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Exploring Human Interaction and Diet Effects on the Behavior of Dogs in a Public Animal Shelter

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This study examined the effects of 2 manipulations—a brief, regular period of human contact and diet—on the behavior of dogs confined in a public animal shelter. A behavioral battery designed to assess reactions to novel situations, and a test of responsiveness to an unfamiliar human were administered both prior to (pretest) and immediately following (posttest) the 8-week intervention period. Overall, the regular periods of increased human contact together with a diet that contained augmented levels of digestible protein, fat, calories, and animal-derived ingredients reduced signs of behavioral reactivity from pretest to posttest. In some cases, the comparison diet appeared more effective, but only for dogs receiving minimal human interaction. The results indicate that a combination of human interaction and high quality diet may positively affect the behavior of dogs in animal shelters.

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Animal or rescue shelters provide a valuable service by housing stray, released, neglected, and injured nonhuman animals and by affording an opportunity for their subsequent adoption. Yet, even modern and well-run shelters present animals with an additional set of stressors or challenges that include confinement, novelty, separation from attachment figures, and a generally unpredictable and uncontrollable environment. Neuroendocrine evidence supports the idea that the shelter environment is stressful: Dogs admitted to a public shelter were found to exhibit protracted activation of the stress-responsive hypothalamic-pituitary-adrenal (HPA) axis (Hennessy, Davis, Williams, Mellott, & Douglas, 1997).

The experience of dogs in shelters is of concern, not only in terms of animal welfare but also for its potential effects on the behavior of the dog and, therefore, for the likelihood of a successful adoption. Confinement in cages has long been associated with the development of behavioral stereotypies in dogs and other species (Fox, 1965; Luescher, McKeown, & Halip, 1991; Mertens & Unshelm, 1996; Thompson, Melzack, & Scott, 1956). Furthermore, young dogs reared in shelter-like conditions for an extended period (4 to 6 months) may exhibit behavioral disturbance, such as extreme timidity, when adopted as companion animals (Scott, Stewart, & DeGhett, 1973).

Clinical experience indicates that stays in shelters, boarding kennels, or other forms of prolonged separation from attachment figures frequently precede development of extreme responses to separation (Voith & Borchelt, 1996b). Dogs adopted from shelters appear to be prone to behavior problems related to separation and play (Voith, Goodloe, Chapman, & Marder, 1993). Although such differences almost certainly reflect in part the population of dogs admitted to shelters, the shelter environment also probably contributes to these effects (Tuber et al., 1999). In sum, exposure to a shelter can reduce the immediate welfare of the dog and also may affect the probability of a successful adoption.

Here, we report the results of an exploratory study that evaluated two means of moderating the impact of shelter housing. We examined the independent and combined effects of behavioral and nutritional interventions on the behavior of dogs during an 8-week period in a public animal shelter. The behavioral intervention was a 20-min session of human interaction occurring 5 days each week. During this session, a handler provided a dog who was brought to a small room with quiet tactile contact followed by a period of positive-reinforcement-based training. This intervention was chosen because previous experience suggests that it can calm shelter dogs (Tuber et al., 1999), and because interaction of this sort can reduce HPA responses (Hennessy, Williams, Miller, Douglas, & Voith, 1998). Finally, the training provides a practical means of shaping desirable behavioral traits.

Informal observations made in the shelter prompted our dietary manipulation. In the course of work by one of the authors (Gary M. Davenport) on another topic, it was noted that the behavior or emotional state of dogs seemed to be affected by the diet they were fed. Specifically, dogs fed a high quality diet of the type designated as "premium" by industry standards (Case, Carey, Hirakawa, & Daristotle, 2000) appeared to become less distressed and agitated over an 8-week period. However, these observations clearly were prescientific in that objective behavioral measures and appropriate controls were lacking.

This study provided a more formal test of these observations. In addition to any main effects of diet or human contact on behavior, we also were interested in possible statistical interactions. It was reasoned that if diet were to have a beneficial effect on dogs, it might act by affecting the way in which they respond to human contact. The study evaluated the effects of the behavioral and dietary interventions on two general aspects of behavior important for successful adaptation to an adoptive home; that is, responses to unpredictable environmental events and to human companions.

METHOD

Subject Selection and Assignment

The subjects were 20 male and 20 female dogs admitted to the Montgomery County Animal Shelter in Dayton, Ohio, over a 9-month period. The potential pool consisted primarily of strays and dogs brought in by their caretakers for various reasons. Both intact and gonadectomized males and females (nonlactating) were included. Thus, the sample approximated the population of dogs commonly available at shelters. For a dog to be eligible for the study, a shelter veterinarian had to determine that the dog was in good health. Furthermore, the dog had to be a suitable candidate for adoption once the study had ended. This latter judgment was based largely on observations of the behavior of the dog by shelter staff and project personnel. To restrict the age range of subjects, dogs younger than 6 months of age as judged by inspection of dentition were excluded from the study. Because of the difficulty of documenting the source of many dogs brought to the shelter, no attempt was made to distinguish subjects on the basis of provenance.

