considered, a looped method of linkage gives to the system a sensitivity to changes in direction of approach such that transition from position 1 to position 2 implies a reversal in direction of impulses along the corresponding linear projection. On the other hand, a spiral arrangement gives the system a greater stability, in that the shape of the phrase does not depend on direction of approach. In both instances, should the array be approached in a direction normal to the plane of the paper, the result will be a reiterated pattern of single notes, since we are supposing that the same linkage pattern is repeated throughout the block.

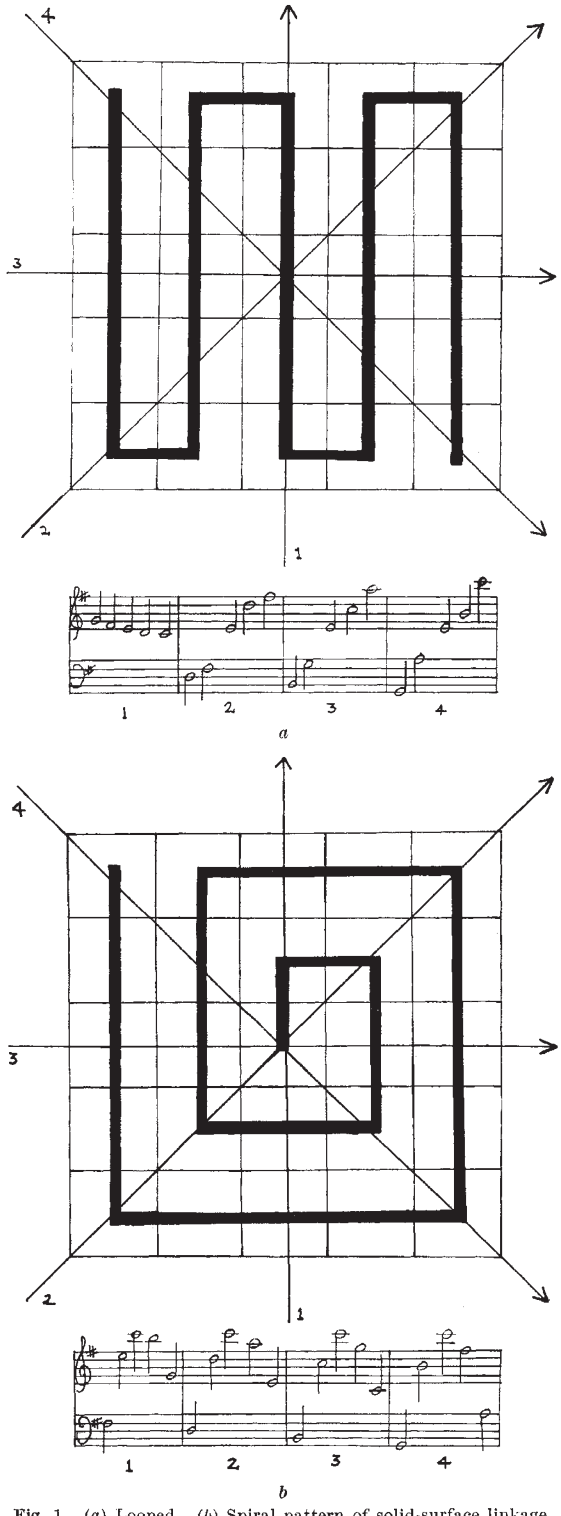

Fig. 1. (*a*) Looped. (*b*) Spiral pattern of solid-surface linkage. Each bar of music corresponds to the activation pattern obtained by scanning in the direction of the numbered arrow

The analysis of excitation patterns within neuronal arrays, the patterns depending on modes of linkage between elements of a solid and of a surface, would lead into relational mathematics, since we are dealing with *n*-dimensional manifolds. Musical notation, however, is a simple and universally understood system whereby changing linkage patterns may be expressed and examined in a manner which is potentially quantitative. We are provided here with a simple and unified means of depicting sequences of events that may take place in the sensory modalities —not necessarily auditory—and which are the physical basis of perception.

In a theoretical model such as is described, it is more convenient to regard L as constant and to allow θ to vary. In the central nervous system, however, where nerve centres are as a rule approached by bundles of afferent fibres running parallel to one single line of direction, values for θ would remain fixed, while L varied.

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Threshold Differentiation of Drive and Reward in the Olds Effect

According to Deutsch's theory[1], the Olds effect[2] of electrical self-stimulation is produced as a result of the concomitant simulation of both drive and reward pathways. If two such systems, one mediating drive and one reward, are indeed involved, the threshold stimulus intensities required to activate each might differ. If the drive system has a lower threshold than the reward system, then electrical stimulation of lesser intensity than that necessary to produce learning (where reward is also requisite) should prolong a habit which has already been learned, irrespective of the timing of the stimulation with respect to the performance of the habit. That is, the stimulation should prolong, say, bar-pressing, even if its administration is non-contingent on the act of pressing. If, on the other hand, such non-contingent stimulation is administered at an intensity above the threshold intensity necessary to produce learning, then a habit which the animal has already learned for intracranial stimulation should become weaker, since the animal will also be accidentally rewarded for other acts and so come to repeat these instead. Such learning of alternative habits should not occur when the non-contingent stimulation is of sub-threshold intensity for learning, and so there should be less interference with the original habit.

