as a function of the age of the observer. On this plot, a correct size match would fall on the horizontal line representing 20 inches, the size of the overhead disk. It can be seen that all subjects underestimated the overhead disk and that the amount of underestimation is a function of the age of the subject. The youngest children demonstrate an underestimation of about 50 percent, this value decreasing with increasing age to about 16 percent for the adult subjects.

These data were corroborated by the indoor experiment in which 10 children and 10 adults participated. The adults underestimated the overhead disk by 19.1 percent, and the children, who ranged in age from 5 to 8 years, by 32 percent. In both experiments the data for the adults are comparable to those obtained by Schur. In addition, the effect is seen here to be related to the age of the subject, the diminution in apparent size of the overhead disk increasing with decreasing age of the observer.

It is our interpretation that these results can be related to normal perceptual processes as indeed must be the case for all illusions. Since the moon illusion is a special case of the perception of size, any explanation of this effect must be in terms of the processes which generally subserve size perception.

It is a remarkable achievement of the human visual system that the apparent size of objects tends to be perceived correctly despite extensive changes in the dimensions of the corresponding retinal image resulting from variation in viewing distance. Although the mechanisms underlying this biologically important phenomenon, referred to in the psychological literature as size "constancy," have not been completely identified (*3*), the effects are clear. Size constancy results from a "correction" such that the greater the viewing distance for an object subtending the same visual angle—that is, producing the same sized retinal image, the larger the object will appear (*4*). The ability to make this correction for objects located near to the observer is good for both adults and children so that, for a given retinal image size, perceived size is proportional to distance. However, as the observation distance is increased, this correction is no longer complete, and especially so the younger the subject. Presumably the ability to make a size correction for distantly viewed objects depends on experience (*5*).

Such results for size perception in general suggest that the moon illusion may be a consequence of the fact that human beings have more experience with objects in the horizontal than in the vertical plane, and thus make a larger size correction for an object subtending the same visual angle—for example, the moon—when viewed horizontally. Since children have less experience with distantly viewed objects, especially when viewed directly overhead, the magnitude of the moon illusion is greater the younger the observer. Thus the moon illusion is interpreted as resulting from a normal developmental process, namely the dependence of the magnitude of the size constancy correction on experience (*6*).

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Self-Regulation of Brain-Stimulating Current Intensity in the Rat

Abstract. A modification of the self-stimulation technique of Olds enabled rats to regulate and maintain at a preferred level the amount of brain-stimulating current they received as reinforcement for lever pressing. The method used two levers to deliver brief brain shocks: each response at one lever increased the current intensity a small step and each response at the other lowered it one step.

It is well established that animals will work to stimulate certain portions of the brain electrically (*1*). This self-stimulation technique has considerable promise as a tool for investigating the central nervous system actions of many variables. Olds has reported, for example, that food deprivation, castration, or drugs will selectively change the base-line rates of self-stimulation of particular brain structures (*2*).

The present report describes an elaboration of the self-stimulation technique in which animals are furnished with the means to regulate the amount of brain-stimulating current they receive as reinforcement. The new method thus permits a continuous determination of the preferred intensity of stimulation, and at the same time gives the rate of self-stimulation as before (*3*).

The animals were trained in a small, sound-resistant box with two levers in one wall. Operations of either lever delivered brief brain shocks. A two-way stepping relay provided 24 equal current steps (from 0 to approximately 50 ma, depending on the electrode impedance) by introducing appropriate resistances into the stimulating circuit. Responses at one lever drove the stepper forward, producing brain shock reinforcements of increasing intensity, and responses at the other stepped it back, decreasing the intensity. Any current level, once established, could be maintained by alternating responses between the levers.

Continuous records of the amount of current selected were drawn by a recording potentiometer whose input voltage was controlled by the two-way relay through an auxiliary bank of resistances (*4*). A cumulative response recorder and impulse counters simultaneously provided records of the self-stimulation rate.

The stimulating current was supplied from a pulse-pair generator similar to that described by Lilly *et al.* (*5*). The relatively noninjurious wave form had positive and negative peaks each 50 μsec in duration and separated by 200 μsec. A brain-shock reward consisted of a train of pulse-pairs 50 to 100 cy/sec in frequency and fixed in duration at either 0.25 or 0.5 sec; the stepper could not be reoperated until a train was delivered. Optimal values of frequency and train duration varied for different animals and were selected experimentally.