On admission to the study, dogs were assigned to one of four groups defined by the factorial combination of two levels of human interaction (with and without the behavioral intervention) and two diets (the experimental diet and a comparison diet). Assignment was made in a quasi-random fashion with the following restrictions: Each group had to consist of five males and five females, and the average weight of dogs in the four groups had to be roughly equivalent. To provide some estimate of, and balance in, the phenotype of dogs in the study, a trained observer judged which of the seven American Kennel Club breed groups each dog best fit. This judgment represented a forced-choice procedure because many of the dogs possessed characteristics of more than one breed group. To the extent possible, given the other restrictions, dogs judged to be of the same breed group were distributed across the four groups of the experiment (Table 1).

The dogs were maintained in a dedicated room containing a bank of metal cages of various sizes (0.6 to 0.9 × 0.7 × 0.6 to 0.7 m) as well as two larger pens (1.5 × 0.8 × 1.9 m). Dogs were kept in cages or pens based on body size in accordance with how dogs were housed elsewhere in the shelter. The room was illuminated during daylight hours by a combination of artificial and natural lighting.

Interventions

The 8-week intervention period began on the dog's sixth day in the shelter. During the first 5 days (designated Week 0) dogs were evaluated for their suitability for the study, and the behavioral pretests (described later) were conducted. Figure 1 presents a schematic representation of the design of the study.

The behavioral intervention, herein referred to as the living room, occurred in a small room (7.1 m^2) located 19.5 m from the housing area in the shelter. The room was intended to simulate rooms to which the dogs were likely accustomed prior to admission to the shelter and to which they might be exposed following adoption. The room was carpeted, contained an additional rug as well as a desk and chair, and was illuminated by a lamp and overhead fluorescent fixtures. It adjoined the public waiting room and so was buffered from the noise of the animal housing area. Five days each week, trained handlers brought the designated dogs individually to the living room for 20 min during the afternoon. Each dog was exposed to the same handler for at least 70% of the dog's living room sessions. In each of the

TABLE 1
Number of Dogs Judged to Be in Various Breed Groups in Each Experimental Condition

	Experimental Condition			
	No Living Room		*Living Room*	
Breed Group	*Comparison Diet*	*Experimental Diet*	*Comparison Diet*	*Experimental Diet*
Herding	1	2	2	2
Hounds	3	2	4	3
Nonsporting	1	2	1	2
Sporting	2	2	2	1
Terriers	2	1	1	1
Toys	0	0	0	0
Working	1	1	0	1
Total	10	10	10	10

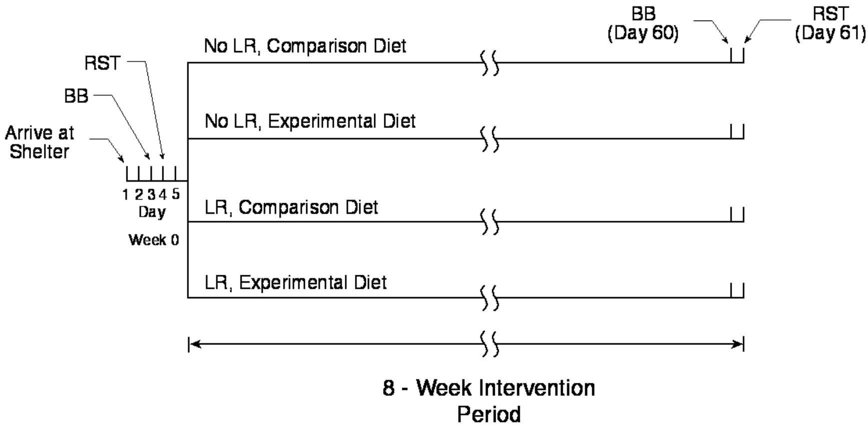

FIGURE 1 Schematic representation of the design of the study, including the timing of the behavioral battery (BB) and response to stranger test (RST). Dogs were either not exposed to the living room (No LR) or were exposed to the living room (LR) and were fed either the comparison or experimental diet over the 8-week intervention period.

two diet conditions, six dogs were exposed predominantly to a male handler, and four dogs were exposed primarily to a female handler.

During the first 3 min in the living room, the dog could explore freely. For the next 10 min, the dog was gently and slowly stroked and massaged while spoken to in a soothing manner (Hennessy et al., 1998; Tuber, 1986). At this time, the dog was encouraged to lie quietly on the rug. For the last 7 min, the dog was reinforced with food reward in an escalated appetitive training regime. Training began with simple tasks (come, sit) and progressed through more difficult exercises (remain seated while the human left and re-entered the room). During each training session, one half of a hot dog (Kahn's beef franks) sliced into small pieces was used as positive reinforcement. The diet of dogs not exposed to the living room was supplemented with one half of a hot dog 5 days each week. These hot dogs were the only supplement provided to the assigned diets. The study compared the final level of training reached by dogs of the two diet groups. All dogs in the study were given a 10-min outdoor walk on a lead, 5 days per week, for the duration of the study. Project personnel and shelter staff were instructed to minimize interaction with the dogs during walks, feeding, and cage cleaning. Nonetheless, the dogs in the two human interaction groups all received modest human interaction during these procedures and differed only in whether they were exposed to the living room.

To assess the effects of a high quality, premium diet, we chose for comparison a diet corresponding to the industry standard of "popular" (Case et al., 2000). Both diets met or exceeded daily minimum nutrient requirements established by the Association of American Feed Control Officials (1999), and both were capable of fulfilling the basic nutritional needs of the animal while avoiding any overt nutritional deficiencies. However, the experimental diet provided greater nutritional quality than did the comparison diet in terms of overall levels and digestibility of protein, fat, and calories as well as a higher percentage of animal-derived ingredients. The amount of diet offered to each dog was calculated to maintain body weight and condition based on the National Research Council (NRC; 1985) recommendation for estimating daily metabolizable energy requirements. That is, to compensate for differences in nutrient content per unit of food, dogs were fed more of the comparison diet.

