AN ABSTRACT OF THE THESIS OF

Mechelle A. Mayleben for the Master of Science in
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Title: The effect of lead on increased aggressiveness
and emotionality in the rat.

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Stephen F. Davis

Environmental pollution has become a focused concern of researchers in the recent past. Among the more common contamimants is lead, which has been implicated in emotional disorders (Marlowe, 1985) and hyperactivity (Rimland & Larson, 1983) in children. In addition, lead may play a role in increasing aggressive tendencies in both children and adults (Hanninen, 1982). In order to clarify some of the inconsistencies in the research literature, the present project was undertaken. Rats were chronically exposed to lead acetate (PB) via their drinking water for 60 days, or were given regular tap water (N). Following exposure, the subjects were trained in a straight runway and given either continuous (CRF) or parital (PRF) reinforcement. Thus, four groups resulted: PBPRF, PBCRF, NPRF and NCRF. Relying on classic frustration theory (Amsel, 1958), and assuming that lead does increase aggressiveness and emotionality, the prediction would be that those exposed to lead and given partial reinforcement (Group PBPRF) would persist longer during Extinction when compared to those subjects given water and receiving partial reinforcement (Group NPRF). Conversely, those animals exposed to lead and receiving continuous reinforcement (Group PBCRF) would be expected to extinguish most rapidly because of the increased frustration experienced for the first time at the outset of Extinction, when compared to their water counterparts (Group NCRF). Results indicate that lead does lead to an increase in emotionality in the rat. Implications of this finding, along with future avenues for research, are discussed.

THE EFFECT OF LEAD ON INCREASED AGGRESSIVENESS AND EMOTIONALITY IN THE RAT

A Thesis
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Research in this area has found a relationship between exposure to lead and an increased intake (consumption) of alcohol. For example, factory workers in a plant on the east coast who were found to have elevated blood-lead levels consistently drank more alcohol. Further, these same factory workers had a higher incidence of alcoholism than did the normal population (Cramer, 1966; Nation, 1990).

In addition to research done in the area of lead contamination, investigators have looked at other environmental pollutants. Nation, Grover, Bratton and Salinas (1990) exposed rats to one of four conditions: a control group (this group received no treatment), lead alone, cadmium alone, or a combination of lead and cadmium in their daily food. The assumption was that given the deleterious effects these two contaminants have in

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In addition to research done in the area of lead contamination, investigators have looked at other environmental pollutants. Nation, Grover, Bratton and Salinas (1990) exposed rats to one of four conditions: a control group (this group received no treatment), lead alone, cadmium alone, or a combination of lead and cadmium in their daily food. The assumption was that given the deleterious effects these two contaminants have in isolation, by combining them one would expect to see an even greater alteration in the animals' behavior, as assessed by activity chambers measuring various types of behavior (e.g., vertical activity, horizontal activity, stereotypy time, etc.). However, while these predictions were quite attractive at the outset of the experiment, the hypotheses were not borne out. Lead and cadmium again showed an effect on the rats' behavior consistent with earlier reports (i.e., lead increased the rat's behavior relative to controls, whereas cadmium decreased movement time relative to controls), but the combination of the two metals did not have an additive effect. In fact, Nation et al. found the two toxins to be antagonistic toward each other. In other words, the animals in the lead-cadmium group did not change their activity as much as the lead and cadmium groups alone.

Other research done in the area of toxins has investigated the relationship of the combined effect of lead and cadmium. Nation, Frye, Von Stultz & Bratton (1989) exposed rats to one of four diets: no contaminant, lead alone (500 parts per million, ppm), cadmium alone (100 ppm), or lead and cadmium together (500 and 100 ppm, respectively). Following 60 days of exposure to the treated food, animals were put on a food deprivation schedule and trained to lever press for Noyes pellets. The researchers found that there were no overall differences in the rates of lever pressing for reward among the four groups. However, those exposed to cadmium in isolation showed increased rates of responding early in training, but then tapered off to become relatively equal to control animals. Those animals exposed to lead in isolation demonstrated increased responding as well, though this effect was delayed. That is, those on the lead diet alone increased their response rate but didn't show this until late in training. Again, these animals reverted back to control-level responding by the end of training. In addition, those rats exposed to the combination diet actually showed a decrease in lever responding, contrary to the expected results. Thus exposure to lead and cadmium in isolation appears to increase the animal's responsiveness, though the effect is transitory, and exposure to both metals at the same time engenders decreased rates of responding, an effect that is not understood at this point.

The interaction of metal toxicity with other chemicals has also been investigated. Among the other chemicals under consideration are ethanol and cocaine. Grover et al. (1990) exposed rats to cadmium (100 ppm) for 60 days via their laboratory chow. In addition, a comparable control group was maintained on regular laboratory chow. After exposure was complete, animals were initially trained to lever press for a 20% sucrose solution, with gradual replacement of the sucrose with ethanol. For example, all animals began with the 20% sucrose solution. Following exposure to this, the solution became 10% sucrose and 5% ethanol. This procedure was implemented until a solution containing 10% ethanol was achieved. While this may seem to be a cumbersome procedure, it is necessary because ethanol is typically aversive to rats, especially when the concentration exceeds 6% (v/v). The results demonstrated that animals exposed to cadmium responded at higher rates (were more responsive) for the 20% sucrose solution than did control animals. This increase continued for the early fading phases, though when the concentration of ethanol increased, the rate of responding for the cadmium rats declined. The researchers concluded, from this study and other work done in their lab, that cadmium exposure will increase a rat's intake of ethanol in a free-access paradigm, but when reinforcement is contingent on the animal responding, the rats are unwilling to persist in lever pressing. These seemingly contradictory findings are explained by Nation et al. as being the result of the particular procedure used in different studies and by hypothesizing that cadmium may change the pharmacologic effect of the ethanol. However, this hypothesis has not yet been supported.

In terms of cadmium's interaction with cocaine, Nation et al. (1990, submitted for publication) exposed rats to cadmium for 60 days via their diet. Upon completion of exposure, rats were trained to lever press for cocaine reinforcement. In addition, rats were injected intraperitoneally with cocaine to observe the effect on the animal's overt behavior. Normally cocaine heightens an animal's responsiveness and increases activity. This effect was observed in the control animals. However, there was a significant difference in activity for those animals exposed to cadmium when compared to control animals: rats exposed to cadmium didn't demonstrate the increased reactivity normally engendered by cocaine ingestion. Again, cadmium appears to alter the pharmacologic effect of the drug.

