5.0 and 6.0 cm were used.

Apparatus

The equipment used in the first experiment was employed. In addition, a piece of green cellophane was placed above the red cellophane, and a second 7½ w bulb was situated behind the green cellophane window. Either light could be presented, thus brightly illuminating the interior of the tank with one or the other color.

Procedure

Fish 3 and 4 were tested daily for 20 trials: 10 green light presentations followed by the mirror, and 10 with the red light presented alone. Thus, the green light was the positive and the red light was the negative conditioned stimulus. The intertrial interval varied from 30 to 240 sec, with a mean intertrial time of 120 sec. The randomized presentation of the two stimulus lights was arranged using the Gellerman series (1933). As in the first experiment, the home tank was transferred to the test apparatus 10 min before the first trial began, and responses were recorded on standardized score sheets. Extinction was conducted by presenting the green light for 10 sec, but no longer following it by mirror presentation. During this procedure the one-way glass was left in place. This contrasted with the extinction procedure of Exp I, in which the illumination changes associated with mirror presentation also occurred during extinction. The procedure in Exp II controlled for the possibility that the mirror may produce slight reflectance during CS presentation capable of eliciting the unconditioned response. The criteria for acquisition and extinction were the same as those used in Exp I.

Results

Figure 5 presents the number of occurrences of the four aggressive display components in the presence of the positive CS and the negative CS during each block of 10 trials. With the exception of one fin erection by Fish 4 in the presence of both the positive and negative CS, no responses occurred during the 20 adaptation trials. Fin erection and undulating movements were the first two components to

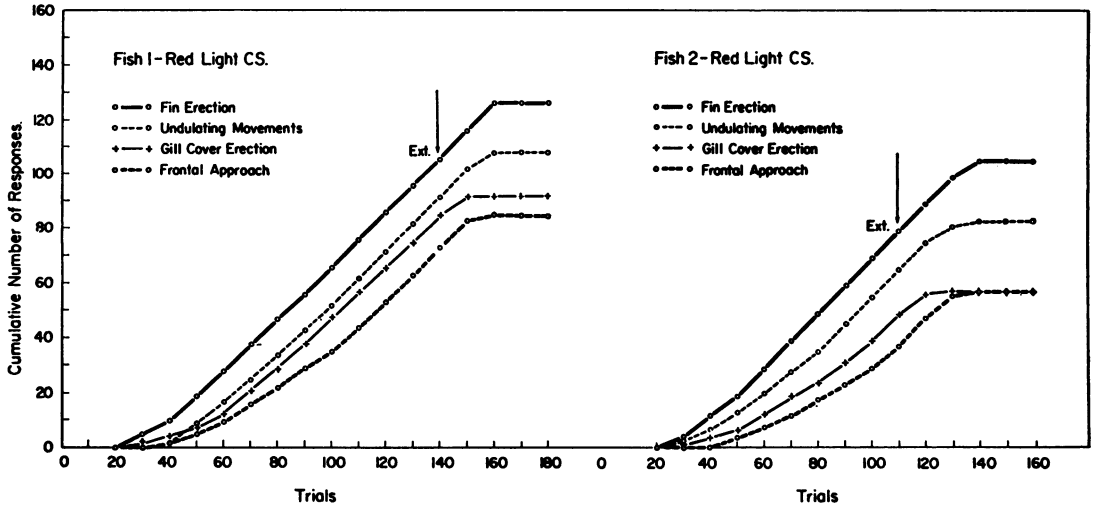

Fig. 4. The cumulative number of displays exhibited by Fish 1 and 2 during Exp I. Extinction began at the arrow (Ext).