The subjects were male albino rats with bipolar electrodes (0.01-in. platinum wires, twisted together and insulated except at the tips) permanently implanted in rhinencephalic, hypothalamic, and midbrain tegmentum sites (*6*). In preliminary training, the animals practiced conventional self-stimulation—either lever gave brain shocks of a fixed, moderately reinforcing intensity. After the self-stimulation rates had stabilized, the rats were required to alternate between the levers to obtain the fixed-intensity electrical stimulus (one 2-hour session).

Training in regulating the current followed on the next day. Most animals learned readily how to control the intensity of the stimulation, and variability decreased rapidly with practice. Assistance from the experimenter early in training—for example, raising the current when it was driven down and held at zero, or lowering it when punishing or convulsive levels were approached—greatly facilitated the process.

Sample records of several consecutive hours of current regulation by two well-trained animals are shown in Fig. 1.

Five-minute periods of self-stimulation were alternated with 5-minute rest periods during which the stimulator and the box lights were turned off. Resetting the current to zero in the rest periods required the animals to recover the preferred intensity at the start of every stimulation period and provided a stringent test of regulating ability.

Current regulation may be observed to be good in both cases, although the levels selected tended to rise somewhat during the experimental sessions. Both the amount of current preferred and the width of the self-selected intensity band were stable for many weeks and, after sufficient "warm-up," even following long breaks in training (*7*).

The self-selected intensity level was always well above the reinforcing threshold; usually it was higher than most experimenters would care to assign under the conventional fixed-intensity procedure. Exaggerated and even violent motor activity was often produced by the intensities selected, and after a session of a few hours an animal generally was physically exhausted and wet with saliva.

The effect on intensity regulation of manipulating the frequency of the stimulating current for a rat with an electrode in the midbrain tegmentum is depicted in Fig. 2. Similar experiments with other animals employing a limited range of frequencies (25 to 150 cy/sec) indicate that increases in frequency lead to the selection of smaller intensities, and decreases in frequency lead to higher intensities. The fact that animals tend to compensate for frequency changes in one direction by selecting intensities in the opposite direction suggests that self-regulation is based on a preferred energy of stimulation.

Some of the neural mechanisms that may underlie current-regulating performance may be discussed briefly. Increasing the intensity of the stimulating current train has at least two important effects: (i) the probability or frequency of activation of neurons in the stimulating field is increased; and (ii) the effective stimulating field is enlarged to include new elements. On the assumption that animals will work to maximize the firing of positively reinforcing cell groups, it may be expected that, within physiological limits, the greater the current the better. That intermediate intensities are favored may be due, in part, to the spreading of stimulation with large currents to inhibitory or negatively reinforcing regions.

