two-thirds submerged in water. This apparatus has been described (*2*, *6*). The rats were placed individually on separate wheels that rotated at a constant speed of 2 rev/min; the total distance traversed by an animal was approximately 0.7 mile (1.1 km) per 24-hour period. Sleep cycle was recorded with the same movement-sensing device that was used in the first experiment. Food and water were freely available in each cubicle.

Five animals were used at each of two deprivation levels (24 and 72 hours). The sleep-waking cycle was recorded for 3 days before and 5 days after the sleep-deprivation period. During the periods before and after deprivation the rats were in the same cages and enclosures that had been used in the first experiment; during the deprivation period they were on the treadmill. Deprivation on the treadmill was not maintained as long as deprivation from dextroamphetamine since previous studies have shown that animals, at the ages used, became exhausted between 72 and 120 hours on the treadmill (*6*).

The major findings of this experiment are identical with those of the first experiment. Sleep time temporarily increased after treadmill deprivation ($P < .001$ for a comparison of days 2 and 3 before deprivation with days 1 and 2 after deprivation) and had returned to normal by the end of the study (no significant difference between sleep time on days 1 to 3 before deprivation and days 3 to 5 after deprivation). Also, the duration of deprivation failed to significantly influence the amount of compensatory sleep obtained (Fig. 2). However, the amount of compensatory sleep obtained after treadmill deprivation is considerably less than that obtained after dextroamphetamine deprivation (21 percent of the debt incurred for the 24-hour group and 13 percent of the debt for the 72-hour group; see above for the comparable figures on drug deprivation).

The use of dextroamphetamine succeeded in almost completely eliminating sleep during the deprivation period. The major findings of this experiment are: (i) The drug-induced sleep deprivation resulted in a temporary compensatory increase in sleep time after discontinuing the drug; and (ii) increased sleep deprivation from 24 hours to 72 to 120 hours did not produce any significant change in the amount of compensatory sleep. These data suggest the conclusion that increasing sleep deprivation over 24 hours up to 120 hours does not result in an increased need for sleep above that present in the 24-hour sleep-deprivation group. A possible alternative to this conclusion is that, although the amount of sleep during deprivation is very small compared with the normal level, the sleep during a state of heightened need was "more valuable" in relieving that state than it is under normal drive conditions. An experiment that investigates the effect of small amounts of sleep, at various times during deprivation, should help to answer this question.

The results of treadmill-induced sleep deprivation are in agreement with results obtained with dextroamphetamine-induced deprivation. Deprivation resulted in a temporary increase in sleep, and the duration of deprivation failed to significantly influence the amount of compensatory sleep obtained.

The two major findings of this study are: (i) Sleep does act as a need state (compensation for lost sleep does occur); and (ii) increasing deprivation from 1 up to 5 days does not increase the total amount of compensatory sleep. The second finding may suggest that, within the deprivation range utilized, the sleep need became asymptotic at 24 hours and is consistent with anecdotal reports by humans that prolonged sleeplessness can be recovered from with minimal additional sleep.

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Qualitative versus Directional Cues in Two Forms of Differentiation

Abstract. *Dogs given opportunities to base their instrumental conditioned responses in differentiation learning on either the quality of the auditory conditioned stimulus (for example, metronome versus buzzer) or the direction of its source (in front or behind) choose different cues in different tasks. In $S_1 \rightarrow R_1$, $S_2 \rightarrow R_2$ (left leg–right leg) differentiation they exclusively use directional cues and are almost unable to learn this task when only quality cues are available. When confronted with Pavlovian $S+ \rightarrow R$, $S- \rightarrow$ no R (go–no go) differentiation, however, they generally learn on the basis of quality cues, although some animals also attend to the directional cues. Thus an animal's success or failure in a given differentiation procedure depends not only on its ability to discriminate the stimuli but also on the task with which it is confronted.*

Lawicka (*1*) has shown that, in a free-moving situation, success or failure of training in go left–go right differentiation or go–no go differentiation depends on the character of auditory cues used for the particular task. While for go left–go right differentiation the adequate cues are provided by auditory stimuli presented from *different directions*, for go–no go differentiation they are provided by stimuli of *different quality*. We have now further investigated the same problem, using a different technique.

We used 29 dogs in a Pavlovian soundproof conditioned-reflex (CR) chamber. An animal, placed on a stand, was given food by remote control from a feeder situated before him. An instrumental CR consisted in placing the left or right foreleg on the feeder in response to a conditioned stimulus (CS); intertrial intervals were about 1 minute.

