and a glycoside in *Coronilla glauca* seeds which can be hydrolyzed to yield psoralene (*7*). The former yields coumarin not only on hydrolysis with emulsin, as above, but also with an endogenous β-glucosidase in *Melilotus* (*8*).

Table 1 shows the results of the tracer experiments. The results of experiment 1, with L-phenylalanine, support earlier findings (*2, 6, 9*) which indicate that this amino acid is a general precursor of coumarins. The appreciably higher specific activity of herniarin as opposed to coumarin suggests that the former did not arise through introduction of a methoxyl into the latter. The data from experiments 2 and 3 clearly show that *o*-coumaric acid and its glucoside were used with high specificity for the synthesis of coumarinyl glucoside, and that *p*-coumaric acid was used with similar specificity for synthesis of the glucoside which yields herniarin. Glucose-G-C^{14}, as expected, was used with lower efficiency for both syntheses.

The stage at which O-methylation takes place during the biosynthesis of 4-methoxycoumarinic acid glycoside is unknown. But the existence of this glycoside, and the fact that it is formed from *p*-coumaric but not *o*-coumaric acid, indicate the following partial biosynthetic sequence: (i) *para*-hydroxylation of a phenylpropanoid precursor (probably cinnamic acid), (ii) *ortho*-hydroxylation, and (iii) formation of a glycoside at the *ortho*-hydroxyl group. The results strongly suggest that lactone ring formation occurs, as in the case of coumarin (*4, 8*), simply by spontaneous dehydration after glycoside hydrolysis.

STEWART A. BROWN
Prairie Regional Laboratory,
National Research Council,
Saskatoon, Saskatchewan, Canada

References

1. K. Chambers, G. W. Kenner, M. J. Temple Robinson, B. R. Webster, *Proc. Chem. Soc.* **1960**, 291 (1960); R. D. Haworth, *J. Chem. Soc.* **1942**, 448 (1942); W. D. Ollis and H. Grisebach, *Experientia* **17**, 4 (1961).
2. W. W. Reid, *Chem. Ind. London* **1958**, 1439 (1958).
3. J. Koukol and E. E. Conn, *J. Biol. Chem.* **236**, 2692 (1961).
4. S. A. Brown, *Z. Naturforsch.* **15b**, 768 (1960).
5. H. Reznik and R. Urban, *Naturwissenschaften* **44**, 13 (1957); J. B. Harborne and J. J. Corner, *Biochem. J.* **81**, 242 (1961).
6. S. A. Brown, G. H. N. Towers, D. Wright, *Can. J. Biochem. Physiol.* **38**, 143 (1960).
7. A. Stoll, A. Pereira, J. Renz, *Helv. Chim. Acta* **33**, 1637 (1950).
8. T. Kosuge and E. E. Conn, *J. Biol. Chem.* **236**, 1617 (1961).
9. F. Weygand and H. Wendt, *Z. Naturforsch.* **14b**, 421 (1959); T. Kosuge and E. E. Conn, *J. Biol. Chem.* **234**, 2133 (1959).

1 May 1962

Effects of Early Perceptual Restriction on Simple Visual Discrimination

Abstract. Dogs were raised from infancy to maturity in lighted cages that restricted their visual experience but did not deprive them of all patterned stimulation. After they were released from their cages, they had greater difficulty than normally reared littermates in performing a simple black-white discrimination and in subsequent reversal training.

Severe restriction of the early perceptual experience of dogs has profound effects on their behavior at maturity (*1*). One of the most striking results is their frequent failure to perceive noxious stimuli.

Scottish terriers raised in restriction cages often failed to show any responses indicative of pain (apart from reflex movements) when their noses were touched with flaming matches or when they were jabbed with a dissecting needle. Moreover, the Scotties banged their heads repeatedly on low-lying water pipes without showing any signs of pain. However, intense stimulation, such as strong electric shock, produced violent emotional disruption in all the dogs.

This abnormal pain perception suggests that perception in other sensory modalities may also be affected by early restriction. A study of the effects of early perceptual restriction on discrimination of simple visual stimuli was therefore carried out (*2*). The subjects were five pure-bred Beagle littermates. Two dogs ("Dulla" and "Sin") were raised in a restricted environment. Each was placed, at 3 weeks of age, in a specially constructed cage that permitted feeding and care but prevented the dog from making contact with the outside environment. Each cage was well-lit, so that the dogs were able to see visual patterns provided by the cage construction (lines, angles, circles, and rectangles) and their own bodies. But the variety of patterned stimuli, compared with that in a normal environment, was drastically reduced. Starting at 9 months of age, the two restricted dogs were released from their cages for 15-minute periods each day for general observation. The three dogs comprising the control group were raised normally on a farm until they were 9 months old. They were then brought to the laboratory, where they lived two in a cage and were frequently permitted to run in a large outdoor enclosure.