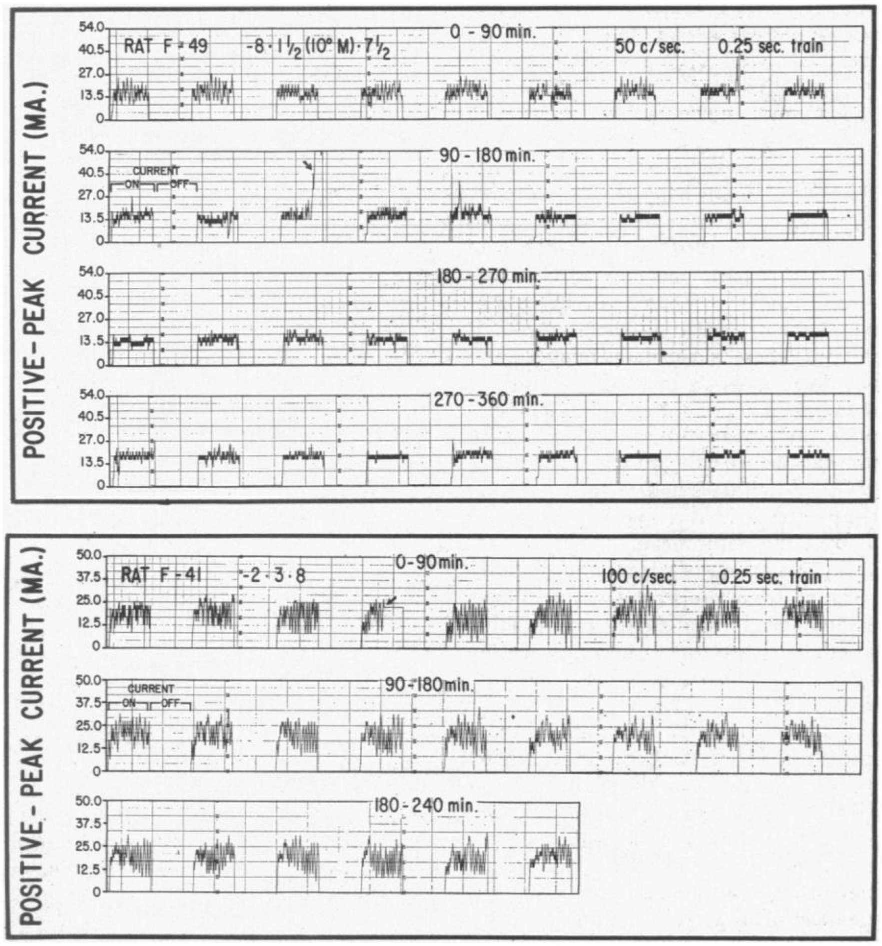

Fig. 1. Current intensities selected throughout an experimental session by two well-trained rats. (Top) Graph for rat F-49, with electrode in midbrain tegmentum. In the 90- to 180-min segment of the graph, the arrow marks an example of the current-maximizing behavior described in (*7*). (Bottom) Graph for rat F-41, with electrode in the lateral hypothalamus. The arrow in the 0- to 90-min segment of the graph indicates a period of no response during which the stimulating leads were untangled. The self-stimulation rates were quite constant throughout the sessions and averaged 34 per minute for rat F-49 and 42 per minute for rat F-41.

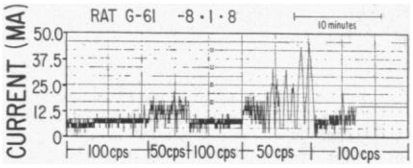

Fig. 2. Changes in the self-selected intensity level induced by manipulation of the frequency (pulse-pair repetition rate) of the stimulating wave form. The data at the end of the experiment are unreliable, owing to the physical exhaustion of the animal.

It follows from this that the amount of current selected to stimulate a positively reinforcing site will depend importantly on its proximity to negative cell groups. According to mapping studies of Olds (*2, 8*), negative reinforcing effects are localized caudally in the rat brain; hence, smaller currents should be selected to stimulate caudal rewarding sites (for example, hypothalamus and midbrain tegmentum) than rostral sites (for example, septum and cingulate cortex).

Preliminary findings suggest that this is the case. Electrodes in the region of the septum produced poor regulation—for the most part, the current was increased until convulsions occurred (*9*). Even more compelling evidence was provided by an animal (rat F-49) with both an anterior electrode in the cingulate cortex (just rostral to the septum) and a posterior electrode deep in the midbrain tegmentum. Cingulate performance consisted mainly of intensity increases to convulsion-producing levels (usually 40 to 50 ma), although at the tegmental site the animal self-regulated expertly (*10*).

It is anticipated that the self-regulation technique will be useful in a variety of situations. Some data have been collected already on the effects of drugs; and to suggest one other example, it seems feasible, by stimulating other brain sites during self-regulation in a particular structure, to obtain information concerning relations of facilitation and inhibition between central structures.

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7. The amount of rest between sequences of brain-stimulation, both during and between experimental sessions, appears to be a critical factor. Rat F-49, for example, on continuous tegmental self-regulation, typically maintained the preferred level of 13 to 15 ma for about 30 minutes, and then increased the current to the top step, keeping it there by working only the "up" lever. This current-maximizing behavior was practically eliminated by introducing the 5-minute on-off procedure and spacing experimental sessions 2 to 3 days apart. Keeping in mind the discussion at the end of the present paper, and assuming with Olds (*2*) that positive and negative cell groups are reciprocally inhibitory, one may conclude that these effects may reflect temporary increases in the thresholds of negatively reinforcing structures that are brought about by the intensive self-stimulation of the positive site and which dissipate in time when rest is permitted.
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Simple Method for Determining Potential Evapotranspiration from Temperature Data

Abstract. A value for the total amount of water that, theoretically, could be lost from soil and vegetation through evaporation and transpiration, if sufficient soil moisture were always available, may be obtained readily by multiplying a given time-period factor by the sum of time-unit means of positive centigrade temperatures divided by the number of time units in the period.