The major ingredients contained in the diets are shown in Table 2. Table 3 displays the nutrient content and digestibility coefficients of each diet. The nutrient content of each diet reflects results from laboratory analyses conducted on representative samples of each diet using procedures established by the Association of Official Analytical Chemists (AOAC, 1984). The nutrient digestibility coefficients were determined by feeding these diets to a second panel of dogs (again, based on the NRC [1985] recommendation for estimating daily metabolizable energy requirements) and quantitatively collecting fecal and urinary excreta for nutrient analysis using AOAC procedures.

The experimental and comparison diets were administered beginning on the sixth day in the shelter. Prior to Day 6, dogs were fed a different diet, which varied depending on what was being provided by the animal shelter at that time. All project personnel and shelter staff were blinded to the identity of the experimental and comparison diets. Dogs who were obviously underweight on entry to the study were fed rations suitable for their estimated ideal weight. At the time of feeding, the amount of food remaining in the bowl from the previous day was recorded. Dogs were weighed each Friday for the monitoring of health and determination of ration size for the following week. Because dogs entered the study on different days of the week, these dates of weighing did not correspond to specific days relative to the start of the study. For purposes of analysis of weight change during the study, we used weights obtained on Day 5 (the last day of Week 0) and Day 61 (the last day of Week 8).

Behavioral Test Procedures

Behavioral battery. A behavioral battery that was nearly identical to that described in an earlier study (Hennessy et al., 2001) was used to assess reactions to startling or novel circumstances. The battery was administered on Day 3 (Week 0, pretest) and Day 60 (Week 8, posttest) and was conducted in a wooden building with a concrete floor located in close proximity to the shelter. Two 1.6-m high walls were joined to two inside walls of the building to create a 5.5 × 5.7 m test arena. In one corner of the arena was a permanent observation booth (occupying 1.4 m^2 of

TABLE 2
Major Ingredients, Categories of Ingredients, and Percentage of Total Ingredients for the Two Diets (in Descending Order of Contents Within Each Category)

	Comparison Diet		Experiment Diet	
Category	*Ingredient*	*%*	*Ingredient*	*%*
Animal-based protein		17.9		44.6
	Meat and bone meal		Chicken	
			Fish meal	
			Dried egg	
Vegetable-based protein		13.5		0
	Soybean meal			
	Corn gluten meal			
Carbohydrate		59.3		35.8
	Ground corn		Ground corn	
			Grain sorghum	
			Brewer's rice	
Fat		4.8		6.9
	Animal fat		Poultry fat	
			Ground flax	
			Menhaden oil	
Other		4.5		12.8
	Wheat flour		Beet pulp	
	Wheat midds		Flavor digest	
	Flavor digest		Dicalcium phosphate	
	Sodium chloride		Potassium chloride	
	Calcium carbonate		Brewer's yeast	
	Dicalcium phosphate		Sodium chloride	
	Vitamins		Magnesium sulfate	
	Minerals		Choline chloride	
			Calcium carbonate	
			DL-methionine	
			Vitamins	
			Minerals	

floor space) formed by plywood walls that extended perpendicularly into the arena from each of the two intersecting arena walls to meet at a right angle. Each of the plywood walls contained a 0.5 m^2 viewing window located 1.8 m above the floor. The remaining portion of the arena floor was marked off with lines of tape 0.9 m apart to form squares for estimating activity.

The battery was divided into four phases (Table 4). The first assessed the initial reaction of being placed alone into the novel test arena. Phase 2 was concerned with the dog's reaction to an unfamiliar person. Phases 3 and 4 addressed how the dog would respond to startling stimuli in the novel environment. Behaviors scored

TABLE 3
Nutrient Content and Digestibility of the Diets

Nutrient	*Comparison Diet*	*Experimental Diet*
Protein	23.0	29.9
Fat	10.1	20.5
Moisture	7.5	8.0
Crude fiber	3.2	1.9
Carbohydrate	47.2	32.2
Ash	9.0	8.0
Calcium	1.4	1.0
Phosphorus	1.1	1.0
Metabolizable energy	3.3	3.9
Animal derived ingredients	25.7	53.6
Cereal derived ingredients	72.8	36.6
Digestibility		
Dry matter*	85.4	90.3
Organic matter*	88.5	92.8
Protein*	88.4	94.0
Fat*	89.4	94.5
Carbohydrate	90.5	91.2
Digestible energy*	88.6	93.5
Metabolizable energy*	84.9	90.3

Note. All are given in percentages except metabolizable energy (Kcal/g).
*$p < .001$ for the comparison diet versus the experimental diet by least squares means test in the panel of dogs used to determine digestibility.

TABLE 4
The Four Phases of the Behavioral Battery

Phase	*Description*
1	Dog is placed alone into arena and behavior is scored for 2 min.
2	Unfamiliar woman stands motionless in center of arena for 2 min. She walks around perimeter of arena for 1 min. Behavior is scored throughout. Woman leaves.
3	Phase is preceded by 30-sec period during which observer activates remote-controlled toy car located in arena to repeatedly approach dog. The car is inactivated and behavior is scored for 2 min.
4	Phase is preceded by blast of airhorn; behavior is scored while dog is alone in arena for 2 min.

during each phase (Table 5) were determined by the focus of each phase and the restriction that the behaviors had to be accurately scored by a single observer.