Visual discrimination training began 5 weeks after the restricted dogs were first released from their cages. The dogs, which were kept on a 24-hour food-deprivation schedule, were trained to run down an alleyway 4 feet long and to obtain food by pushing open one of two doors at the end of the alley. The door carrying the positive stimulus could be opened by a slight push; the door holding the negative stimulus was locked. Food was always present behind both doors. The dogs were usually returned to the start box immediately after they made an error; correction was permitted only on the first training problem and during black-white reversal training after a significant difference had been established. The dogs were subjected to ten trials a day until they achieved criterion on a given problem (18 correct responses out of 20 trials, given on two consecutive days).

The dogs were first trained to perform a visual brightness discrimination. They learned to run to the side lighted by a 60-watt bulb and to avoid the unlit side. There was no difference between the two groups. One control dog learned the discrimination after 10 days and the other two after 12 days; one of the restricted dogs learned after 7 days and the other after 12 days.

Striking differences were noted, however, when the dogs had to discriminate between a white card (positive stimulus) and a black card (negative stimulus) which were located on the doors (Fig. 1). The response patterns of the two restricted dogs were almost identical. Each showed rapid initial learning of the problem, presumably a transfer from the earlier brightness discrimination, which was followed by a rise in errors before they finally achieved criterion performance. The increase in errors was accompanied by vicarious trial and error behavior at the choice point, in which the dogs appeared suddenly to become aware of the cues provided by the cards on the doors. The control dogs, on the other hand, showed a smooth decrease in errors after the second day. The difference in error scores between the two groups is significant at better than the .05 level ($t = 3.08$).

The differences between the two groups were even more marked in reversal training, which was carried out 6 weeks later. The procedure was reversed so that the black card now signaled food and the white card was on the locked door (Fig. 2). The control dogs showed a gradual decrease in er-

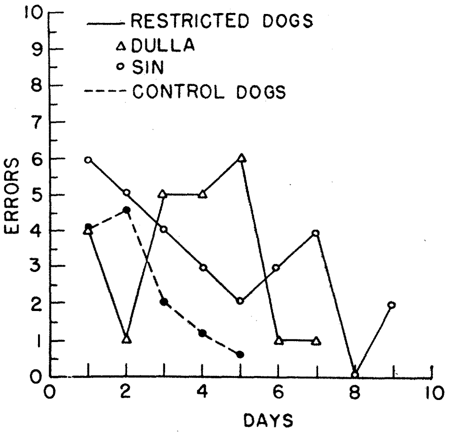

Fig. 1. Errors made by restricted and control dogs during white (+) vs. black (—) discrimination training.

rors, while both restricted dogs made significantly higher error scores ($t = 4.1$; $p < .02$) for a prolonged period. The plateaus in the curve reflect a position habit that was developed by both dogs during the training. One ran to the right side only and the other to the left side only on nine or ten trials each day. Both dogs also showed a high level of excited behavior during the entire training period. Only after one of the dogs was permitted to correct its errors (on the 22nd day) was it able to learn the reversal problem.

The next discrimination, between a horizontal and vertical line (a 1- by 5-inch white line on a black ground), failed to reveal a clear-cut difference between the two groups. The primary reason for the failure was unexpected. One of the "normal" control dogs underwent a remarkable change in "personality" in the course of the training, and became almost indistinguishable from the restricted dogs. It showed an increasingly high level of behavioral excitement and struggled violently when it was picked up. At the same time it developed a strong position habit, and "superstitious" behavior patterns, such as turning two complete circles before responding to the stimuli. In the course of this dramatic behavioral change, this dog's error scores shifted into the range of the restricted dogs.

