sents more complex cooperative problem-solving than seen previously in monkeys.

Both chimpanzees and baboons are commonly used as models for inferences regarding the behavior of early hominids. Baboons may be conceived as models for a more primitive hominid grade than that represented by chimpanzees. Since cooperation involving tool use is thought to have been instrumental in hominization it is of interest that extant baboons are capable of such behavior. Sophisticated tool behavior may considerably predate the differentiation and radiation of hominids in the Pleistocene. The disruption of cooperative behavior due to female-2's estrous cycling lends credence to speculation that the nearly continuous sexual receptivity of the human female is an adaptation to social and economic cooperation between bonded heterosexual pairs.

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Impairment of Timing Behavior after Prolonged Alcohol Consumption in Rats

Abstract. *Prolonged alcohol consumption (5 months) concomitant with adequate nutrition was found to impair the acquisition and performance of timing behavior. Alcohol was administered in the form of a liquid diet containing 35 percent ethanol-derived calories as the only source of fluid and calories. One control group received the identical liquid diet with isocaloric substitution of sucrose for ethanol, and another control group received laboratory chow and water without restriction. Thirty days after ethanol was discontinued in the diet, the alcohol-consuming rats were severely impaired in acquisition and performance of timing behavior as compared to controls.*

Brain damage or impairment of learning and recent memory, or both, often associated with chronic alcohol ingestion have been attributed to malnutrition, especially thiamine deficiency (*1*). However, brain damage and associated mental deterioration have also been reported in alcoholic patients with no history or clinical evidence of malnutrition, head trauma, or exposure to other toxic agents (*2*). Proper control of nutritional, environmental, and genetic variables is difficult in studies involving alcoholic patients, however. Investigations of the long-term effects of alcohol in animals is thus clearly desirable since the above variables can be precisely controlled.

The potential brain toxicity of ethanol in the absence of malnutrition has been demonstrated previously in an animal model (*3*). We have reported that mice (*4*) or rats (*5*) consuming ethanol-containing liquid diets for 3 to 7 months were severely impaired in shock avoidance learning when tested 2 to 18 weeks after ethanol was omitted from the diet. In order to determine whether the alcohol-induced impairment of shock avoidance learning reflects a more general learning deficit that is not specific to the shock avoidance situation, it is necessary to investigate the effect of prolonged alcohol consumption on subsequent acquisition of other behavioral tasks quite different from shock avoidance.

The purpose of the present investigation was to determine whether prolonged alcohol consumption, concomitant with more than adequate nutrition, would result in impairment of the acquisition and performance of a differential reinforcement of low rate (DRL) task (*6*). The DRL task has sometimes been referred to as timing behavior (*7*) because reinforcement by a food pellet is contingent on lever presses spaced apart at some specified time interval. In the present experiment prolonged consumption (5 months) of alcohol, incorporated into a nutritionally adequate liquid diet (*5, 8*), severely impaired the acquisition and performance of DRL 30 days after alcohol was omitted from the diet.

Twenty-four male Sprague-Dawley rats (Carworth CFE strain), 90 days old, were reduced to 85 percent of their body weights (when they were fed freely) and were trained to press a bar (*9*) to receive 45-mg food pellets (P. J. Noyes Co.) on a continuous reinforcement schedule (CRF). After CRF training was completed, all rats were given water and laboratory chow (Ralston Purina Laboratory Chow) without restriction for 3 weeks. Following the 3-week refeeding period, the rats were weighed and divided into three groups of eight rats matched as closely as possible for weight. The experimental group received a liquid diet containing 35 percent ethanol-derived calories (the alcohol group). A control group for the liquid diet was individually pair-fed the identical liquid diet except for isocaloric substitution of sucrose for ethanol (the sucrose group). The liquid diets were the only source of calories and water for the alcohol group and sucrose control group during the 5-month experimental diet period. The preparation, composition, and documentation of the nutritional adequacy of the liquid diets have been presented in detail (*10*). A third group received laboratory chow and water without restriction (the lab chow group) throughout the 5-month experimental diet period. Consumption of the liquid diets was measured daily and each rat was weighed three times weekly (*11*).

After 5 months on the experimental diets all groups were changed to unlimited laboratory chow and water for 30 days. After the 30-day period of this feeding, all rats were again reduced to 85 percent of their body weights (when they were fed freely) and were maintained at that weight for the remainder of the experiment. All rats were then given 20-minute CRF ses-

sions daily for 5 days in which each lever press was rewarded with one 45-mg Noyes food pellet. The total number of responses was recorded for each CRF session. An analysis of variance of the total number of responses during the five CRF sessions resulted in no significant differences among the three groups, supporting the conclusion that all groups were performing equally on CRF. On the day after the last CRF session, the DRL task was begun. Food reinforcement was contingent upon lever press response following the previous response by 20 seconds or more (DRL-20). Responses occurring in less than 20 seconds after the previous response resulted in no food reward and in a timer being reset for another 20-second waiting period. All rats received 36 sessions of DRL-20 training, each training session being 30 minutes long. The total number of responses, the total number of food reinforcements, and the interresponse times (IRT) in 5-second intervals were recorded (*7*). The number of reinforcements per session is a good indication of how closely the rats' response intervals are to the specified 20 seconds. In a 30-minute session the maximum number of reinforcements would be 90 if the rat responded exactly every 20 seconds. Responding sooner or significantly later than every 20 seconds would result in fewer reinforcements per session and thus in reduced efficiency.