While research into the effects of other metals has received much attention, lead contamination appears to be more of a concern than the other toxins. The reason for this seems to be easy access to lead sources (as stated at the beginning of this paper). As a result, lead contamination is an especially pertinent concern for children. Specifically, research has focused on lead's relationship to emotionally disturbed children (Chaiklin, Mosher & O'Hara, 1985; Marlowe, Errera, Ballowe & Jacobs, 1983; Marlowe & Errera, 1982; Marlowe, Errera, Stellern & Beck, 1983) and hyperactivity (Baloh, Sturm, Green & Gleser, 1975; David, Hoffman, Sverd, Clark & Voeller, 1976; Rimland & Larson, 1983). Marlowe and Errera (1982) took hair samples from children displaying behavior problems, as assessed by their teacher's judgment. These hair samples were analyzed for lead concentration. In addition, children were rated by their teachers using the Walker Problem

Behavior Identification Checklist (WPBIC). Correlations between lead concentration and the WPBIC found children with higher lead levels to be more distractable, aggressive, immature, and have more difficulty in peer relations. Further, Baloh et al. (1975) compared children who had regular lead levels with children who had elevated lead levels. "Elevated" lead children were defined as those having blood-lead levels greater than 50 mg/100ml. "Control" or "regular" lead children were those found to have blood-lead levels less than 30 mg/100ml. Children in these groups were matched according to age (in months), sex, race, socioeconomic status, and blood-lead levels. While the researchers admitted other variables may indeed play a role, children with elevated lead levels had a higher incidence of hyperactivity than did their matched controls. As lead is potentially accessible to young children via paint, auto emissions, and lead crystal, these findings are quite significant albeit alarming.

In a comprehensive review of the literature relating to lead toxicity in children, Marlowe (1985) discussed some of the effects even low levels can have on children. These effects include impairment on the Wechsler Intelligence Scale for Children - Revised (WISC-R), both verbal and full scale IQ; decreases in attention; and declines in auditory and language processing were observed. In addition, research in children has found that high lead concentrations are associated with poorer psychological functioning. In a study performed by Lansdown, Yule, Urbanowicz, and Millar (1983), children with elevated blood-lead levels demonstrated lower full and verbal IQ scores, poorer reading and spelling performance, and poorer performance in the classroom, as assessed by teacher evaluations. Lansdown et al. also found that there appears to be a dose response curve associated with lead toxicity. In other words, with increasing levels of lead, there is a related increase in the amount of cognitive impairment.

Lead contamination has further been investigated in adults. Hanninen (1982) summarized the research done utilizing adults as subjects. Most of the contamination experienced by adults is related to their working environment. The effects observed for adults tend to mirror the effects observed in children. Hanninen reported that lead ingestion as an adult is associated with psychomotor disturbances, which include tremors, eye-hand coordination, muscular strength and endurance, as well as latency to respond. All of the subjects found to have high blood-lead levels were observed to be deficient in these categories when compared to those that did not exhibit elevated lead levels. In addition, those adults having increased levels of lead exhibited a deterioration in their intellectual capacity. Intellectual capacity was assessed by either the Wechsler Adult Intelligence Scale or other neuropsychological tests. Further, elevated lead levels were found to have been associated with alterations in emotional states, with the change leading to increased hostility and aggression. Thus, the effect of lead ingestion seems to be consistent across age levels, whether one is studying children or adults. This could be important in that ingestion of lead and the effects that it could possibly engender may be reversible if lead contamination is detected and discontinued. The pattern of results suggest that lead toxicity affects humans in the same manner, regardless of age. As a result, the animal models being developed will apply equally well to all affected. It is also interesting to note that exposure to mercury appears to produce similar effects in humans when compared to lead's effects (Hanninen, 1982).

As closely as possible, studies in this area have tried to mirror the level(s) of lead reported in humans. These relatively low levels of lead often do not result in overt signs of toxicity.

To corroborate observations made in humans when lead has been ingested, animal research was undertaken. Recent research by Nation and his colleagues (Nation, Dugger, Dwyer, Bratton & Grover, unpublished manuscript; Nation, Grover & Bratton, in press) postulated that exposure to lead attenuates the pharmacologic effects of ethanol. As a result, more alcohol needs to be consumed in order to achieve the anxiolytic effects associated with alcohol. Nation et al. (in press) exposed rats to a low level dose (500 ppm) of lead for 60 days, while maintaining a comparable group on a regular diet. After 24 hours of water deprivation, rats were trained to lick for a 5.5% sucrose solution. On the following day, rats were given an ip injection of either saline or 1.5 g/kg ethanol and placed in the box to lick for the same 5.5% sucrose solution. The results indicated that rats exposed to a regular diet and injected with ethanol continued to lick more, even though they were being shocked on the tongue, than did rats exposed to lead and injected with ethanol. Both of these groups licked significantly more than did rats that received saline injections. Thus, lead exposure may decrease the pharmacologic effect of ethanol, resulting in the decreased amount of licking for the lead treated-ethanol injection group. While no overt tests of emotionality were conducted, one can infer from the lick-rate data that lead increased the rats' emotional state such that injection of ethanol did not have as much of an effect as it might normally have had.

To investigate the neurobehavioral effects associated with lead, Winneke, Brockhaus and Baltissen (1977) exposed rats to low levels of lead from conception to adulthood. Exposure to lead was in the form of lead acetate, at a concentration of 745 mgPb/kg diet. During adulthood, rats were subjected to various behavioral tests, including open-field running and visual discrimination learning. Results showed that lead-exposed rats were significantly more restless and prone to overreaction. In a related study, Dolinsky, Burright and Donovick (1983) exposed rats to lead (0.5% lead acetate) through their drinking water either prenatally, postnatally or continuously (prenatally and postnatally). The researchers found that rats exposed to lead postnatally were affected the most, demonstrating more aggressiveness. An interesting result was that the effects of lead are not additive, that is, being exposed to lead pre- and postnatally did not increase lead's effects. However, all groups exposed to lead showed a shorter latency to fight when compared to the control group (no lead).

