lus was changed (*7*). It can be argued in such instances that the subject was simply approaching the positive pattern and ignoring the negative. Against this interpretation, however, are the responses to the tests of Table 3, in which the positive form was changed but the negative remained constant. In these cases, one may say, the animal was only avoiding the negative stimulus in going to the various positive stimuli. Yet neither of these arguments holds for the forms of Table 4, where *both* of the test stimuli differed from those in the originally learned pair.

The dolphin passed two of the tests of Table 4 but failed four of them. Those which it failed, it appears, required stretching of an association or transposition beyond the animal's capability. Probably the dolphin could have *learned* to make the discriminations which it failed to make in these tests had it been given regular training in doing so, but in the "unsuccessful" responses of Table 4 the stimuli were not recognized as being related to the learned pairs.

Although the literature on the problem-solving abilities of other animals is extensive, few studies have been made under conditions sufficiently like those described here to permit valid comparison. The work of Klüver (*8*) with monkeys and that of Robinson (*9*) on chimpanzees is indirectly related to our studies. Each of these investigators trained his subjects with one set of visual stimuli and tested them with others. Klüver's tests were based on discrimination of size differential between paired visual designs, and Robinson's, on discrimination of sameness and differences between three-dimensional objects. After a subject had mastered the common principle involved, it could perform test problems by applying the principle to them. On the other hand, the dolphin in our tests had no single rule or principle by which to make the transfer from the originally learned pairs to the corresponding test pairs; the arrangement was more complex than one in which the same rule is followed in multiple situations.

The studies by Rensch (*10*) on a 5-year-old Indian elephant are probably closest to our studies with the dolphin. When tested in a two-choice situation, Rensch's elephant learned to discriminate 20 different pairs of figures. Rensch also tried altering some of the learned pairs (the method employed in our tests) and found that the elephant could transpose the learning to test pairs which were changed in various ways. Rensch believes (as we believe in the case of the dolphin) that his subject could, with additional training, have learned the correct response to many more pairs.

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Drug Administration to Neonatal Rats: Effects on Later Emotionality and Learning

Abstract. *The effects of extra stimulation during postnatal days 2 to 4 in rats are mitigated by the injection of either norepinephrine or chlorpromazine prior to the stimulation. Behavioral changes in locomotion and defecation occurred in the open field, and there were changes in speed and accuracy of learning a simple maze problem.*

There is a substantial amount of evidence to indicate that extra stimulation, when experienced during infancy, has profound effects on adult behavior. In many of the studies from which significant results have been obtained, the neonate was stimulated physically (by handling, mechanical rotation, loud sounds, or temperature variations, and so forth) and the animals became less emotional and more resistant to stress. The mechanisms by which these effects are mediated have remained unexplored.

It has been generally accepted that when an organism encounters a sudden or marked environmental change, or an emergency situation, there results a massive autonomic response (*1*). The organism is mobilized to a "flight or fright" response by the sympathetic division of the autonomic nervous system. Extra stimulation in early infancy may represent such a situation.

The pituitary-adrenal axis appears to be essential for the adult stress response; little is known of the biological basis of the infantile stress response. Pituitary and adrenal responsiveness to stimulation has been demonstrated in infant rats. However, there is still some question as to the age at which there is a functional unity of the axis (*2*). Regardless of whether or not there is complete maturation of the axis, it is possible that even partial activation of this system may alter enzymatic processes which could produce long-term impairment of the physiological mechanisms upon which the adult animal depends for stress reactivity and emotional behavior.

One approach to the study of this problem is to inject the neonate with hormones which initiate the stress syndrome while systematically manipulating the environment. As a second approach, which we devised for exploring the mediation of early experience on later behavior, we injected chlorpromazine, following Killam's suggestion (*3*) that chlorpromazine may enhance the central filtering-out of afferent impulses. Our experiment was designed specifically to examine the effects of infantile extra stimulation, the injection procedure, the pharmacological treatment, and the possible interactions between the extra stimulation and pharmacological treatment on later emotional and learning behaviors.

Twenty-four litters of Wistar strain rats were used. Offspring were assigned by litter to one of four groups; groups 1 to 3 received injections of norepinephrine, chlorpromazine, and saline, respectively, and the rats in group 4 served as noninjected controls. (A group of animals injected with epinephrine was discarded because one animal refused to rear her litter and several of the remaining offspring developed local skin irritations at the sites of injection.) Each of groups 1 to 3 was divided equally into groups A and B for treatment. On postnatal days 2, 3, and 4, animals in group A were individually removed from the cage, injected, and left with littermates in a small paper-lined compartment for 15 minutes before being returned to their home cage; animals in group B received the same treatment, but, in addition, at the end of the 15-minute delay, they received extra stimulation, being rotated rapidly in a cylindrical plastic container for 3 minutes, after which they were returned to the cage. One-half of group 4 was handled in the same way as group B; the other half remained with their mothers and was not handled until behavioral testing began. In each of the eight groups, $N = 20$.

