Preliminary analyses indicated that responsiveness to patterning was not influenced by sex or by age; hence these factors were combined for testing the main effect of degree of hue difference on preference for pattern. The most apparent finding from the data in Table 2 is that pattern information provided by hue differences readily elicits the infant's natural preference for patterned over plain targets. The most disparate hue combinations, such as red-green or red-blue, elicit differential fixation as strong and as reliable as any found in infants for patterned over plain targets (*3*). Table 2 also shows that the greater the difference in the hues making up a checkerboard, the stronger is the preference for pattern. This is reflected in a large and highly significant Kendall rank correlation coefficient of .82 ($z = 3.71$, $N = 12$, $P < .001$) between the differences $X_1 - X_2$ and the percentages of total fixation to patterned targets. In contrast, a Kendall rank correlation coefficient of .01 between pattern preferences and physical intensity differences rules out an interpretation on the basis of within-pattern differences in physical intensity.

In short, infants are capable of discriminating on the basis of hue by 4 to 6 months. The greater the disparity in hue, the more easily is it discriminated. Perhaps more important is the method used to obtain these results. Selective attention to patterned stimuli is a basic visual preference demonstrated even in newborn infants. Hence, it should be possible to test the detection of patterning based on hue discrimination from birth and to observe the early development of color preception. In a more practical vein, it should also be possible to detect early deficiencies in color vision.

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8. Physical intensity values were estimated from a thermopile, with illumination from a 40-watt incandescent light source and readings, in microvolts, taken from a Keifhley model 149 millimicrovolt meter.
9. The Munsell samples also varied in terms of tristimulus value *Z*, or saturation. Analyses showed that the variations in *Z* bore no reliable relation to obtained preferences. This does not imply that larger variations in saturation, with hue and brightness controlled, cannot be discriminated by the infant. Discrimination of saturation remains an interesting and testable problem.
10. A sample of 28 infants at 23 weeks and 20 at 15 weeks were tested on 5 Red–5 Green, 5 Red–5 Blue, and 5 Green–5 Blue. Tests with 5 Yellow Red–10 Green and 5 Purple Blue–5 Red, and tests with 5 Purple Blue–5 Blue and 5 Yellow Red–5 Red, were given to 28 infants at 23 weeks. Twenty 23-week-old infants were given 5 Red–10 Red, 5 Green–10 Green, and 5 Blue–10 Blue. Simultaneous observations by two observers using the technique described by S. B. Miranda [*J. Exp. Child Psychol.* **10**, 189 (1970)] were made of 11 infants at 23 weeks and 13 infants at 15 weeks on tests of 10 Red–10 Green, and of 9 infants at 23 weeks on 2.5 Green–7.5 Green. The two observers were in good agreement on percentage of differential fixation, with means of 84.1 and 85.2 percent (Pearson correlation coefficient $r = .95$) for the 24 infants tested on 10 Red–10 Green and 49.9 and 49.4 percent (Pearson correlation coefficient $r = .98$) for the 9 infants given 2.5 Green–7.5 Green.
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Inhibition of Neighboring Motoneurons in Conscious Control of Single Spinal Motoneurons

Abstract. *Multiple fine-wire electrodes were implanted in the biceps brachii of five subjects, and artificial electronic feedback was provided to subjects from only one electrode. By this technique, it was shown that neighboring units progressively stop firing as subjects concentrate on activating an isolated unit. The inhibition of neighboring spinal motoneurons in the same pool further indicates that selective inhibition is an automatic part of single motor-unit training.*

Although single motor-unit training is now widely employed (*1*), some disagreement exists as to the degree of isolation achieved. Basmajian and Simard reported inhibition of adjacent muscles (*2*), and the immediately surrounding units monitored from the same electrode are rapidly inhibited. In an effort to study motor units some distance away in the same muscle which are not monitored by the subject on the feedback apparatus, we designed a simple multiple-electrode carrier that provided feedback to the experimenter from three sites but to the subject from only the middle site.

The subjects were five volunteers ranging in age from 14 to 30 years (three female, two male). None had previous experience in training a single motor unit, although all were familiar with the technique.

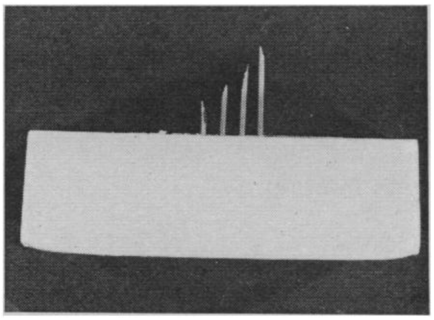

Fig. 1. Carrier block with four hollow channels of varied length for inserting electrodes (only three channels were normally used for these experiments).

The arrangement of the apparatus, including insertion of bipolar fine-wire electrodes, source followers, cathode-ray oscilloscope, monitor oscilloscope, loudspeaker, audio amplifier, and FM tape recorder, has been described (*3*). A unique carrier was devised to implant multiple electrodes at fixed depths and distances apart. In a rectangular Silastic block (17.5 by 59 by 30 mm), three 21-gauge needles were inserted 3 mm apart along the same plane (Fig. 1). These needles were sheared off so that one end of each was flush with one surface of the Silastic while the other ends protruded from the opposite surface 6.5, 9.5, and 12.5 mm, respectively.