Other researchers have also found that exposure to lead increases aggressiveness and emotionality (Barrett & Linesey, 1985; Burright, Engellenner & Donovick, 1983; Donald, Cutler & Moore, 1987; Donald, Cutler, Moore & Bradley, 1986; Engellenner, Burright & Donovick, 1986; Driscoll & Stenger, 1978; Geist & Balko, 1980, Lanthorn & Isaacson, 1978). After exposing rats to lead (0.25% lead acetate) in their drinking fluid beginning at conception and continuing to maturity, Donald et al. (1987) observed a significant increase in aggression for males, though the increase wasn't as pronounced for females. In addition, Engellenner et al. (1986) found that males exposed to lead had a shorter latency to aggression. After exposing young

(60 days of age) and old (540 days of age) mice to lead in the form of a lead acetate solution (0.5% w/v), and having a comparable control that was not administered lead through their drinking water, these investigators administered behavioral tests, assessing latencies to contact, aggressiveness, the frequency of fighting, defense posturing, tail lashing, and total time spent fighting. While the results showed that younger animals fought more vigorously, exposure to lead increased all the aggressive tendencies of all animals. Interestingly, the younger lead-exposed animals were typically submissive in fighting situations among their peers, whereas older animals exposed to lead were typically dominant in their peer fighting. This replicated a previous finding by Burright, Engellenner and Donovick (1983), which also investigated the effect of low-level lead ingestion on two different age groups. Burright et al. had also found young lead-treated mice to be submissive in fighting situations, with the reverse being shown in the older lead-treated animals (i.e., the older lead-treated animals were dominant in fighting situations). The reason for these discrepancies is unclear, though age-related changes in endocrine function and lead-induced hippocampal function are suggested by Engellenner et al. as possible explanations.

Barrett and Livesey (1985) attempted to determine the effect lead exposure engendered through the dams' milk had on both pups and mature rats. In investigating this phenomenon, they exposed female rats to one of four different lead conditions: no lead, 0.2%, 0.4% or 1.0% by weight via their drinking water. Lead exposure was continued after the pups were born via their drinking water as well. Rats were tested using three different stress tests. These included changing the apparatus the rat was familiar with, testing longitudinally and cross-sectionally the test apparatus the rat was accustomed to, and comparing the rats' reactivity in the presence and absence of a loud noise. The researchers found that rats who were exposed to lead reacted more vigorously to the stress tests than those who were not exposed to the metal. However, Barrett & Livesey qualify their finding, stating that reactivity was largely dependent on the test applied and the measure taken. In addition, the level of lead ingested was related to the results obtained. Those rats exposed to the 1.0% lead by weight showed physical reactions to the lead relative to the other lead groups (e.g., lower body weights). Thus the conclusions must be taken cautiously, since the physical effects of the lead may have impaired the rats' performance.

In an attempt to reconcile some of the discrepancies reported in the literature concerning the assertion that lead increases an animal's aggressiveness and emotionality, Driscoll and Stegner (1978) exposed rats to no, low (10^{-4} M) or high (10^{-2} M) lead via their drinking water. The rats were then subjected to an open field test to determine their reactivity and responsiveness. The researchers found that those rats exposed to the high concentration of lead showed changes in their relative rate of activity, though the change was not consistent. However, rats exposed to the low level of lead did demonstrate a consistent increase in their overall activity. It would seem, then, that an increase in an animal's responsiveness would be dependent on the level of lead ingested.

In assessing the behavioral effects of lead ingestion, Nation, Bourgeois and Clark (1983) exposed their rat subjects to laboratory chow laced with lead acetate, either 0 or 10 mg/kg. Following the 60 day exposure regimen, rats were trained to lever press for food reward. The results indicated that animals exposed to the lead decreased their rate of responding relative to controls. Experiment 2 exposed rats to either 1 mg/kg, 5 mg/kg, or 10 mg/kg lead acetate. After the traditional exposure period, rats were again trained to lever press for food reward. Interestingly, the researchers found that the low doses of lead caused an increase in the rate of operant responding, while the high dose (10 mg/kg) again engendered a decrease in the rate of responding. Thus it appears that mild doses of lead facilitate an increase in responding and reactivity, while high doses actually cause the animal to decrease operant responding. This rather interesting finding has thus far remained unexplained.

In contrast to the above cited findings of Driscoll and Stegner (1978), Geist and Balko (1980) found that exposure to a high concentration of lead resulted in the greatest effect on emotionality. These investigators exposed their rat subjects to lead in their drinking water, at levels of either 0 (ppm), 25 ppm or 50 ppm. The animals were then tested in an open-field task and measurements were taken on duration and frequency of grooming, rearing, number of squares traversed, boli excreted and urinations. Results demonstrated that there were no significant differences in the duration and frequency of grooming, rearing or the number of squares traversed. However, the researchers noted that there was a marked difference in the emotionality displayed by the animals. Those rats exposed to 50 ppm lead exhibited significantly greater emotionality when compared to those exposed to 25 ppm lead or 0 ppm lead. The researchers conclude that lead ingestion may have an effect on emotional reactions but may not influence general activity.

All research is not in agreement with the above results. Finch and Reiter (1976) found a decrease in aggression in rats exposed to lead. Cutler (1977) exposed mice to lead (as a 0.1% lead acetate solution) through the dams' milk and then continued exposure after weaning. Mice exposed to lead showed a decrease in the frequency and duration of aggressive acts. In addition, lead-treated mice showed a higher incidence of non-social activity, such as "exploring," "scanning," and "eating."

After exposing rats to either no, low (10^{-4} M) or high (10^{-2} M) lead through their drinking water, Driscoll & Stegner (1976) found that ingestion of lead actually decreased the activity of their rat subjects in an open field setting. This result was found in all four experiments performed and the researchers conclude that lead ingestion, especially high lead ingestion, does not increase emotionality. In fact, it has just the opposite effect.

To investigate the effect of lead ingestion early in the development of the rat, Hastings, Cooper, Bornschein and Michaelson (1977) exposed rats to three different concentrations of lead acetate (0.0%, 0.02%, or 0.10%) through the dams' milk. Following weaning, all rat pups were switched to regular tap water as their source of fluid. Thus lead exposure lasted from conception to weaning. The researchers then tested each of the animals in a wheel running apparatus to discover if there was any difference in the rats' activity. No discernible differences were observed. In addition, Hastings et al. assessed aggressive tendencies of the groups by administering a shock to the rat and increasing the voltage until the first flinch was observed. The researchers found that there were no differences among any of the groups in terms of aggressiveness and reactivity to the shocks. However, increases in emotionality were observed in the lead-exposed rats relative to controls. Hastings et al. conclude that lead ingestion may alter some emotional aspect of an organism, but the effect may not be as global and dramatic as some of the research in the field contends.