Testing always occurred at the conclusion of the dog's scheduled 10-min walk. The person walking the dog brought the dog into the building and to the gate of the arena. The lead was then removed, and the dog was placed in the arena and observed there for 2 min (Phase 1). To begin Phase 2, a woman who was unfamiliar to the dog entered through the gate and walked slowly to the middle of the arena where she stood for 2 min. At the end of the 2 min, the woman walked slowly to a point in front of the gate, and then around the entire perimeter of the arena (total walking time = 1 min) before exiting through the gate. Following Phase 2, the observer activated a remote-controlled toy car located in one corner of the arena and moved it in the direction of the dog. If the dog did not retreat, the car was made to approach the dog repeatedly. No attempt was made to contact the dog with the car. After 30 sec of movement, the car was sent back to its starting location, and the dog was observed for 2 min (Phase 3). To begin Phase 4, an airhorn was sounded through a small hole located near the floor, midway along one long wall of the arena. Behavior was recorded during the next 2 min.

Response to stranger test. To more completely assess the dog's response to an unfamiliar human, each dog was examined for 10 min with an unfamiliar woman (stranger) on Day 4 (Week 0, pretest) and on Day 61 (Week 8, posttest). Following a 10-min walk, testing took place in a portion of the arena used for the behavioral battery. The two ends of a length of chain fencing were attached to intersecting walls of the arena to form a 6.5 m^2 test area. The stranger sat quietly on a stool in a corner of this area. The dog was taken off the lead and placed into the test area. The woman was instructed to pet the dog slowly (1 stroke per sec) when the dog was within arm's reach. If the dog jumped on the woman, she was instructed to say "down" and to push the dog gently back to the floor.

The observer, located in the observation booth, recorded the number of seconds that the dog panted and the number of times the dog yawned and licked (scored separately for licking self, the stranger, inanimate objects, and nondirected licking). The stranger used a stopwatch to score the number of seconds in physical contact with the dog (other than the petting hand). In addition, an overhead video camera (Panasonic WV–BP310 with Panasonic lens WV–LA210C3; VCR: Panasonic AG–7350) recorded the test session. The tapes were scored to determine the number of seconds spent in contact or proximity to the person (within one square), walking, or lying down. After each behavioral test, any feces were removed, and a mop and detergent were used to remove traces of feces or urine.

Women were used as strangers in this test and the behavioral battery to preclude any effect of differential response by the dogs to men and women and because more women than men were available for this purpose. The woman serving as a stranger for a dog never interacted with the dog at other times. To minimize any ef-

TABLE 5
Behaviors Observed in the Battery

Behavioral Measure	*Brief Definition*	*Phases Observed*
Line-crossing	Number of times all four feet cross line on floor	1, 3, 4
Escape	Number of bouts of movement suggesting intent to jump or climb over, dig under, or squeeze or break through walls or door of arena	1, 3, 4
Jump	Number of times dog completely leaves ground or rears up on hind legs other than apparent attempts at escape	1
Vocalization	Number of discreet vocalizations	1
Latency to contact person	Number of seconds until dog makes physical contact with handler standing in center of arena (no contact scored 120 sec)	2
Stranger contact	Number of seconds in physical contact with stranger (scored by stranger)	2
Stranger proximity, stationary	Number of seconds within one square (created by lines on floor) of stranger while stranger is stationary	2
Stranger proximity, walk	Number of seconds within one square of stranger while stranger walks about perimeter of arena	2
In far corners	Number of seconds that dog is in corners farthest from the car or horn (three corners: intersection of observation blind with far wall and perpendicular wall; intersection of far wall with other perpendicular wall[a]	3, 4
Latency to contact car	Number of seconds from cessation of car's movement until dog makes contact with car (no contact scored as 120 sec)	3
Latency to approach horn	Number of seconds from horn blast until dog enters .5-m radius semicircle centered about aperture in wall through which horn blast is projected (no approach scored as 120 sec)	4
Approach	Number of movements in direction of car (following cessation of car movement) or horn (following sounding of horn)	3, 4
Withdrawal	Number of movements in direction opposite car (following cessation of car movement) or horn (following sounding of horn)	3, 4

[a]This measure corresponds conceptually to “in door well” from Hennessy et al. (2001), but actual behaviors differ due to physical differences in the test areas used for this and the earlier study.

fect of individual differences in the behavior of the women, they followed regimented protocols of behavior and always wore a white lab coat. The same woman typically served as the stranger in the pretest and posttest for a particular dog in a particular test.

Data Analysis

Because this was an exploratory study, a large number of behavioral measures were included. For the behavioral battery and response to stranger test, each measure had to be assessed for effects of both diet and human interaction (only effects of diet could be assessed on the training measures because only dogs receiving human interaction were trained). Two steps were taken to simplify analyses while still focusing on the primary question of whether behavior changed during the intervention period. First, difference scores (posttest minus pretest) were used to analyze behavior in the battery and response to stranger tests. When significant differences were obtained, pretest scores were then examined to determine if the groups had diverged from similar baselines. Second, because subjects were a heterogeneous assortment of intact and gonadectomized, prepubertal, and adult dogs, sex was not treated as a variable in analyses. Nonetheless, sex was balanced across groups (five males and five females in each group).