The acquisition and asymptotic performance of DRL-20 was severely impaired in the alcohol group as compared to the sucrose and lab chow control groups (Figs. 1 and 2). Analysis of variance of the number of reinforcements per session over all 36 sessions (Fig. 1) resulted in a statistically significant group effect ($F = 29.86$, $P < .001$). Planned group comparisons showed that the alcohol group was significantly impaired ($P < .001$) relative to either the sucrose or the lab chow group. The performance of the sucrose and lab chow groups was statistically indistinguishable. Analysis of variance of the total number of responses over all 36 sessions (Fig. 2) also resulted in a significant group effect ($F = 5.30$, $P < .05$). Planned comparisons showed that the alcohol group made significantly more responses per session ($P < .05$) than either the sucrose or the lab chow group. The sucrose and lab chow groups did not differ statistically in the number of responses during the 36 sessions. Although the alcohol group made more responses overall during the 36 sessions, during the last three sessions (Fig. 2) there were no differences among the three groups in number of responses, as indicated by a nonsignificant analysis of variance. In contrast the alcohol group received fewer reinforcements ($F = 6.52$, $P < .01$) than the sucrose or lab chow groups during the last block of three sessions (Fig. 1). Therefore, by the end of training the alcohol group was no longer emitting more total responses than the control groups but was receiving fewer reinforcements for the same number of responses. This resulted from a poor temporal spacing of responses on the DRL-20 schedule. The alcohol group had fewer responses that fell into the 20- to 25-second range (which was the most efficient interval) and more responses in the shorter and longer IRT intervals than the controls did. The DRL deficit in the alcohol groups, then, was not simply a result of only short or only long IRT's, but of poor temporal spacing of responses that resulted in both too many long and too many short IRT's (as compared to controls).

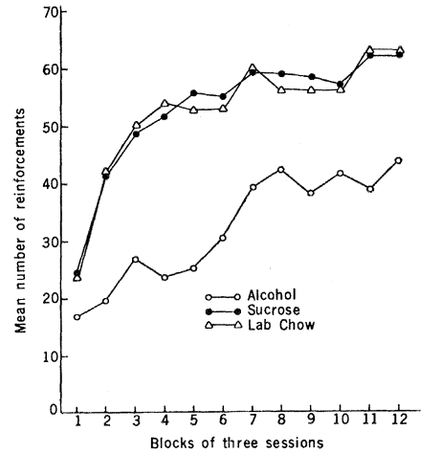

Fig. 1. Performance of rats on a DRL-20 schedule expressed as the mean number of reinforcements per block of three 30-minute sessions.

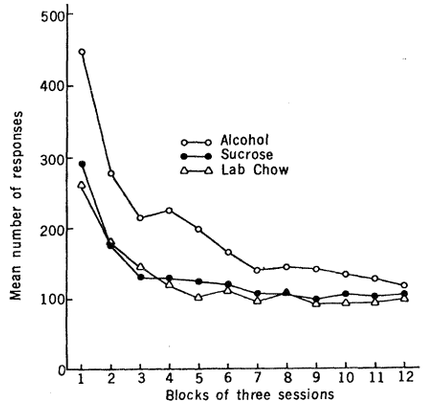

Fig. 2. Performance of rats on a DRL-20 schedule expressed as the mean number of responses per block of three 30-minute sessions.

The present results corroborate and extend (to a completely different learning task) our previous results (*3–5*) supporting the conclusion that prolonged alcohol ingestion per se can result in severe learning and performance deficits in rodents. The possibility that malnutrition played a role in producing the observed impairment is highly unlikely for several reasons: the rats maintained on the liquid diets consumed approximately 3 to 34 times the daily requirement of vitamins and minerals (*5*), showed above average weight gain throughout the experiment, demonstrated no clinical signs of malnutrition, and the pair-fed sucrose group, consuming identical amounts of nutrients except alcohol, was not impaired.

The alcohol-induced DRL impairment reported here provides strong evidence that prolonged alcohol consumption can result in a learning impairment that is not specific to the shock avoidance situation. A deficit specific to shuttle box shock avoidance might occur if alcohol consumption resulted in a motor deficit, a sensory deficit, or decreased fear, although these possibilities have been considered unlikely (*3–5*). However, the DRL task does not require rapid response initiation as shock avoidance does but requires pacing of responses or some degree of response suppression. Neither does this task require sensory or perceptual processing of external or painful stimuli as shock avoidance does. Taken together, the present report of an alcohol-induced DRL deficit and previous reports of alcohol-induced shock avoidance deficits (*3–5*) strongly support the conclusion that prolonged alcohol consumption per se can result in an impairment of associative processes of learning in the central nervous system.