Thus, additional research is needed to verify this proposed relationship between lead exposure and increased emotionality. The present project sought to provide such supportive data. As the research cited in this chapter demonstrates, lead exposure may lead to increased hyperactivity and emotional disturbances in humans, increased aggressiveness and a shorter latency to fight in animals, or to a decrease in aggressiveness (as assessed in animal models). Taken in conjunction with classic frustration theory (Amsel, 1958), the lead-emotionality relationship suggests an interesting prediction. Frustration theory asserts that animals who had received partial reinforcement continued responding longer during extinction than did continuously reinforced animals. The explanation for this finding was that partially reinforced animals had already experienced frustration during training. Because they persisted in making the instrumental running response in the presence of frustrative cues, these cues became part of the stimulus complex controlling responding.

Hence, when extinction began, the frustrative cues engendered by nonreward served as prompts to continue responding. Animals that received continuous reinforcement during training would encounter frustration for the first time during extinction. These subjects would be expected to extinguish more rapidly because frustration would not be a cue to persist.

Using this reasoning, the hypothesis follows that there should be a difference between lead-exposed and normally reared animals during extinction following partial reinforcement and continuous reinforcement training. The hyperemotionality engendered by the lead exposure should result in more rapid extinction in continuously reinforced animals and greater resistance to extinction in partially reinforced animals. Based on the assumption that exposure to lead increases emotionality in subjects, those animals receiving partial reinforcement along with lead will persist in responding because the frustrative cues associated with nonreward have been conditioned to elicit the instrumental response. Conversely, those animals receiving lead along with continuous reinforcement will extinguish most rapidly because the increased frustration associated with lead exposure will heighten the frustration experienced at the onset of extinction. Such effects, of course, would be seen to occur relative to comparable groups of normally reared animals.

CHAPTER II

Method

Subjects

Subjects used in this project were 36 male Holtzman rats, obtained from the Holtzman Company (Madison, WI). They were be approximately 60 days old when received. Upon receipt from the supplier, rats were randomly assigned to individual, wire-mesh cages. Animals were kept in the Emporia State University vivarium, with a light/dark cycle of 12 hours (0800 hrs lights on and 2000 hrs lights off), and a temperature of 22 degrees Celsius.

Apparatus

A single straight runway served as the test apparatus. The runway was 11.40 cm wide and 12.70 cm high. It consisted of a gray start box (38.10 cm), black run section (91.44 cm), and a black goal box (30.48 cm). A masonite guillotine door separated the start from the run section, while a second one separated the run from the goal section. A microswitch located on the start door, and three photoelectric beams (located 15.20, 92.40 and 116.80 cm beyond the start door), in conjunction with four Lafayette (Model 54030) digital timers, yielded start, run, goal, and total latencies on each trial. A plastic receptacle, recessed into the distal end of the runway, served as the goal cup.

Procedure

Upon arrival from the supplier, the animals were randomly divided into two main groups: lead-exposed and water exposed. Following three rest days, a 60-day lead exposure period began for the lead-exposed animals. Lead exposure was accomplished by mixing .92 grams of lead acetate per liter of water. This yielded a solution having 500 ppm lead. This solution was presented on an ad libitum basis for the duration of the experiment. Bottles for both groups were weighed and filled every other day to ensure the groups were consuming equal amounts of liquid. In addition, each bottle was shaken on days the bottles were not weighed. This was necessary to remix the lead solution since lead acetate is mildly insoluble in water.

The implementation of a food-deprivation regimen, designed to maintain the animals at 80-85% of the free-feeding body weight, coincided with the end of the 60-day lead-exposure phase. This food-deprivation regimen remained in effect for the duration of the experiment. At this time, two equal-sized subgroups were randomly formed within each of the main groups. In turn, these subgroups were designated to receive either continuous or 50% partial reinforcement during runway training. Thus, Group NCRF was normal (i.e., water exposed, N) and received continuous reinforcement (CRF). Group NPRF was normal (i.e., water exposed, N) and received partial reinforcement (PRF). Group

PBCRF was lead-exposed (PB) and received continuous reinforcement (CRF). Group PBPRF was lead-exposed (PB) and received partial reinforcement (PRF).

A six-day Pretraining phase immediately preceded runway training. During the first three days of Pretraining, the subjects were individually handled and tamed for three minutes daily. On each of the last three days, each subject was given an individual five-minute exploration period in the apparatus with the doors raised and all electrical equipment operative. The goal box was baited with 10, 45-mg Noyes pellets on these exploration periods. Each subject also received daily habituation to the reward pellets in the home cage.

An 80-trial Acquisition phase began 24 hours following Pretraining. Prior to Acquisition, 8 squads, composed of 1 subject from each of the 4 groups, were formed. The subjects were run in these squads for the remainder of the experiment. The order for running squads was cyclic from day to day (i.e., 1-2-3-4-5-6-7-8, 2-3-4-5-6-7-8-1, etc.). On any given day, each squad received all trials before trials were administered to other squads. Within a given squad, all subjects received Trial 1 before Trial 2 was administered, and so forth. This resulted in an intertrial interval (ITT) of approximately 5 minutes. Daily reward (R) and nonreward (N) trials were assigned to the partial reinforcement subjects randomly, with the restriction that

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An 80-trial Extinction phase began 24 hours following the completion of Acquisition. Trials were administered during Extinction in the same manner as during Acquisition, with the exception that reward was never present. Trials were administered at the rate of four per day during both Acquisition and Extinction.

CHAPTER III

Results

Prior to analyses of runway latencies, the following data transformation was employed. Each latency was reciprocated and then multiplied by the appropriate metric constant to yield speed scores in meters per second. This transformation was employed in order to satisfy the mathematical assumptions that underlie the analysis of variance (ANOVA) technique -- independence of errors, homogeneity of variance, and normal distribution of errors. Subsequent ANOVAs were performed on the average daily speed score for each subject for each measure. In all instances an alpha level of .05 was employed to ascertain statistical reliability.