Parametric tests—analysis of variance (ANOVA) and *t* tests for comparison of two groups—were used when appropriate. ANOVAs included the between-subject factors of human interaction and diet. The within-subjects variable of weeks was included in tests of diet consumption and weight gain. In repeated measures ANOVAs, the Mauchly test was used to assure that sphericity was not a problem. Significant interactions were further analyzed with tests for simple main effects (Winer, 1971). If distributions violated assumptions for ANOVA procedures, data were transformed or nonparametric tests (Mann-Whitney *U*) were used. A two-tailed probability level of $p = .05$ was considered significant throughout.

RESULTS

Diet Consumption, Body Weight, and Training

The percentage of diet eaten across weeks is illustrated in Figure 2. Data were subjected to arcsine transformation prior to analysis. Although there was a tendency for dogs to consume a greater percentage of the experimental diet than the comparison diet during the first 2 weeks in the study, a three-way ANOVA (Human Interaction × Diet × Weeks, with the last factor treated as a repeated mea-

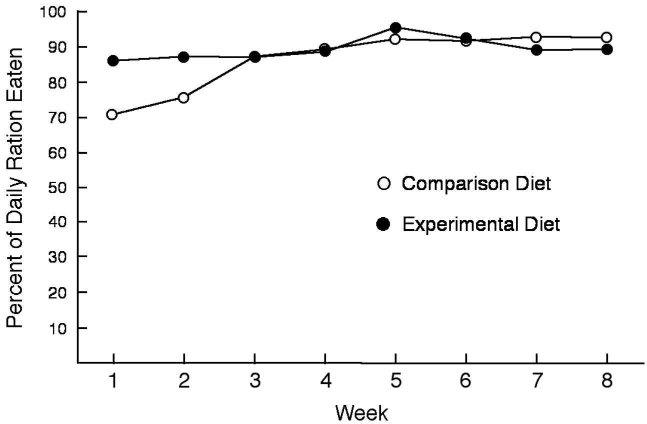

FIGURE 2 Mean daily percentage of the comparison diet and the experimental diet consumed by dogs during the 8-week intervention period.

sure) yielded only a significant effect of weeks, $F(5, 162) = 4.64$, $p = .001$, reflecting greater consumption as the study proceeded.

Dogs generally gained weight during their stay in the shelter, particularly if they were given the experimental diet. Whereas 13 of 20 dogs (65%) provided the comparison diet gained weight, 18 of 20 dogs (90%) given the premium, experimental diet did so. A differential effect of diet on weight gain was confirmed in ANOVA by a significant Diet × Weeks interaction, $F(1, 36) = 7.37$, $p = .01$ (see Figure 3). Tests for simple main effects showed that there was a significant increase in weight across the treatment period for dogs given the experimental diet ($p < .01$), but not for dogs given the comparison diet.

Overall, the dogs readily learned new tasks in the living room. However, there was no difference in final level of training achieved by dogs fed the two diets, $t(18) = 1.06$, $p > .10$.

Behavioral Battery

Analyses of individual measures in the behavioral battery resulted in one significant effect: a main effect of diet on line crossings in Phase 4, $F(1, 36) = 6.87$, $p < .05$. As seen in Figure 4, activity in Phase 4 diminished across the study for those dogs given the experimental diet, but not for those dogs given the comparison diet.

The following derived measures also were analyzed: suppression of locomotion in Phases 3 and 4 (line crossings in Phase 1 minus line crossings in Phase 3; line crossings in Phase 1 minus line crossings in Phase 4), total line crossings, and total escape attempts (sum of line crossings or escape attempts, respectively, during the three phases—1, 3, and 4—in which line crossings and escape attempts were assessed). These analyses revealed a significant Human Interaction × Diet interaction for escape attempts, $F(1, 36) = 5.47$, $p < .05$. As seen in Figure 4, this was due to a relative reduction in escape attempts across the 8-week intervention period for those dogs exposed to human interaction and the experimental diet. Tests for simple main effects revealed that the experimental diet significantly reduced escape attempts among dogs exposed to the human interaction treatment ($p < .05$). There was no significant effect of diet for those dogs not provided supplemental human interaction. Because of the effect of diet on line crossings in Phase 4, we were particularly interested in whether line crossings over all phases would be reduced. This effect was found to be marginally significant, $F(1, 36) = 3.10$, $p < .09$.

Because our earlier study employing a factor analysis procedure with a test nearly identical to the battery used here indicated that a small group of factors could account for most of the variance, we also assessed the effect of the living room and diet on the five factors derived from the previous study—locomotor activity, flight, sociability, timidity, and wariness (Hennessy et al., 2001)—and computed by combining *z* scores of individual measures. For these factors, the only effect that approached significance was a tendency for the experimental diet to reduce locomotor activity (sum of *z* scores for line crossings in Phase 1 + line crossings in Phase 3 + line crossings in Phase 4 + approaches in Phase 3 + approaches in Phase 4 + withdrawals in Phase 3 + withdrawals in Phase 4), $F(1, 36) = 3.41$, $p < .08$.