In experiment 1, 11 dogs were trained to place their right forelegs on the feeder in response to the sound of a metronome situated in front of them (Ma) and to place there their left forelegs in response to a buzzer situated behind them (Bp). During training the two stimuli were presented randomly; 5 seconds after presentation of the stimulus the appropriate leg was passively placed on the feeder and food was immediately delivered. Passive placement was remotely controlled by a system of ropes and pulleys. After a few sessions the animals started to execute the trained movements actively in response to the CS's. If the response was correct, food was immediately presented; if incorrect, the CS was discontinued and food was not delivered. If a dog did not respond to 5 seconds of CS, it was prompted by a tug on the proper leg. Eight reinforced trials were given per session, each CS being presented four times in random order.

The task was mastered to a criterion of 80 consecutive correct responses in an average of 230 (range, 120 to 360) trials; these scores include the trials with passive movements. During each of the ten test sessions that followed, interspersed among the regular trials were two trials with (i) a buzzer presented in front of the animal (Ba) and (ii) a metronome presented behind it (Mp). In all trials either movement was reinforced by food. The results (Table 1) show that in eight dogs at least 90 percent of the responses were determined by the direction of the CS, with total neglect of its quality; that is, the metronome presented from behind evoked the same movement as the buzzer from behind, while the buzzer presented in front evoked the same movement as the metronome in front. In three other dogs the responses were mixed. In no dog, however, did the quality cue prevail over the directional cue.

Table 1. Results of test trials in $S_1 \rightarrow R_1$, $S_2 \rightarrow R_2$ differentiation with 11 dogs, in which the metronome was shifted behind (Mp) and the buzzer in front of (Ba) the animals.

Responses (No.)					
Mp			Ba		
To quality (M)	To direction (p)	None	To quality (B)	To direction (a)	None
0	9	1	0	10	0
0	10	0	0	10	0
1	8	1	0	10	0
0	10	0	0	10	0
0	10	0	1	9	0
0	10	0	0	10	0
0	10	0	2	8	0
5	5	0	1	9	0
2	8	0	2	8	0
0	10	0	0	10	0
4	1	5	0	10	0
Totals (%)					
10.9	82.7	6.4	5.5	94.5	0

Table 2. Results of test trials in $S_1 \rightarrow R$, $S_2 \rightarrow$ no R differentiation with ten dogs. Symbols B, buzzer; M, metronome; T_1, 900-cy/sec tone; T_2, 600-cy/sec tone; a, presented in front; p, presented behind.

CS+	Reverse location	Responses (No.) to Quality	Responses (No.) to Direction	CS−	Reverse location	Responses (No.) to Quality	Responses (No.) to Direction
Ba	Bp	0	10	Mp	Ma	10	0
Ba	Bp	3	7	Mp	Ma	9	1
Ba	Bp	9	1	Mp	Ma	10	0
Bp	Ba	4	6	Ma	Mp	10	0
Bp	Ba	10	0	Ma	Mp	10	0
Bp	Ba	7	3	Ma	Mp	10	0
T_1a	T_1p	9	1	T_2p	T_2a	10	0
T_1a	T_1p	8	2	T_2p	T_2a	0	10
T_1p	T_1a	10	0	T_2a	T_2p	10	0
T_1p	T_1a	10	0	T_2a	T_2p	10	0
Totals (%)							
		70	30			89	11

Further evidence indicating the significance of the directional cues for right leg–left leg differentiation is provided by the results of a control procedure. Six dogs were similarly trained except that both CS's sounded from the same point in front of the animal, so that the directional cue was absent; three of them eventually mastered the task after 1000 to 1500 trials, while the other three could not learn even after longer training. In all six dogs symptoms of neurosis developed from time to time. In contrast, when two CS's of different modalities (visual versus auditory) were presented in front of two dogs, the task of right leg–left leg differentiation was quickly learned within about 250 trials.

In experiment 2, ten dogs were trained in go–no go differentiation, the instrumental response being movement of the right foreleg. Response by this movement to the positive CS was always reinforced by food, while the negative CS never brought food. Either the buzzer or a 900-cy/sec tone was the positive CS, while the metronome or a 600-cy/sec tone was the negative CS. For five dogs the positive CS was in front of the animal and the negative one was behind; for the other five these positions were reversed. The dogs learned the buzzer-metronome differentiation almost immediately; the high tone–low tone differentiation required a few hundred trials.

When the animals were responding correctly in 100 percent of the trials, 20 test trials were given in the same way as in experiment 1—but always without reinforcement, so as not to teach the animal to respond with the movement to the new stimulus combination. The results (Table 2) show that for every dog but one the negative CS placed in the position of the positive CS completely preserved its negative significance—that is, the animals never performed the taught movement in response to it. As for the positive CS placed in the position of the negative CS, it maintained its positive significance in the majority of trials with seven dogs, while negative responses prevailed in three dogs. In all, the animals reacted according to the quality of the CS in 80 percent of the trials and to the direction of the CS in only 20 percent.