Preexperimental Group Equivalence

In order to establish group equivalence prior to the start of Acquisition, ANOVAs were performed on the final consumption and weight data recorded prior to the inception of deprivation. As these results failed to yield significant between-groups effects [weight, $F(1, 34) = .005$, $p > .05$; consumption, $F(1, 34) = .161$, $p > .05$], the assumption of group equivalence was satisfied.

Acquisition

Start. The lead exposure, $F(1, 32) = 4.37$, $p = .042$, days, $F(19, 608) = 136.33$, $p < .001$, and reinforcement schedule x days, *F*(19, 608) = 2.67, *p* < .001, effects achieved significance. Inspection of the data indicated that the water-exposed animals had starting speeds faster than did the lead-exposed animals. A series of simple main effects analyses performed on the partial reinforcement versus continuous reinforcement scores across the 20 days of acquisition yielded significant reinforcement effects on Days 13-20, smallest *F*(1, 608) = 5.78, *p* < .05. In all instances the continuous reinforcement animals (Groups PBCRF and NCRF) started faster than did the partial reinforcement animals (Groups PBPRF and NPRF).

Run. Only the days factor achieved significance in the run-measure analysis, *F*(19, 608) = 127.12, *p* < .001. As with the start measure, this significant effect demonstrated that all animals were running faster at the end of Acquisition than at the start.

Goal. Analysis of the goal speed measure yielded significance for the lead exposure, days, *F*(19, 608) = 100.76, *p* < .001, and reinforcement schedule x days, *F*(19, 608) = 1.93, *p* < .01, effects. Simple main effects analysis, employed to probe the significant interaction, yielded significance, smallest *F*(1, 608) = 4.17, *p* < .05, for the reinforcement schedule factor on Days 14-20. On these days the continuous reinforcement animals (Groups PBCRF and NCRF) approached the goal faster than did the partial reinforcement animals (Groups PBPRF and NPRF).

Total. Analysis of the total runway speed measure yielded significance for the days, $F(19, 608) = 135.83$, and reinforcement schedule x days, $F(19, 608) = 1.66$, $p = .037$, effects. Simple main effects analyses indicated that the continuous reinforcement animals (Groups PBCRF and NCRF) displayed significantly, $F(1, 608) = 5.72$, $p < .05$, faster total speeds than did the partial reinforcement animals (Groups PBPRF and NPRF) on Days 5-8.

Extinction

Start. Analysis of the start-measure of speeds during Extinction yielded significance for the reinforcement schedule, $F(1, 32) = 19.66$, $p < .001$, days, $F(19, 608) = 56.25$, $p < .001$, and reinforcement schedule x days, $F(19, 608) = 9.25$, $p < .001$, effects. Simple main effects analyses probed the significant interaction. The results of these analyses indicated that the partial reinforcement animals (Groups PBPRF and NPRF) started significantly faster, smallest $F(1, 608) = 5.53$, $p < .05$, than did the continuous reinforcement animals (Groups PBCRF and NCRF) on Days 2-13.

Run. Analysis of the run-measure speeds during Extinction yielded significance for the reinforcement schedule, $F(1, 32) = 28.78$, $p \le .01$, days, $F(19, 608) = 65.75$, $p < .001$, and reinforcement schedule x days, $F(19, 608) = 11.00$, $p < .001$, effects. Simple main effects analyses yielded significance, smallest $F(1, 608) = 6.22$, p

< .05, for the reinforcement schedule factor on Days 2-17. On these days the partial reinforcement animals (Groups PBPRF and NPRF) ran significantly faster than did the continuous reinforcement animals (Groups PBCRF and NCRF).

Goal. Goal-speed analysis yielded significance for the reinforcement schedule, $F(1, 32) = 14.63$, $p < .001$, days, $F(19, 608) = 62.34$, $p < .001$, and lead exposure x reinforcement schedule x days, $F(19, 608) = 4.59$, $p < .001$, effects. Simple main effects analyses incorporating the lead exposure and reinforcement schedule factors were employed to probe the significant triple interaction. These analyses yielded significance, smallest $F(1, 608) = 5.21$, $p < .05$, for the reinforcement schedule factor on Days 3-20. On these days the partial reinforcement animals (Groups PBPRF and NPRF) approached the goal significantly faster than did the continuous reinforcement animals (Groups PBCRF and NCRF). Additionally, the lead exposure x reinforcement schedule interaction achieved significance, smallest $F(1, 608) = 5.99$, $p < .05$, on Days 4-11 and 13-20. Of particular relevance to the present study, subsequent Newman-Keuls tests indicated that the lead-exposed partial reinforcement animals (Group PBPRF) approached the goal significantly ($p < .05$) faster than the water-exposed partial reinforcement animals (Group NPRF) on Days 8-11 and 13-20. Conversely, the lead-exposed continuous reinforcement animals (PBCRF) approached the goal significantly ($p < .05$) more slowly than did the water-exposed continuous reinforcement animals (Group NCRF) on Days 4-10.

Total. Analysis of the total runway speeds during Extinction yielded significance for the reinforcement schedule, $F(1, 32) = 42.22$, $p < .001$, days, $F(19, 608) = 76.72$, $p < .001$, and reinforcement schedule x days, $F(19, 608) = 12.55$, $p < .001$, effects. Simple main effects analyses yielded significance, smallest $F(1, 608) = 6.01$, $p < .05$, for the reinforcement schedule factor on Days 2-18. The total speeds of the partial reinforcement animals (Groups PBPRF and NPRF) were significantly faster than the total speeds of the continuous reinforcement animals (Groups PBCRF and NCRF) on these days.

Analysis Summary

Acquisition. The following points are highlighted by the Acquisition analyses: (a) a significant increase in speeds was shown in all measures (significant days effects), (b) continuous reinforcement resulted in superior performance on selected days in the start-, goal-, and total-speed measures (significant reinforcement schedule x days effects), and (c) lead exposure resulted in slower start speeds than did water exposure (significant lead-exposure factor).