Response to Stranger Test

There were several significant effects in the test of responsiveness to the stranger (Figure 5). Significant Human Interaction × Diet interactions were obtained for the change from pretest to posttest in seconds panting, $F(1, 36) = 7.49$, $p = .01$, and number of yawns, $F(1, 36) = 5.04$, $p < .05$. For those dogs not ex-

FIGURE 3 Mean body weight of dogs fed the two diets on the day prior to the initiation of the intervention period (Day 5) and on the last day of the intervention period (Day 61). Vertical lines indicate the standard errors of the means. Dogs fed the premium experimental diet, but not dogs fed the popular comparison diet, gained weight during the intervention period ($p < .01$).

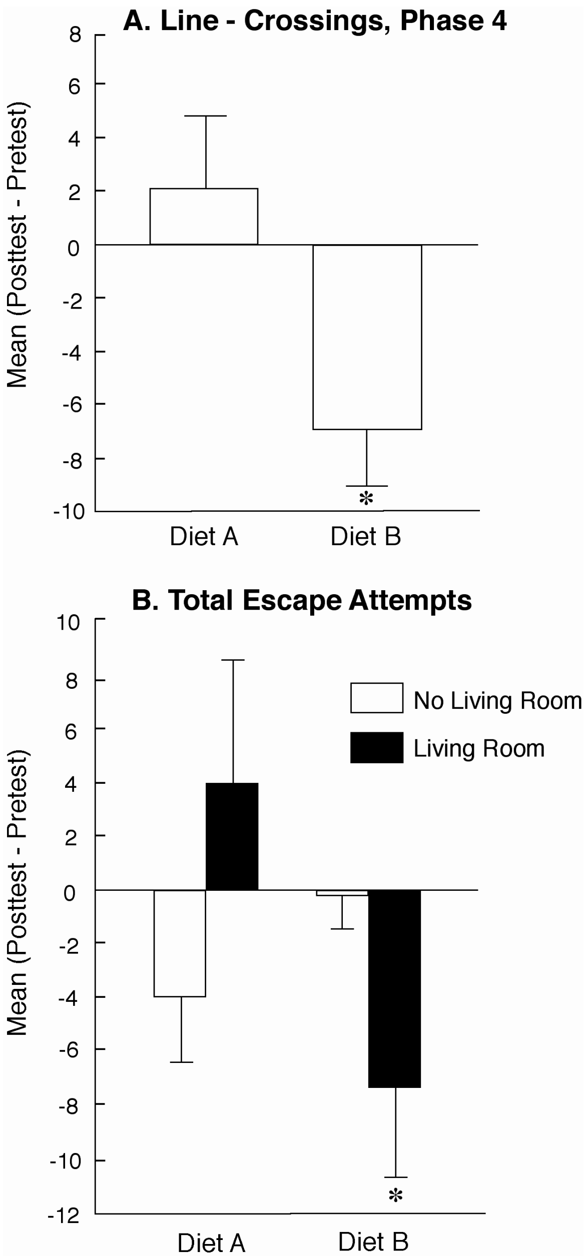

FIGURE 4 Mean difference scores (posttest – pretest) for significant effects in the behavioral battery. Vertical lines represent standard errors of the means: (a) line crossings during Phase 4, * $p < .05$ versus comparison diet; (b) total escape attempts, * $p < .05$ versus comparison diet, living room.