Potential evapotranspiration from areas of natural vegetation may be determined from temperature records alone by the use of the following formula:

$$\begin{matrix}\text{Potential}\\ \text{evapotrans-}\\ \text{piration}\\ \text{(in mm)}\end{matrix} = \left[58.93\left(\frac{\text{Unit period of time}}{\text{No. of units of time in 1 yr}}\right)\right] \times \left[\begin{matrix}\text{Comparative plant growth}\\ \text{mean temperature (°C)}\end{matrix}\right]$$

Solved values for the first bracket for periods of time normally used for determining potential evapotranspiration are as follows: 1 year, 58.93; month of 31 days, 5.00; month of 30 days, 4.84; month of 28 days, 4.52; and 1 day, 0.16. For leap years, monthly values would be: 31 days, 4.99; 30 days, 4.83; and 29 days, 4.67.

For tropical and subtropical regions (except at high elevations) for all periods, and for other regions for periods when temperatures do not drop below 0°C, mean temperatures, as usually recorded or published, are represented by the value within the second bracket. For periods of time which include recorded temperatures below 0°C, the comparative plant growth mean temperature must be obtained in a different manner. The latter mean temperature was utilized as one factor for determining plant formations or life zones in a chart published in 1947 (*1*), and is considered to be the mean temperature of greatest significance to vegetation, and to be directly comparable in terms of plant life with the mean at any other point on our planet. The comparative plant growth mean temperature equals the sum of the average positive temperatures in degrees centigrade per unit of time, divided by the total number of these units of time in the period of the mean.

Thus, the mean annual temperature to be utilized in the formula equals the sum of the mean monthly temperatures above 0°C divided by 12. The monthly mean equals the sum of the daily means above 0°C, divided by the number of days in that particular month. The daily mean equals the sum of the hourly means above 0°C, divided by 24. At stations where mean daily temperatures are determined as one-half the sum of the maximum and minimum temperatures, such means are satisfactory except for days when the minima are below 0°C; on such days half of the maximum temperature, if it is positive, may be used as the daily mean.

Determination of potential evapotranspiration from temperature values alone, without need for data on precipitation or other climatic factors, is possible because of the two following considerations.

1) The potential evapotranspiration rate at a given temperature decreases proportionately along the gradient of increasing precipitation from arid to wet areas, so that the product of the evapotranspiration rate and the mean annual precipitation is the same all along the gradient. This is reflected in the regularity of the pattern of changes in physiognomy between the single climatic plant associations of each of the formations along the precipitation gradient.

2) Local variations in edaphic and atmospheric factors sufficient to cause an appreciable change in either evaporation or transpiration, or in both, are counterbalanced by the different physiognomies of the natural vegetation, developed in the past through evolutionary processes, which bring the actual evapotranspiration into equilibrium with the potential evapotranspiration rate and the moisture available. These variations are reflected in the diversity of aspect and lack of regularity of the pattern of changes of the physiognomies of the (usually several) edaphic, atmospheric, and hydric associations of the same plant formations along the moisture gradient.

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Decrease in Threshold without Depolarization in Cyanide-Treated Muscle

Abstract. When smooth muscle of *Mytilus* is treated with relatively weak solutions of sodium cyanide, a transitory hyperpolarization or no change in polarization precedes final depolarization. Thresholds for thermal, chemical, and electrical stimulation are all decreased during this period. Strength-duration curves indicate a reversible decrease in threshold of about 50 percent during this period.

As an outgrowth of investigations into the nature of the mechanism of the cooling stimulus in smooth muscle of *Mytilus* (*1*), we decided to examine the relationship between inhibition of respiration by metabolic poisons and the effects of these

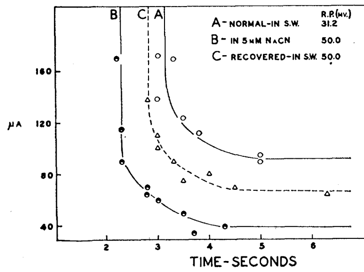

Fig. 1. Strength-duration curves for (A) normal *Mytilus* muscle in sea water; (B) the same muscle after treatment for 1 hour in 5m*M* NaCN; and (C) the same muscle subsequently allowed to recover for 1.5 hours in sea water (intensity of threshold square wave pulses in microamperes versus duration in seconds). The rheobase is decreased after treatment with cyanide, and this effect is partially reversible in sea water. The resting potential, which usually returned to the normal value after recovery in sea water, did not do so in this particular muscle, perhaps because of relatively long treatment with cyanide.