Extinction. The Extinction analyses highlight the following points: (a) speeds decreased in a predictable manner as extinction progressed (significant days effects),

(b) partial reinforcement effects in which Groups PBPRF and NPRF extinguished slower than Groups PBCRF and NCRF were displayed in all measures (significant reinforcement schedule effects), (c) partial reinforcement effects were not shown on all days (significant reinforcement schedule x days interactions), and (d) predicted lead-engendered emotionality effects were displayed only in the goal measure analysis (significant lead exposure x reinforcement schedule x days interaction).

Graphic Representation. Because the general trends common to all measures, as well as the predicted effects of lead exposure, were found in the goal-measure analysis, these speeds were selected for graphic representation. Figures 1 and 2 present the goal-measure speeds for the four groups during Acquisition and Extinction, respectively. The increase in speeds and facilitative effects of continuous reinforcement during Acquisition are clearly visible in Figure 1. The general decrease in speeds shown by all groups, as well as the greater resistance to extinction shown by the partial reinforcement subjects (Groups PBPRF and NPRF) are depicted in Figure 2. Figure 2 also shows the predicted lead-engendered effects -- lead exposure increased resistance to extinction in partially reinforced animals and decreased resistance to extinction in continuously reinforced animals. Namely, Groups PBPRF displayed reliably faster speeds than did Groups NPRF on Day 8-11 and 13-20.

Conversely, Group PBCRF approached the goal more slowly than did Group NCRF on days 4-10.

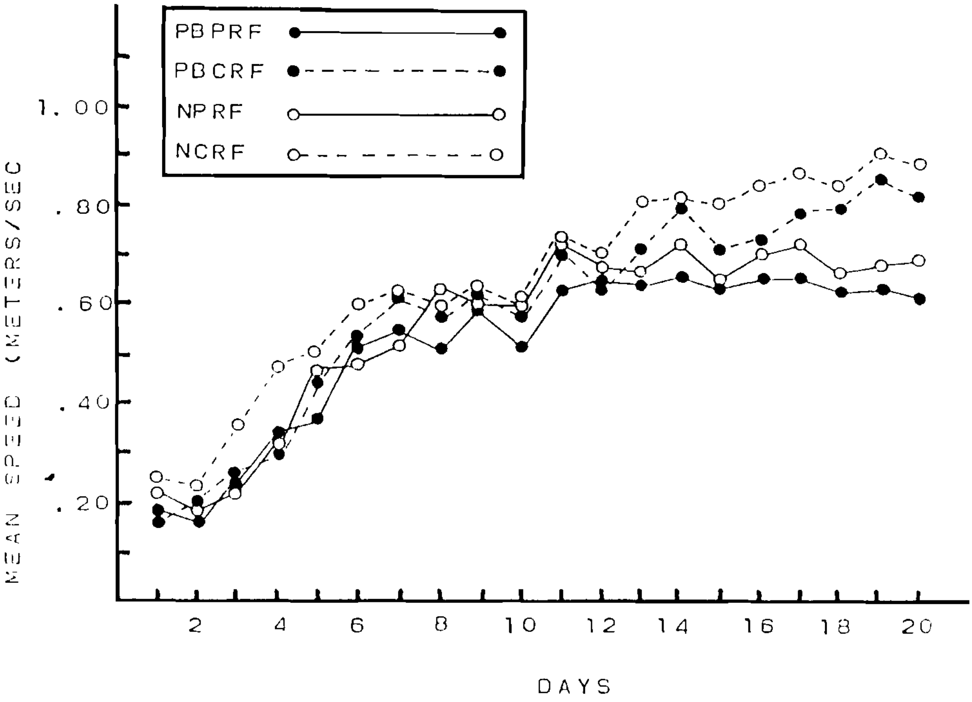

Figure 1 - Mean goal speeds (meters per second) for the lead-exposed partial reinforcement animals (Group PBPRF), lead-exposed continuous reinforcement animals (Group PBCRF), water-exposed partial reinforcement animals (Group NPRF), and water-exposed continuous reinforcement animals (Group NCRF) - Acquisition.

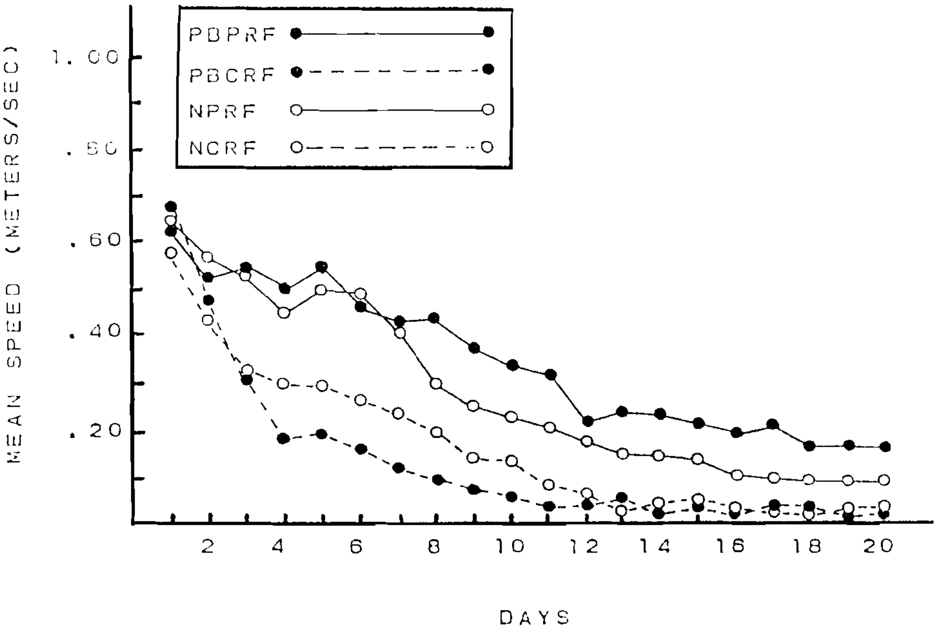

Figure 2 - Mean goal speeds (meters per second) for the lead-exposed partial reinforcement animals (Group PBPRF), lead-exposed continuous reinforcement animals (Group PBCRF), water-exposed partial reinforcement animals (Group NPRF), and water-exposed continuous reinforcement animals Group NCRF) - Extinction.

CHAPTER IV

Discussion

On a general level, the results of the present experiment replicate several well-established findings in the area of basic learning processes. During Acquisition the presence of food reinforcement resulted in an increase in the speed of making the instrumental running response. This increase in performance occurred in all three section measures of the alleyway, as well as the composite total performance measure.