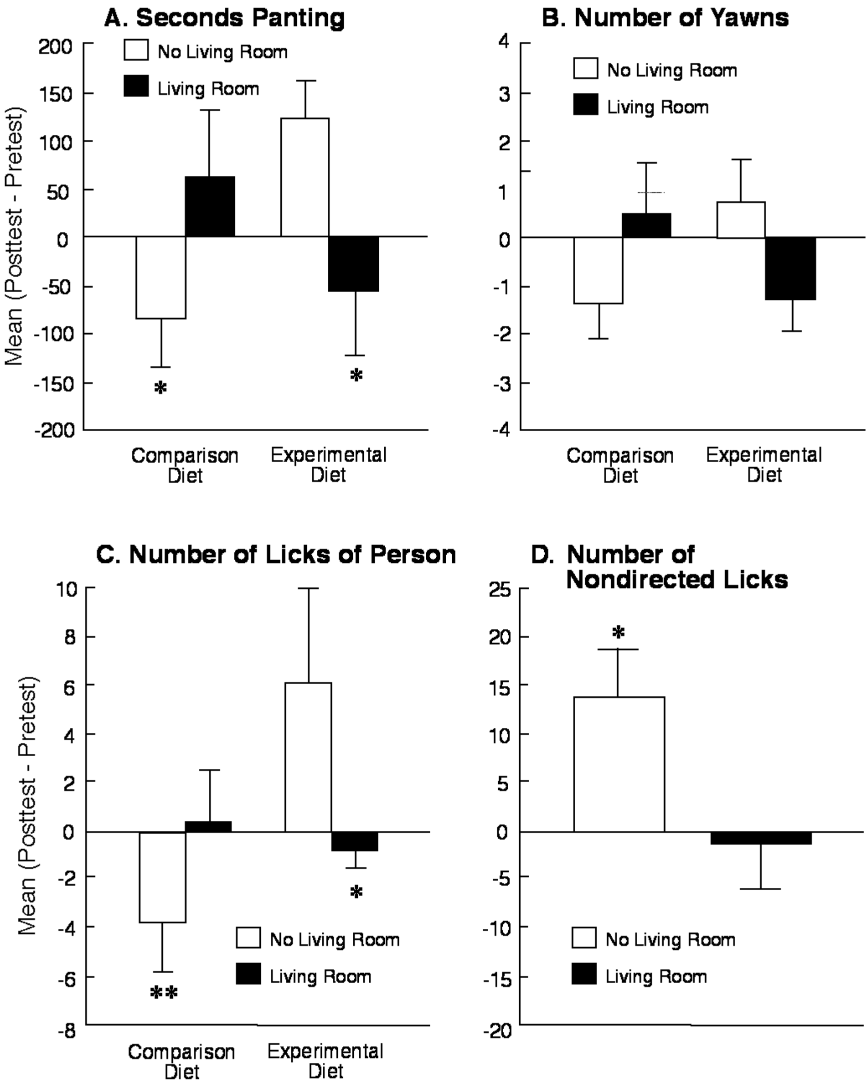

FIGURE 5 Mean difference scores (posttest – pretest) for significant effects in the response to stranger test. Vertical lines represent standard errors of the means: (a) seconds panting, $*p < .05$ versus the experimental diet, no living room; (b) number of yawns; (c) number of licks of person, $*p < .05$, compared to the experimental diet, no living room, $**p < .01$, compared to the experimental diet, no living room; (d) number of nondirected licks, $*p < .05$, compared to living room.

posed to the living room, there was a relative reduction in seconds spent panting from pretest to posttest if fed the comparison diet and a relative increase in panting over this time if fed the experimental diet ($p < .05$). This pattern tended to reverse for dogs exposed to the living room. A similar pattern was evident for the number of yawns, although tests for simple main effects were not significant.

These interactions also were assessed by examining how the living room affected behavior within each diet condition. For dogs fed the comparison diet, there was no significant effect of the living room on seconds spent panting. For dogs fed the experimental diet, the difference between the relative increase in panting from pretest to posttest, if not exposed to the living room, and the relative decrease in panting from pretest to posttest, if exposed to the living room, was significant ($p < .05$). For yawns, there again were no significant simple main effects.

Licking of the stranger also showed a similar pattern, although because of the large number of "zero" scores, nonparametric tests were required for this measure. These indicated that among dogs not exposed to the living room, there was a relative reduction in licking of the stranger from pretest to posttest, if dogs were fed the comparison diet, and a relative increase in licking of the stranger across this period, if dogs were fed the experimental diet ($p < .01$). Furthermore, the relative increase in licking the stranger from pretest to posttest in dogs fed the experimental diet was eliminated if the dogs had been exposed to the living room manipulation ($p < .05$).

For nondirected licking, an ANOVA revealed a main effect of human interaction, $F(1, 36) = 5.21$, $p < .05$, reflecting a relative increase from pretest to posttest in nondirected licking among those dogs not exposed to the living room, but not among those dogs exposed to the living room. For seconds in contact with the stranger, the main effect of diet approached significance, $F(1, 36) = 3.83$, $p < .06$. Those dogs fed the comparison diet showed a relative increase in seconds in contact from pretest to posttest ($M = 49.4$, $SE = 42.4$ sec), whereas dogs fed the experimental diet showed a relative decrease in this measure over the same period ($M = –73.1$, $SE = 46.0$ sec).

Analysis of Pretest Scores

A series of ANOVAs and Mann-Whitney *U* tests were carried out on pretest scores for all measures on which difference scores were found to be significant. The only effect that approached significance was a tendency for fewer total escapes during the pretest for dogs not exposed to the living room if given the experimental diet than if given the comparison diet ($p < .06$).

DISCUSSION

This study found effects of both a program of human interaction and diet on the behavior of dogs confined in a public animal shelter. Line crossings in the last phase of the behavioral battery were reduced in the posttest relative to the pretest if the dogs had been fed the experimental diet, which provided higher overall levels—and greater digestibility—of protein, fat, and calories as well as a higher percentage of animal-derived ingredients. This effect did not reflect a reduction in activity in response to the airhorn in Phase 4 by dogs fed the experimental diet: A direct assessment of reduction in line crossings in Phase 4 relative to Phase 1 was not significant. Rather, it appears that dogs fed the experimental diet showed a general reduction in activity in the test arena from pretest to posttest, and this difference reached significance in Phase 4. The marginally significant effects of diet on line crossings totaled across Phases 1, 3, and 4, and on the factor of locomotor activity support this conclusion. We would argue, therefore, that the reduction in activity most likely reflects a calming influence of the experimental diet and not behavioral "freezing" in response to the airhorn.

The experimental diet also reduced the number of escape attempts made during the behavioral battery, but only in dogs that also had been given regular exposure to the living room. In the response to stranger test, we found a main effect of the living room manipulation. Those dogs exposed to this quiet, human contact on a regular basis showed fewer instances of nondirected licking in the posttest relative to the pretest than did dogs not given these supplemental periods of human interaction. Nondirected licking consisted primarily of protruding and then retracting the tongue, a common sign of uneasiness or anxiety in dogs (Voith & Borchelt, 1996a). Together, these results suggest that a high quality diet and a regular, but limited, period of supplemental human interaction can have a calming influence on dogs housed in a public shelter. The interventions appeared to act both independently (fewer line crossings by dogs fed the experimental diet and less nondirected licking by dogs exposed to the living room) and conjointly (fewer escape attempts by dogs fed the experimental diet only if they had been exposed to the living room).