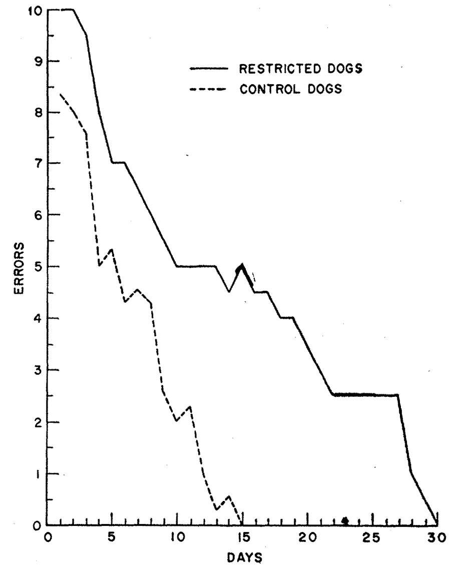

Fig. 2. Errors made by restricted and control dogs during black (+) vs. white (—) reversal training.

Dogs raised in a restricted environment, then, encounter more difficulty than normally reared littermates in learning a simple visual discrimination and in utilizing it in a new situation (the reversal problem). Since the restricted dogs were exposed to patterned visual stimulation in their cages, their difficulty cannot be attributed to a deficit in pattern perception. Rather, the explanation may lie in the exceptionally high level of emotional excitement—including "whirling fits" similar to a seizure (*1*)—that pervades all the behavior of restriction-reared dogs. It is possible that the dogs are so "aroused" and distracted by the unfamiliar environment surrounding them that they have difficulty in attending selectively to the "cue" properties of the stimuli which are to be discriminated. The effects of restriction thus seem best explained in terms of Hebb's (*3*) cue-arousal model, which suggests that high levels of arousal interfere with discrimination and selection of relevant cues from the environment. Indeed, even the increase in emotional excitement in one of the control dogs was accompanied by a marked rise in errors during discrimination learning.

These results have important implications for Riesen's (*4*) reports in which he states that animals deprived of patterned visual stimulation fail to discriminate between simple visual patterns at maturity. These effects are generally attributed to an absence of pattern perception.

Deprived animals, however, are also restricted to small cages or rooms and show hyperexcitability, seizure activity and other emotional abnormalities that resemble those observed in restricted dogs. Moreover, Riesen has observed that visually deprived animals have much less difficulty in discriminating patterns if the differences to be discriminated are replicated throughout the stimulus figures. It seems reasonable, then, that at least part of their difficulty in discrimination may be attributed to inability to select relevant patterns from the total sensory input (because of the high level of arousal) rather than to absence of pattern perception per se.

RONALD MELZACK

Psychology Section and Research Laboratory of Electronics, Massachusetts Institute of Technology, Cambridge

References and Notes

1. R. Melzack and T. H. Scott, *J. Comp. Physiol. Psychol.* **50**, 155 (1957); W. R. Thompson and W. Heron, *Can. J. Psychol.* **8**, 17 (1954); W. R. Thompson, R. Melzack, T. H. Scott, *Science* **123**, 939 (1956).
2. This study was supported in part by the U.S. Army Signal Corps, the Air Force Office of Scientific Research, and the Office of Naval Research, and in part by grants from the National Institutes of Health (M-4235-[C1]) and from the U.S. Air Force (AF 49 [638]-898). I thank Joseph Mendelson for his assistance in carrying out this experiment.
3. D. O. Hebb, *Psychol. Rev.* **62**, 243 (1955).
4. A. H. Riesen, in *Functions of Varied Experience*, D. W. Fiske and S. R. Maddi, Eds. (Dorsey, Homewood, Ill., 1961), p. 57; A. H. Riesen, in *Sensory Deprivatton*, P. Solomon, P. E. Kubzansky, P. H. Leiderman, J. H. Mendelson, R. Trumbull, D. Wexler, Eds. (Harvard, Cambridge, Mass., 1961), p. 34.

2 July 1962

Myotonia in a Horse

Abstract. Congenital myotonia, similar to that which has been reported in humans and in goats, is here reported for the first time in another species. Evidence is given to show (i) that the myotonic phenomenon is present despite complete block of neuromuscular transmission; (ii) prior to injection of curare, synchronous activity of muscle fibers may result not only from ephaptic stimulation of neighboring fibers but also from reflex firing; and (iii) water deprivation does not relieve the myotonia.

The myotonic phenomenon—which consists of prolonged contraction of skeletal muscle upon mechanical, electrical, and chemical stimulation—has been shown to be accompanied by bursts of high-frequency muscle action potentials when a needle is inserted into the muscle (the so-called "myotonic discharge" or "dive-bomber" pattern described by the electromyographer) (*1*). This phenomenon has been reported in humans and in goats. In both these species myotonia may occur as a congenital abnormality of the muscle (*2*).

We wish to present data to support the finding of myotonia in a registered thoroughbred horse. The filly was first noted to be lame at age 3 weeks. The