A consideration of the Acquisition results also indicated that the type of reinforcement schedule, continuous versus partial, exerted some effect upon performance. More specifically, it was found that the receipt of partial reinforcement had a deleterious effect upon performance. Thus, the performance of Groups PBPRF and NPRF was inferior to that of Groups PBCRF and NCRF. Because these effects occurred only in the start and goal measures, it is arguable that type of reinforcement schedule may not exert a major, or at least consistent, influence upon Acquisition performance, especially in discrete-trial instrumental learning situations such as the straight runway. This contention is given further credence by data indicating that just the opposite pattern of results may occur (e.g., Goodrich, 1959). In such instances partial reinforcement has been shown to facilitate or enhance acquisition performance. As with the depressive effects that characterized the present data, these partial reinforcement acquisition effects (PRAEs) may not occur in all measured segments of the runway.

Less clear is an explanation for the finding that the lead-exposed animals started more slowly than the water-exposed animals did. One possibility is that the extra emotionality created by the lead ingestion resulted in an increase in the number of competing responses. Thus, when the start door was raised during Acquisition, the competing responses being shown by the lead-exposed animals (Groups PBPRF and PBCRF) interfered with performance of the locomotor response. As both lead- and water-exposed animals would be expected to make competing responses during extinction, the differential effects would not be expected to persist.

The finding that both groups of partial reinforcement animals (Groups PBPRF and NPRF) displayed significantly greater resistance to extinction replicated one of the most robust findings in the basic learning literature -- the partial reinforcement extinction effect (PREE). As noted previously, Amsel's (1958) frustration theory is well suited to account for the PREE. If one assumes that the receipt of partial reinforcement during Acquisition engenders frustration on nonreward trials and that interoceptive frustration cues may be conditioned to the instrumental approach response, then the PREE is explained by appealing to the function of these cues during Extinction. For animals experiencing partial reinforcement during Acquisition, frustration is a stimulus that has been associated with approaching the goal. Thus, these animals continue to approach the goal during Extinction due to the presence of the cues of frustrative nonreward. On the other hand, continuous reinforcement animals who experience frustration only during Extinction do not have these cues conditioned to the approach response. Hence, when Extinction is encountered the continuous reinforcement animals are repelled by the aversive frustration state that is created by experiencing nonreward in a situation where reward was expected.

This same logic may be appealed to in order to explain the significant lead-exposure effects that were noted in the goal measure during extinction. Here it was noted that Group PBCRF displayed speeds that were significantly slower than those of Group NCRF on several Extinction days. Conversely, Group PBPRF evidenced speeds that were significantly faster than Group NPRF on several days of Extinction. It is arguable that the added emotionality produced by the lead exposure resulted in an intensified frustration reaction. For Groups PBPRF the occurrence of this intensified reaction during Acquisition presumably contributed to the stronger conditioning of frustration cues to the instrumental response than in Group NPRF. Conversely, the intensified frustration reaction was experienced by the lead-exposed continuous-reinforcement animals when Extinction was begun. Thus, the added emotional component served to deter performance beyond the level exhibited by Group NCRF.

While the lead-exposure effects are well explained by the frustration theory account, one might question why they were displayed only in the goal measure. Again frustration theory provided an answer. Frustration theory postulates that frustration is engendered most strongly at the precise location where reward has been received but is not currently available. In the straight runway, this location is the goal box. Because the magnitude of the frustration response diminishes with increasing distance from the goal box, differential effects of this added emotionality also would be expected to dissipate and not be operative in the more distal run and start measures. These are the results that were observed in the present experiment.

Further research in this area could include investigating the effects certain drugs have on the effects attained. Specifically, utilizing pentobarbital injections prior to running would allow for the clarification of whether the effects found in this experiment are attributable to increased emotionality or to memory deficits. In addition, investigations could include use of an extended runway rather than the single runway. The reason behind both continuously reinforced groups (PBCRF and NCRF) demonstrating superior running during Acquisition, when compared to the partially reinforced groups (PBPRF and NPRF) also needs to be investigated. Lastly, understanding the reason why the continuously reinforced groups demonstrate significant differences early in Extinction while the partially reinforced groups demonstrated significant differences in the latter stages of Extinction requires more research.

This study supports the hypothesis that chronic ingestion of lead increases emotionality in a subject. This finding is in agreement with Winneke, Brockhaus and Baltissen (1977), a study in which the authors reported lead-exposed animals to be more restless and prone to overreaction. Further, this study supports the findings of Donald et al. (1987), Engellenner et al. (1986) and Burright, Engellenner and Donovick (1983). However, while all studies cited here report a consistent increase in emotionality, it should be noted that different studies employ difference behavioral tests and even different types of lead (lead acetate, pure lead, etc.). In addition, concentrations of lead may vary in the different projects. Thus, while the results are consistent, the reader should be cautioned against direct comparisons.

The area of lead research is growing and expanding, with new findings being reported on a regular basis. For example, the paint on bread bags contains lead and caution should be exercised if they are reused. This area of research is of special concern because of lead's proposed link to deficits in learning in children (Marlowe, 1985), along with the possibility that it may play a causal role in emotional disorders (Chaiklin, Mosher & O'Hara, 1985; Marlowe, Errera, Ballow & Jacobs, 1983; Marlowe, Errera, Stellern & Beck, 1983) and/or hyperactivity (David, Hoffman, Sverd, Clark & Voeller, 1976; Rimland & Larson, 1983). The present project suggests that this may indeed be the case. However, there is still much work to be done before there is a clear understanding of the issue.

References

Amsel, A. (1958). The role of frustrative nonreward in noncontinuous reward situations. Psychological Bulletin, 55, 102-119.

Baloh, R., Sturm, R., Green, B. & Gleser, G. (1975). Neuropsychological effects of chronic asymptomatic increased lead absorption: A controlled study. Archives of Neurology, 32, 326-330.

Barrett, J. & Livesey, P.J. (1985). Low level lead effects on activity under varying stress conditions in the developing rat. Pharmacology, Biochemistry & Behavior, 22, 107-118.

Burright, R. G., Engellenner, W.J. & Donovick, P.J. (1983). Lead exposure and agonistic behavior in adult mice of two ages. Physiology & Behavior, 30, 285-288.