Although there were no other significant main effects in the response to stranger test, there were significant interactions for the measures of seconds spent panting (often indicative of anxiety or fear; Voith & Borchelt, 1996a), number of yawns (a possible displacement behavior indicative of conflict; Voith, McGrave, & Marder, 1987), and the number of instances that dogs licked the stranger in the response to stranger test (a measure of solicitation of human contact in a threatening situation, and therefore, a potential measure of reactivity to the novel environment). In each case, apparent reactivity in the novel environment tended to be reduced in the posttest relative to the pretest in dogs not exposed to the living room, if they had been fed the comparison diet, and in dogs exposed to the living room, if they had been fed the experimental diet (Panels A to C of Figure 5).

The differences were particularly pronounced for those dogs not exposed to the living room. Visual inspection of the number of dogs in each group who showed a particular direction of effect (an increase, a reduction, or no change from pretest to posttest) indicated that the significant interactions could not be accounted for by a small number of dogs in certain groups showing especially large changes.

One interpretation for these results, as well as for the reduction in escape attempts in the behavioral battery by dogs both fed the experimental diet and exposed to the living room, is that the experimental diet somehow affected the sociability of the dogs such that they benefitted more from the human contact provided in the living room and were more negatively affected by deprivation of this contact. On the other hand, not all of the experimental diet's effects can be accounted for in this manner because the diet also reduced reactivity irrespective of whether dogs were exposed to the living room. This is indicated by the main effect of diet on line crossings in Phase 4 of the behavioral battery and also is suggested by the marginally significant reduction by the experimental diet relative to the comparison diet in seconds in contact with the stranger in the response to stranger test (another measure of solicitation of human interaction in a threatening situation).

In an earlier laboratory study, Miller (1991; Tuber et al., 1999) used a living room procedure to shape social behavior that was judged to be desirable in adopted puppies. Human contact was made contingent on the emission of solicitation behaviors (e.g., licking, nosing, pawing the person). Under those conditions, the living room increased later quiet contact with humans in an unfamiliar environment. In the living room procedure of this study, the human contact provided juvenile and adult dogs was not made contingent on solicitation behavior. Therefore, it is not surprising that the living room did not increase contact, licking of the stranger, or other solicitation behaviors in either behavioral test of this study.

Previous studies have suggested that heightened levels of dietary protein can promote aggressiveness in some dogs (DeNapoli, Dodman, Shuster, Rand, & Gross, 2000; Dodman et al., 1996). In this study, any dog who displayed signs of aggression on admittance to the shelter was not considered suitable for adoption and, therefore, was not included in the pool of potential subjects. Among our subjects, frank aggression was never observed in either the behavioral tests or the living room. Moreover, as indicated earlier, the results suggest that the experimental diet, which provided the greatest amount of protein, actually enhanced the positive effect of the living room procedure. In sum, among our sample of dogs selected for nonaggressiveness, no suggestion of diet-induced aggression was obtained.

The specific means by which the dietary manipulation affected behavior in this study remains uncertain. The better nutrition furnished by the experimental diet could have reduced the reactivity of the dogs so that they were less active in a novel environment and were better able to attend to, and benefit from, the human interaction provided in the living room. The lack of significant weight gain in the dogs fed the comparison diet suggests an alternative account—that dogs fed the comparison diet simply were hungry, and that differences in hunger might have somehow led to observed differences in behavior. Two pieces of evidence argue against this second interpretation. First, although the overall weight gain of dogs fed the comparison diet was not significant, 13 of the 20 dogs fed this diet showed an absolute increase in weight. Second, if dogs fed the comparison diet had been hungrier than those fed the experimental diet, one would expect dogs given the comparison diet to eat all of their food, or at least a larger percentage of the diet offered than would dogs given the experimental diet. This was not the case. As Figure 2 illustrates, dogs on average ate most, but not all, of whichever diet was offered to them, and the percentage of offered food eaten did not differ between groups.

Research in the same (Hennessy et al., 2002) as well as another (Hennessy et al., 1998) population of shelter dogs has documented the effectiveness of the procedures used in the living room for moderating HPA responses. The reduction in nondirected licking by dogs exposed earlier to the living room and the reduction in escape attempts by dogs both previously exposed to the living room and provided the experimental diet suggest that the living room also can positively affect the later behavior of dogs in a shelter beyond any change in specific behaviors shaped by the training. Furthermore, the behavioral training affords a means to correct identified behavioral problems and to promote basic skills (sit, stay) that should ease the dog's transition into an adoptive home. The relatively modest investment of time (20 min per day, 5 days per week) and space (one small room) could make the procedure feasible in some shelters, particularly those with volunteer programs in place.

Several limitations of this study should be noted. First, the independent variables represent complex manipulations of behavioral and dietary factors. The critical components of these manipulations remain to be determined. Second, because of the exploratory nature of the study, conclusions reached here should be confirmed in future work. Nonetheless, the results suggest that the program of human interaction together with the high quality diet can calm and reduce the anxious behavior of dogs in animal shelters. Because behavior problems are commonly cited as a reason for relinquishing dogs to shelters (Salman et al., 1998), the reduction of behaviors that are generally considered problems in the home (escape attempts) also potentially could improve adoption success. Earlier work has suggested that housing dogs in groups can improve their behavior, not only in the kennel but also in the adoptive home (Mertens & Unshelm, 1996). Whether effects of human interaction and diet observed here would persist into the adoptive home also remains to be evaluated.

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