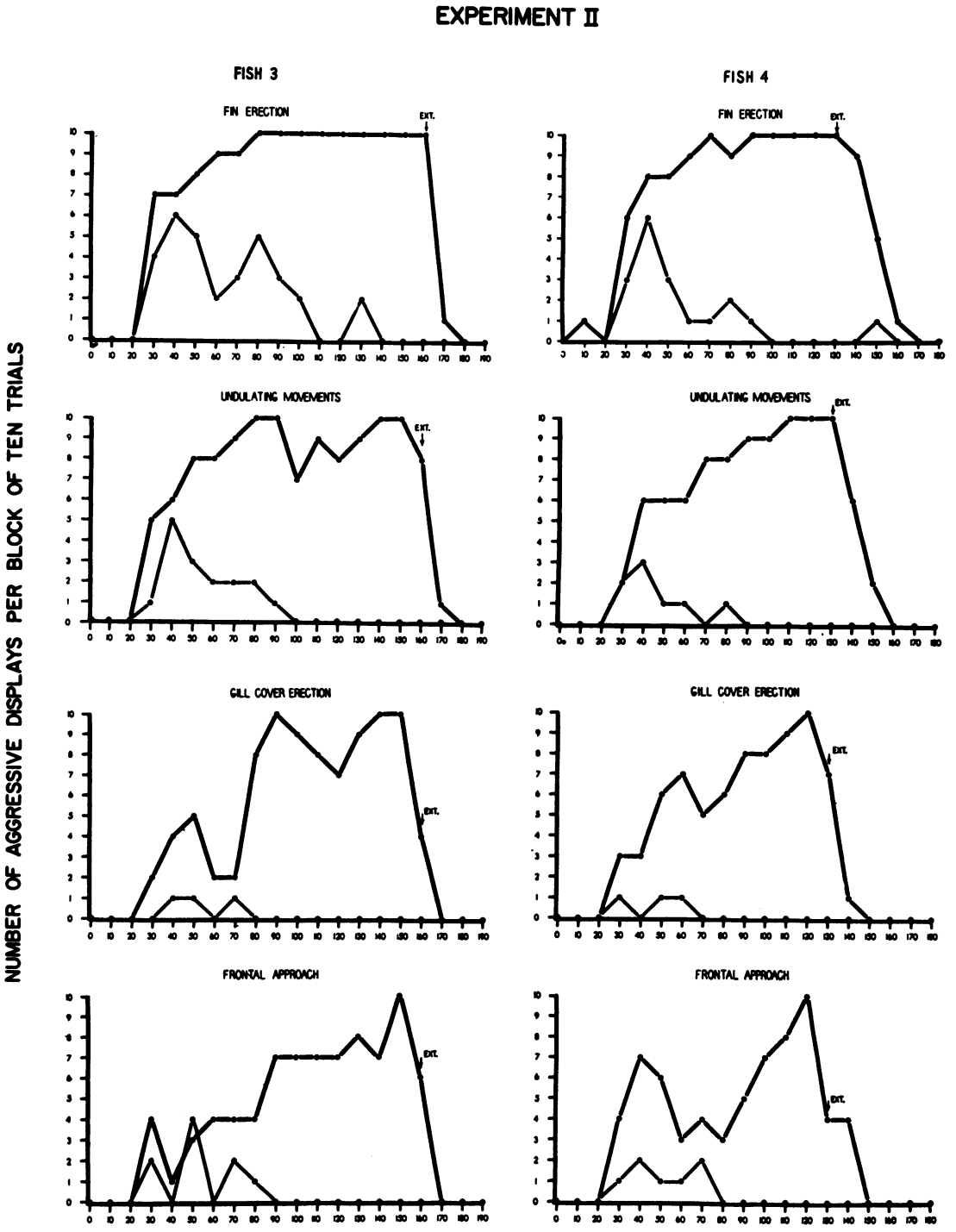

Fig. 5. The number of occurrences of each of the four aggressive display components during each block of 10 trials by Fish 3 and 4 in Exp II. The upper dark line is the record of displays in the presence of the green light (the positive CS) and the lower lighter line indicates the number of displays elicited by the red light (negative CS). Extinction began at the arrow (Ext).

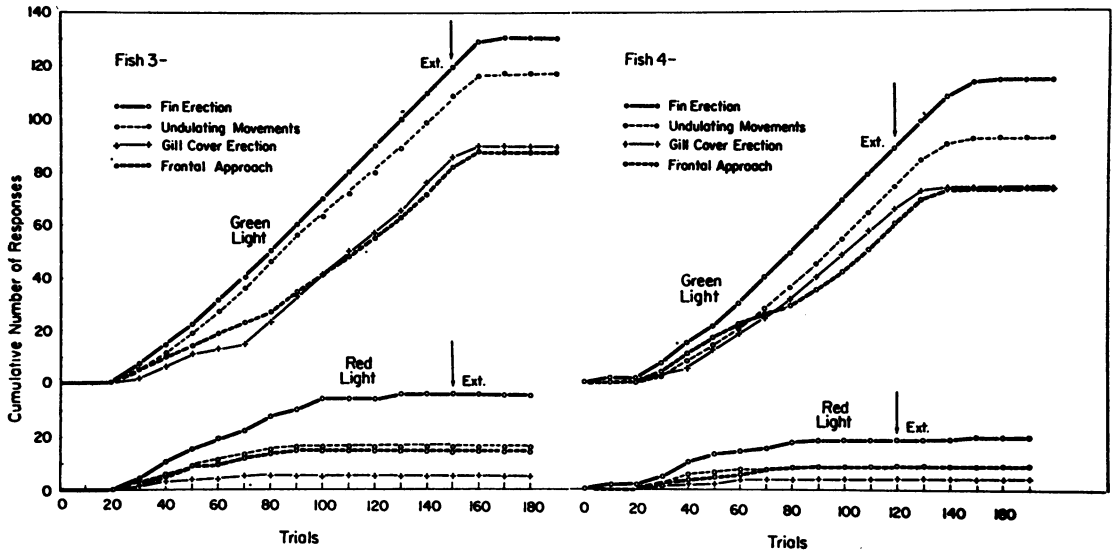

Fig. 6. The cumulative number of displays exhibited by Fish 3 and 4 during Exp II. Extinction began at the arrow (Ext).

be acquired by both fish, whereas gill-cover erection and frontal approach were the last two. In the last 10 trials in which all four components were elicited by every green light presentation (the conditioning criterion), no responses were elicited by the red light. From 20 to 50 trials were required for the four components to reach the extinction criterion of 10 consecutive trials without any display occurrences.

These relationships are clearer when presented as the cumulative number of displays for each component, as in Fig. 6. The difference in rate of acquisition of fin erection and undulating movements as opposed to gill-cover erection and frontal approach, is marked. A comparison of the slopes of the cumulative extinction curves (Fig. 6) reveals considerable differences in the rates of extinction, which is not apparent from examining the number of displays per block of 10 trials (Fig. 5). Gill-cover erection and frontal approach extinguished most rapidly as revealed by their lesser slopes. The cumulative curves for all components paired with the green light were positively accelerated while the curves for responses elicited by the red light were negatively accelerated.

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