Chaiklin, H., Mosher, B.S. & O'Hara, D.M. (1985). The social and the emotional in the etiology of childhood lead poisoning. Journal of Sociology and Social Welfare, 12, 62-78.

Cramer, K. (1966). Predisposing factors for lead poisoning. Acta Medica Scandinavia, 445, 56-59.

Cutler, M.G. (1977). Effects of exposure to lead on social behavior in the laboratory mouse. Psychopharmacology, 52, 279-282.

David, O.J., Hoffman, S.P., Sverd, J., Clark, J. & Voeller, K. (1976). Lead and hyperactivity. Behavioral response to chelation: A pilot study. American Journal of Psychiatry, 153, 1155-1158.

Dolinsky, Z.S., Burright, R.G. & Donovick, P.J. (1983). Behavioral changes in mice following lead administration during several stages of development. Physiology & Behavior, 30, 583-589.

Donald, J.M., Cutler, M.G. & Moore, M.R. (1987). Effects of lead in the laboratory mouse. Development and social behaviour after lifelong exposure to 12 M lead in drinking fluid. Neuropharmacology, 26, 391-399.

Donald, J.M., Cutler, M.G., Moore, M.R. & Bradley, M. (1986). Development and social behaviour after lifelong administration of a small dose of lead acetate in drinking fluid. Neuropharmacology, 25, 151-160.

Driscoll, J.W. & Stegner, S.E. (1976). Behavioral effects of chronic lead ingestion on laboratory rats. Pharmacology, Biochemistry & Behavior, 4, 411-417.

Driscoll, J.W. & Stegner, S.E. (1978). Lead-produced changes in the relative rate of open field activity in laboratory rats. Pharmacology, Biochemistry & Behavior, 8, 743-747.

Engellenner, W.J., Burright, R.G. & Donovick, P.J. (1986). Lead, age and aggression in male mice. Physiology & Behavior, 36, 823-838.

Finch, A.A. & Reiter, L.W. (1976). Alterations in social behavior in the rat during chronic low-level exposure to lead and tritium. Toxicology & Applied Pharmacology, 37, 160.

Geist, C.R. & Balko, S.W. (1980). Effects of postnatal lead acetate exposure on activity and emotionality in developing laboratory rats. Bulletin of the Psychonomic Society, 15, 288-290.

Goodrich, K.P. (1959). Performance in different segments of an instrumental response chain as a function of reinforcement schedule. Journal of Experimental Psychology, 57, 57-63.

Grover, C.A., Nation, J.R., Reynolds, K.M., Benzick, A.E., Bratton, G.R. & Rowe, L.D. (1990) The effects of cadmium on schedule-controlled responding for ethanol using the sucrose-fading procedure. Paper submitted for publication in Neurotoxicity.

Hanninen, H. (1982). Behavioral effects of occupational exposure to mercury and lead. Acta Neurologica Scandinavia, 66, 167-175.

Hastings, L., Cooper, G.P., Bornschein, R.L. & Michaelson, I.A. (1977). Behavioral effects of low level neonatal lead exposure. Pharmacology, Biochemistry & Behavior, 7, 37-42.

Lansdown, R., Yule, W., Urbanowicz, M. & Millar I.B. (1983). Blood lead, intelligence, attainment, and behavior in school children: Overview of a pilot study. Lead versus health, (pp. 267-296). London: John Wiley and Sons, Ltd.

Lanthorn, T. & Isaacson, R.L. (1978). Effects of chronic lead ingestion in adult rats. Physiological Psychology, 6, 93-95.

Marlowe, M. (1985). Low lead exposure and learning disabilities. Psychology, Psychiatry and Behavior, 13, 153-169.

Marlowe, M. & Errera, J. (1982). Low lead levels and behavioral problems in children. Behavioral Disorders, 7, 163-172.

Marlowe, M., Errera, J., Ballowe, T. & Jacobs, J. (1983). Low metal levels in emotionally disturbed children. Journal of Abnormal Psychology, 92, 386-399.

Marlowe, M., Errera, J., Stellern, J. & Beck, D. (1983). Lead and mercury levels in emotionally disturbed children. Journal of Orthomolecular Psychiatry, 12, 260-267.

Nation, J.R., Bourgeois, A.E. & Clark, D.E. (1983). Behavioral effects of chronic lead exposure in the adult rat. Pharmacology, Biochemistry & Behavior, 18, 833-840.

Nation, J.R., Bourgeois, A.E., Clark, D.E. & Elissalde, M. (1984). Effects of acute trimethyltin exposure on appetitive acquisition and extinction performance in the adult rat. Behavioral Neuroscience, 98, 919-924.

Nation, J.R., Dugger, L.M., Dwyer, K.K., Bratton, G.R. & Grover, C.A. (1990). The effects of dietary lead on ethanol-reinforced responding. Paper submitted for publication in Alcohol & Alcoholism.

Nation, J.R., Frye, G.D., Von Stultz, J. & Bratton, G.R. (1989). Effects of combined lead and cadmium exposure: Changes in schedule-controlled responding and in dopamine, serotonin, and their metabolites. Behavioral Neuroscience, 103, 1108-1114.

Nation, J.R., Grover, C.A. & Bratton, G.R. (1990). Lead attenuates the anti-punishment effects of ethanol. Paper submitted for publication in Alcohol.

Nation, J.R., Grover, C.A., Bratton, G.R. & Salinas, J.A. (1990). Behavioral antagonism between lead and cadmium. Neurotoxicology & Teratology, 12, 99-104.

Nation, J.R., Salinas, J.A., Pugh, K., Peltier, R. & Horger, B.A., Bratton, G.R. & Schenk, S. (1990). Cadmium toxicity and cocaine: interactions. Paper submitted for publication in *Neurotoxicity*.

Nation, J.R. (1990). Interaction of heavy metals and ethanol. Grant proposal submitted to the National Institute of Alcohol and Alcoholism.

Rimland, B. & Larson, G.E. (1983). Hair mineral analysis and behavior: An analysis of 51 studies. *16*, 279-284.

Winneke, G., Brockhaus, A. & Baltissen, R. (1977). Neurobehavioral and systemic effects of longterm blood lead-elevation in rats. I. Discrimination learning and open field-behavior. *Archives of Toxicology*, *37*, 247-263.

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