So, as Lawicka discovered, animals trained in a differentiation procedure requiring two different instrumental responses to two auditory stimuli mainly use directional cues; they are almost unable to learn the task when confronted with purely qualitative cues. On the other hand, in a go–no go differentiation procedure based on reinforcement-versus-nonreinforcement of responses to two auditory stimuli mainly utilize qualitative cues.

These facts have been tentatively interpreted in detail (*2*). It is notable that monkeys (*3*) also can establish without difficulty a go–no go differentiation between two different tones emanating from the same point, while their go left–go right differentiations between these stimuli are as difficult as they are for dogs; in contrast, the go right–go left differentiation between directional cues is easy.

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Higher Education: A Population Flow Feedback Model

During the last two decades attention has been turned to the production and retention, within the higher educational sector of the economy, of people holding the doctorate degree. It is generally recognized that the production of doctorates depends to a large degree on the doctorate-holding faculty. Because the doctorate holders, especially in the sciences, are in great demand by the other sectors of the economy, a circular or a "feedback" situation exists. The problem is further complicated by the availability of developed student talent and by various socioeconomic conditions existing at different periods of time within two or three decades prior to the time a study is made. Various studies of these problems have been initiated by agencies of government and by privately financed foundations.

In order to attempt to rectify an existing situation or provide for future needs, initiators of programs are in need of a rational methodology to evaluate the effects of their programs. Historical data and judgment have not always yielded satisfying bases for decisions. Both the military and industry are recognizing, to an increasing degree, the need for quick and economical ways of evaluating the various effects of their decisions. For this they have turned to analytical methods. Computer-based simulation is one method successfully used to study the dynamics of complex and nonlinear problems.

I now offer a conceptual and a mathematical model to study the production of doctorate, master's and baccalaureate degrees and their feedback into higher education (see Fig. 1).

This model breaks the educational sector up into four segments: undergraduate programs, master's programs, doctoral programs, and post-doctoral programs. It breaks the other sectors of society employing college- or university-trained people into segments according to the highest degree earned by those within the segment. Furthermore, it shows the retirement and other attrition sectors more or less as a sink outside of either of the above two sectors. The model delineates the various possible paths for population shifts between the segments. This work is an extension of the model developed and studied by Bolt, Koltun, and Levine (*1*), and it derives from my doctoral dissertation (*2*; see also *3*). In a manner similar to the afore-mentioned works and to many other works in the physical sciences, it accounts for all the net flows to a segment and the rate of accumulation of people within the segment.

The equations recognize the fact that degrees, especially at the doctorate level, are not earned at a given time of the year throughout society. Some schools operate on the semester basis, others operate on a trimester, and yet others on the quarter system. When aggregated, an assumption of continuity in flows seems a little more realistic than an assumption of discreteness. Thus, the equations offered are differential equations. Depending on the postulates regarding lead-lag relationships in the production of the various degrees these equations may be nonlinear. Because of the relative complexity of the model, the final set of equations to be solved simultaneously may be in the order of 40 or 50. However, this should not cause great concern in the age of computers. Back in 1956 I analyzed a hydraulic system which was described by a set of 28 nonlinear differential equations (*4*). These equations were then solved on an electronic analog computer. Certainly the state of computer art has progressed some since.

The basic advantages of this model may be described in outline as follows:

1) It recognizes the input of students into the higher education sector.
2) In the educational sector, it distinguishes between persons who have recently become engaged in the educational function and persons who have worked in education for many years.
3) It recognizes the nonlinearities of the situation studied.
4) It distinguishes between the use of doctorate holders in education at the doctorate, master's and undergraduate levels.
5) It considers the effect of the rates of production of high school, bachelor and master's graduates in successively preceding years.
6) It considers postdoctoral university programs and the interrelated flows from them to teaching at the various levels and to the other sectors employing doctorates.
7) Inasmuch as the rate of doctorate production has changed drastically during the last three decades, because of the depression of the 1930's, World War II, and the post war and the cold war periods, it emphasizes that the age mix is not a uniform one. Thus, the number of degrees granted some years prior (say 30 or 35 years) is the independent variable used in calculating attrition in this model.
8) Concern for economic, social, and physical influences in doctorate production and shifts in employment may be built into it.

Basic balance equations. The basic balance equations of this model follow; symbols are explained in Table 1. The equations state that the total rate of flow into a category less the rate of outflow is equal to the rate of accumulation or growth of a given category.