To minimize the amount of handling, a prior study had ascertained the average weight of a pup over the first 4 days of life, and all animals received drug dosage based upon the daily mean body weight. Drug dosages were norepinephrine, 0.5 mg/kg in 0.05 ml of saline; chlorpromazine, 2 mg/kg in 0.05 ml of saline; and 0.05 ml of saline. The dosages were one-half the adult dose which has been reported to produce behavioral differences. All injections were given subcutaneously. On the last day of injections all cages were coded so that later behavioral testing was conducted "blind."

At 30 days of age, offspring were given individual 2-minute trials in the open-field setup of a modified Hebb-Williams maze (*4*). Animals were placed in the field on three consecutive days (test days 1 to 3), and measures of locomotion and defecation were recorded following the practice of using these measures as an index of emotionality (*5*). Offspring were deprived of water for 23 hours after completion of their first day in the open field. On the 4th and 5th test days animals were trained to find water with no barriers in the maze. On test days 6 to 9, the animals were given three trials per day during which they could solve test problem No. 1 (*4*). The number of errors made and the latency periods before reinforcement was reached were recorded for each trial. At 60 days of age, offspring were given three trials on 1 day in a water adaptation of problem No. 1 of the maze (*4*). The subjects had to swim the maze to escape from the water; again, errors and latency periods were recorded.

The effects of the extra stimulation were revealed clearly by multiple behavioral differences between the rats in the two noninjected control groups (4A and 4B). The animals that received extra stimulation were much more active than those that received normal stimulation, and they learned the simple maze problem with fewer errors and shorter latencies. Animals in group 3B, injected with saline and given extra stimulation, did not differ from those in group 4B, the noninjected controls that received extra stimulation, nor did group 3A differ from group 4A, indicating that the injection procedure alone did not modify later behavior. The behavioral effects of the pharmacological treatment were somewhat similar for both norepinephrine and chlorpromazine (this should not be interpreted as necessarily implying similar mediation mechanisms). Animals in group 2 (injected with chlorpromazine) were less active, made more errors, and had slower latencies than those in group 4B. Offspring injected with norepinephrine (group 1) were highly emotional, made more errors, and took more time to solve the problem than did those in group 4B. The results with norepinephrine are in contrast with the hypothesis that this stress syndrome is one of the physiological mechanisms through which extra stimulation during infancy affects adult behavior.

Evidence of interaction between the effects of extra stimulation and pharmacological treatment was suggested by the fact that the animals in group 2B (injected with chlorpromazine and given extra stimulation) were behaviorally similar to the animals in group 4A. This result suggested that the injection of chlorpromazine by itself does not affect later behavior but it does mitigate the effects of the extra stimulation. The results with norepinephrine suggested that not only does the injection of the hormone interfere with the effects of extra stimulation, but it has a tendency to produce the opposite results; the behavior of animals in groups 1A and 1B were significantly different in all respects from those in group 4B, and differed from group 4A only in increased defecation and in increase in the number of errors made at 60 days of age.

The mean score obtained by a subject for a particular behavioral test was used for the statistical analyses. A series of 2 × 4 analyses of variance performed on the data revealed the following treatment effects to be significant at the $p = .01$ level or less: (i) Open-field locomotion—stimulation treatment, drug treatment, and stimulation and drug interaction; emotionality—drug treatment; (ii) 30-day maze latency—stimulation treatment and drug treatment; errors—stimulation treatment; and (iii) 60-day maze error—drug treatment. A detailed summary of a further analysis of the data is given in Table 1.

The results of this study are consist-

Table 1. Effects of postnatal injections of norepinephrine, saline, chlorpromazine, and extra stimulation on later behavior. Scores shown are the mean scores of each group. Errors indicate the number of times blind alleys were entered. Footnotes show the other group means, which are significantly different on Duncan's multiple-range test.

Group	At 30 days				At 60 days
	Emotionality		Latency (sec)	Errors	Errors
	No. of squares	Defecations			
	Group A (normal stimulation)				
1 (Norepinephrine)	32.44*‡	1.19†‡‖	31.05*§	2.49*‡	7.85*§‖
2 (Chlorpromazine)	32.79*‡	0.71	31.02*§	2.45*‡	7.16*‡
3 (Saline)	32.33*‡	0.68	25.13†‡	2.59*§	6.38
4 (Noninjected)	37.99*	0.51	24.02†	2.51*‡	6.14
	Group B (extra stimulation)				
1 (Norepinephrine)	34.27*	1.18†§‖	28.35*§	2.33*	8.23†§‖¶
2 (Chlorpromazine)	34.58*	0.88	22.05†	2.15*	6.40
3 (Saline)	42.84	0.63	17.98	1.96	5.50
4 (Noninjected)	54.59	0.59	14.54	1.50	5.33