We gave each subject a brief general explanation of the purpose of the experiment with emphasis on his task: to isolate the discrete activity of and to control successively three different single motor units registered from one electrode. He was comfortably seated in a suitable chair, with the carrier taped to his arm approximately parallel to the belly of the left biceps brachii. We then implanted electrodes by introducing a sterile 50-mm 25-gauge needle containing the electrode (*3*) as far as possible through each of the three carrier needles into the biceps. Three bipolar fine-wire electrodes were thus placed 3 mm apart in a plane orthogonal to the muscle fibers at depths of 26 mm (No. 1), 23 mm (No. 2), and 20 mm (No. 3). Appropriate connections gave the subject both audio and visual feedback from the middle electrode (No. 2) via a loudspeaker and monitor oscilloscope. Activity from all three electrodes was observed by the experimenter and recorded on magnetic tape.

The subject was instructed to select a single motor unit from among those registered from electrode No. 2 and to isolate this unit. Once he isolated a unit, he was asked to demonstrate control of it by varying its rate of discharge and then by repeating simple three-beat rhythms. Upon achieving these criteria, the subject was asked to isolate and train a second, and then a third, motor unit in the same manner. The FM tape recording from all electrodes provided permanent records for later analysis.

Although there was considerable variation, all subjects met the usual criteria of control for at least one single motor unit. During the course of selecting, isolating, and controlling the unit on electrode No. 2, three different patterns of response were recorded from the adjacent electrodes (Nos. 1 and 3): (i) random firing of neighboring motor units, (ii) electrical silence, and (iii) cross talk from the unit being trained. (Cross talk was identified by establishing a strict one-to-one correspondence between frequency of the unit being trained and that of the activity recorded from electrode Nos. 1 or 3.) As a rule, random firing of neighboring units recorded from electrode Nos. 1 and 3 decreased as the subject gained more precise control of the trained unit. When there was a high degree of control over a trained unit on No. 2 (ability to vary the rate easily without breakthrough of unwanted units), electrical silence on electrode Nos. 1 and 3 was shown in four of five subjects.

In the one subject for whom this silence was not found, random activity on electrode Nos. 1 and 3 decreased markedly as she achieved more control over the unit on No. 2. An exception to this relationship between control of a unit and silence of its neighbors occurred when subjects attempted to produce three-beat rhythms. Often there was a short burst of activity on electrode Nos. 1 and 3 as the subject initially attempted to discharge a trained unit in No. 2 with the designated cadence. Also, even when the unit was well controlled, firing it at high frequency was generally associated with some activity on electrode Nos. 1 and 3.

We conclude that as a single motor unit in the biceps brachii is trained with biofeedback techniques, the neighboring motor units show a progressive tendency toward electrical silence, even though the subject has no artificial feedback from them. This demonstrates the natural progressive inhibition of surrounding portions of the muscle in which a single unit is being selectively trained. This inhibition is similar to what occurs in surrounding muscles (*2*). These results suggest that the individual members of a motoneuronal pool can be selectively activated without activation of immediate neighbors in the same pool.

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Linearized Heat Transfer Relations in Biology

Kleiber (*1, 2*), Strunk (*3*), and Tracy (*4*) have commented on the nomenclature, uses, and misuses of various linear heat transfer relations in biology, with particular reference to Newton's "law" of cooling and Fourier's law of conduction. These papers reflect the increasing realization within the biological community that the problems of thermoregulatory physiology and ecology are best approached with the proper use of heat transfer relations developed in physics and engineering. Human physiologists have used this approach for some time (*5*), and more recently heat transfer theory has been applied to more general problems in botany and zoology (*6, 7*).

The recent papers (*1–4*) in *Science* are a positive contribution in calling some of this work to the attention of a wider audience. However, we consider that Kleiber (*1, 2*) and Strunk (*3*) have added to the confusion in the use of the various heat transfer relations.

First, Strunk neglects radiative heat transfer. His equation 1

$$dQ/dt = h_c A (T_s - T_a) \qquad (1)$$

gives the rate of heat transfer dQ/dt from an animal of area A and surface temperature T_s to an "ambient" temperature T_a (apparently air temperature), where h_c is the "convective surface conductance" [apparently (*7*) the convection coefficient]. However, heat is also transferred to and from an animal by thermal radiation, and often conduction to the substrate is significant. Total heat transfer can be expressed in the simple form of Eq. 1 only if substrate conduction is negligible; h_c is replaced by the overall heat transfer coefficient $h = h_c + h_r$, where h_r is the linearized radiation coefficient; and the radiative temperature of the environment T_r is equal to air temperature T_a. Even with these corrections, Eq. 1 only approximates dQ/dt since radiative heat transfer is nonlinear. The Stefan-Boltzmann law for radiative heat transfer in a uniform radiative environment

$$dQ_r/dt = F\sigma A (T_s^4 - T_r^4) \qquad (2)$$

depends on the fourth power of the temperatures; σ is the Stefan-Boltzmann constant, and F is a factor to correct for shape and surface emissivities less than 1 (*8*, pp. 216–229). Equation 2 may be approximated by a linear relation (*8*, p. 230), but is accurate only for small (10° to 20°K) temperature differences $T_s - T_r$.

Radiative heat transfer is not negligible relative to convective heat transfer, as may be seen by approximating an animal by a black cylinder in a black cavity with $T_r = T_a$ and comparing h_c with h_r. For typical cases, radiation accounts for 15 to 80 percent of the total heat transfer, even when published values (*8*, p. 411) for the convection coefficient are increased by 50 percent to include turbulence effects (*8*, p. 412; *9*). We comment on Strunk's (*3, 7*) work in more detail elsewhere (*10*).