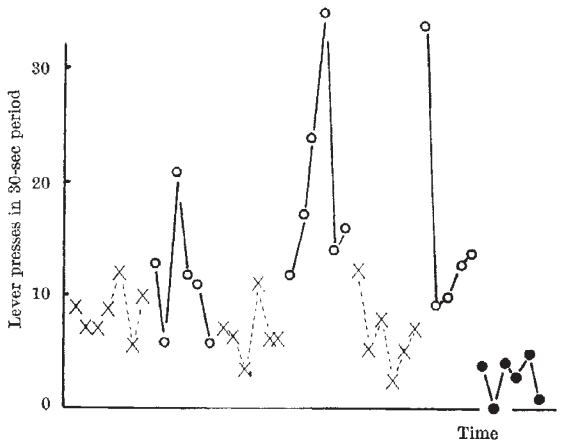

Fig. 1. Results of preliminary experiment on one animal. Crosses show the number of lever presses to extinction in successive 30-sec periods of normal extinction. Circles represent the number of lever presses in 30 sec of extinction during which a low intensity of repetitive stimulation was given, and solid circles show the same for 30-sec periods when full intensity repetitive stimulation was used

In a preliminary experiment, rats were trained to touch a lever for intracranial stimulation. The number of trials it took to 'extinction' when the current was switched off was recorded. Further, the number of trials to 'extinction' was also measured when the stimulating current was suddenly changed from the animal's own control to that of a pulse generator, adjusted to run roughly at the rate at which the animal was obtaining the stimulus through its own responding. In one condition the repetitious non-contingent pulse was at about half threshold strength (threshold strength being defined as that value necessary to produce learning and sustain performance); in the other the repetitious pulse was at threshold. The results of the first animal tested appear in Fig. 1. It is evident that a repetitious sub-threshold stimulus has a large effect on maintaining performance, whereas a threshold stimulus when administered in the same way actually produces a decrement.

Unfortunately such a design relies too much on the individual style of each animal. The animal emitting its responses with a metronome precision does not give the pulse generator a chance to reward it for anything but the response it has already learned. As the stimulus introduces drive also as well as reward, it was found that with other animals elevated rates of responding could be maintained as a superstition.

Consequently, the experiment was redesigned. We decided to compare the animals' response to non-contingent stimulation (delivered at roughly the same rate as its normal rate of responding) with its response to contingent stimulation, each under two conditions, (*a*) stimulus intensity below threshold for learning, and (*b*) stimulus intensity at threshold for learning. What interested us was comparing the two ratios 'contingent-threshold : non-contingent-threshold' and 'contingent-sub-threshold : non-contingent sub-threshold'. For we reasoned that if in the sub-threshold condition drive alone were introduced the animal would perform at least as well in the non-contingent as the contingent situation, since it would be unable to learn new interfering habits. However, in the threshold condition if reward were also introduced the animal should perform less well on the non-contingent than on the contingent condition, since it would quickly learn to perform new interfering habits.

As in the previous experiment, the animal was taught a bar-touching response. Each response triggered 1/10 sec train of 60 c.p.s. at the beginning and end of each response. The current was adjusted to the minimum necessary to produce and sustain learned behaviour. It was administered through an isolation transformer and a 200*K* series resistor.

In the first half of the experiment 1 min training trials were terminated alternately with 1 min periods during which the animal received either contingent sub-threshold stimulation or non-contingent sub-threshold stimulation. Of the eight tegmental animals used, five showing a good effect in the first condition were tested in the second. In the second half of the experiment, 1-min training trials were alternated with 1-min periods during which the animal received non-contingent threshold stimulation. The same threshold stimulation was used throughout the experiment in training and in the second half of the experiment in the non-contingent condition. The rate at which non-contingent stimulation was delivered was the same in the sub-threshold non-contingent and threshold non-contingent condition. Results are given in Table 1. Furthermore, in the 'sub-threshold condition' when cessation of responding occurs, no systematic reaction to the non-contingent stimulation can be detected. The animal sits, grooms, wanders around a little, but does not acquire any superstitious habits in spite of the ample opportunity it has to do so, as it spends a great deal of time away from the lever. This is in marked contrast with its behaviour in the non-contingent threshold situation, where any twitch or mannerism is amplified even while the animal is executing its old response and cyclic superstitious sequences of behaviour are soon established.

Table 1

Rat	Significance of difference between contingent low and non-contingent low	Ratio between contingent low and non-contingent low	Significance of difference between contingent high and non-contingent high	Ratio between contingent high and non-contingent high	μamp Low	μamp High
1	0·03	0·74	0·001	1·89	40	100
2	0·30	0·83	—	—	35	75
3	> 0·0001	0·31	0·20	1·13	100	175
4	0·025	0·53	> 0·0001	16·73	150	300
5	0·05*	1·56	—	—	100	225
6	0·14	0·67	—	—	55	100
7	0·02	0·74	> 0·0001	6·98	110	175
8	0·0005	0·50	> 0·0001	2·36	35	70

* Significant difference in direction opposite to predicted.

These results make it plausible to believe that in the areas from which self-stimulation is obtainable there are two closely adjacent or intermixed systems, one subserving functions of reward and the other producing drive, in the manner postulated by Deutsch's theory[1].

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