* Group 1B, significant at $p = < .01$. † Group 1B, significant at $p = .05$. ‡ Group 3B, significant at $p = .05$. § Group 3B, significant at $p = < .01$. ‖ Group 1A, significant at $p = .05$. ¶ Groups 2B and 3A, significant at $p = .05$.

ent with several previous investigations and formulations, such as those of Levine, Denenberg, and Harlow (*6*). These workers were concerned with the effects of a variety of early treatments and methods of handling, and demonstrated their importance by showing fairly reliable and consistent behavioral changes in the adult. The results of this study also indicate that (i) psychopharmacological intervention during significant periods of developmental and environmental interaction can produce long-lasting changes in the later behavior of the animal; and (ii) it is possible to use psychopharmacological techniques for studying the early development of certain classes of behavior and for investigating the biological basis for their development.

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Equilibrium of Talc with Enstatite and Quartz

Abstract. *A thermodynamic calculation of the vapor pressure of H_2O in equilibrium with talc gives p_{H_2O} of one atmosphere at 718° ± 15°K in contradiction to the results of Mueller.*

A report by Mueller on the chemistry and petrology of the planet Venus (*1*) makes use of certain calculations and data contained in an unpublished thesis by Robie (*2*). Unfortunately, Mueller apparently misunderstood the results of Robie for the equilibrium

$$Mg_3Si_4O_{10}(OH)_2 \rightleftharpoons 3MgSiO_3 + SiO_2 + H_2O$$

The value of 2200 atmospheres for the vapor pressure of water in equilibrium with talc at 700°K which Mueller gives as "extrapolation from data obtained by Robie," is apparently taken from the last entry of Table 18, page 91 of the thesis. This table was a calculation of the decomposition equilibrium based on the heat of formation of talc given by Bennington (*3*), − 35,530 ± 350 calories, and the third law entropy reported in the thesis (*2, 4*). This calculation was made, however, for the sole purpose of pointing out the discrepancy between the equilibrium data of Bowen and Tuttle (*5*) and Bennington's heat of formation of talc. In the same section of the thesis an approximately correct value for the heat of formation was derived, − 43,600 ± 1500 calories at 298.15°K. Values for the vapor pressure of H_2O in equilibrium with $Mg_3Si_4O_{10}(OH)_2$ calculated from this heat of formation gave p_{H_2O} of 0.7 atmosphere at 700°K, several orders of magnitude less than the value of 2200 atmospheres that Mueller attributes to Robie's data. On page 92 of the unpublished thesis is a log p_{H_2O} versus 1/T(°Kelvin) plot of the equilibrium curves for the talc decomposition reaction calculated from these two different heats of formation and including the experimental points of Bowen and Tuttle. The equilibrium curve based on the heat of formation of talc, − 43,600 calories, is in agreement with the available equilibrium data. The curve calculated from the value, − 35,530 calories, differs from the equilibrium data at 700°K by roughly 2000 atmospheres of H_2O pressure. Barany (*6*) has recently redetermined the heat of formation of talc by hydrogen fluoride–solution calorimetry. His value, − 44,890 ± 350 calories, confirms the calculations of Robie and greatly reduces the uncertainty.

Table 1. Calculated decomposition curve of talc.

Temperature (°K)	$\frac{\Delta(F^\circ_T - H^\circ_{298})}{T}$ (cal deg^{-1})	ΔF°_T (cal)	$\frac{(P-1)\Delta V^\circ}{41.2929}$ (cal)	P_{H_2O} (atm)
600	−41.00	+4,740	0	.02
700	−40.80	+780	0	.57
800	−40.56	−3,108	−3	7.1
900	−40.29	−6,921	−23	50
1000	−39.99	−10,650	−113	242
1100	−39.66	−14,286	−471	994
1200	−39.32	−17,844	−1613	(3400)

It follows that the deductions of Mueller concerning the instability of $Mg_3Si_4O_{10}(OH)_2$ on Venus are unfounded and that any conclusions drawn from them must be severely modified.

The equilibrium curve calculated from the calorimetrically determined entropy (*4*), the heat of formation (*6*), and the approximate high temperature heat capacity equation for talc (*4*)

$$C_p = 84.58 + 41.68 \times 10^{-3} T - 17.96 \times 10^5 T^{-2} \quad (298 - 1100°K)$$

is given in Table 1. The data for $MgSiO_3$ and SiO_2 were taken from Kelley (*7*).

The molar volumes of the solid phases and the fugacities of H_2O were those given by Robie (*8*).

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