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11. The mean body weights of the three groups on the first day of the experimental diet period were 416 g (342 to 444 g) for the alcohol group, 400 g (353 to 451 g) for the sucrose group, and 405 g (349 to 439 g) for the lab chow group. At the end of the 5-month experimental diet period the mean body weights were 483 g (439 to 523 g) for the alcohol group, 461 g (423 to 537 g) for the sucrose group, and 463 g (430 to 505 g) for the lab chow group. No clinical signs of malnutrition were observed. The mean daily alcohol consumption of the alcohol-consuming rats was 10.25 g/kg per rat (range, 9.65 to 11.64). In a previous experiment (*10*) we noted that rats consuming identical liquid diets ingested from 3 to 34 times the minimum daily requirements of vitamins and minerals.

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Visual Experience without Lines: Effect on Developing Cortical Neurons

Abstract. *Kittens were reared in a planetarium-like visual environment that lacked straight line contours. Cortical neurons were subsequently highly sensitive to spots of light but not to straight lines, in marked contrast to those from a normal cat. If linear contour processing is an innate function it appears to be subject to substantial modification by early visual experience.*

At successive stages of the visual system, information is abstracted from different environmental features. Neurons in the mammalian visual cortex are sensitive almost exclusively to linear contours (*1*).

But is the sensitivity of the cortex to straight lines an immutable consequence of evolution? The rationale of this question stems from the recent series of experiments concerned with the influence of early visual experience on the subsequnt organization of the visual system. These studies have shown that during early development, the connections of visual neurons are remarkably plastic. Cells not only become sensitive to the orientation of the contours that were predominant in the early visual environment (*2*), they do so within exceedingly brief periods of exposure (*3*).

One would expect that there must be a limit to the degree of environmental shaping of neuronal circuitry. We sought to probe the limit by producing a severe alteration in the normal environment of growing animals. We reared kittens so that they never saw lines or linear shapes. Their only visual experience was from a pseudorandom array of point sources of light, which appeared like bright stars in a dark sky. For controls, we used a normally reared cat and one raised in total darkness. Subsequent physiological study of the kittens reared so that they never saw lines (random dot kittens) showed that their visual cortical neurons were remarkably atypical in that they were selectively responsive to small, moving spots of light, much smaller than the receptive field sizes. Of the few cells that seemed sensitive to edges, only two could be said to approach the normal variety that are most responsive and selective to elongated stimuli. We conclude that if linear contour processing is an innate property of the visual cortex, it is one which can be readily modified.

For the initial experiment, we chose a kitten with an all black coat to reduce the chance of self-observation during the exposure periods. He was kept in a totally dark room until he was 28 days old (*4*). During the next 13 days, he spent 3 hours daily in a large (90 cm diameter), opaque polyethylene sphere. There were 1 mm diameter holes in the upper hemisphere, spaced so that no two would fall within the typical receptive field of a single cortical neuron (*5*). The arrangement of holes was pseudorandom in order to minimize the chance that linear contours would be synthesized from several points. A bank of lights surrounded the sphere, and the utmost precautions were taken to eliminate stray light and to insure that the kitten saw only the point sources of light (*6*). We attempted to gain the kitten's attention by moving the bank of lights around the sphere and by making noises, and he seemed to be active for most of the time. At the end of the 39-hour exposure period, he was returned to the dark room for a week prior to the neurophysiological observations.

The electrophysiological techniques were standard (*7*). Action potentials were recorded extracellularly in area 17 with tungsten-in-glass microelectrodes (*8*). All firing units were tested with a wide variety of stimuli (*9*). These stimuli were also presented continually as we advanced the electrode so that we would not miss neurons that were "edge-detectors" and which lacked spontaneous activity. The stimuli were positioned in the object plane of an overhead projector with a frame attached to an X-Y recorder. All directions of movement could be produced manually or by computer controlled commands to the X-Y recorder. After initial plotting of the receptive field, we used the computer to obtain quantitative estimates of stimulus preference.

The results from the first random dot kitten were most striking. Over a 72-hour period, we made a detailed study of 69 single units from three electrode tracks. On the basis of waveform or binocularity or both (*10*) all of the units were identified to be cortical cells except for three incoming fibers from the lateral geniculate nucleus (*11*). Of the cortical cells studied, 19 were insufficiently responsive for receptive field plotting and 47 had clearly defined fields. Twenty-seven of the latter group gave vigorous and dependable responses to a completely atypical range of stimuli which led us to call them "spot detectors." These cells had the following characteristics. (i) Their optimal response was to moving, circumscribed, bright targets always less than 0.5° and often less than 0.2° in diameter (*11*). (ii) There were vigorous ON or