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Providing Social Contacts and Objects for Nibbling Moderates Reactivity and Oral Behaviors in Veal Calves¹

Isabelle Veissier*, P. Chazal†, P. Pradel‡, and P. Le Neindre*

*INRA, Centre de Clermont-Ferrand-Theix, Laboratoire Adaptation des Herbivores aux Milieux, 63122 Saint-Genès Champanelle, France; †ENITA de Clermont-Ferrand, Marmilhat, 63370 Lempdes, France; and ‡INRA, Centre de Clermont-Ferrand-Theix, domaine de Marcenat, 15190 Marcenat, France

ABSTRACT: The aim of this work was to assess the role of social and physical enrichment in the adaptation of veal calves to their environment. We compared calves housed in individual stalls that varied in the extent of contacts they allowed between neighbors (16 calves: open partitions; 16 calves: solid partitions; 32 calves: solid and extended partitions preventing all contact). All but 16 out of the 32 isolated calves were provided with a piece of tire and a chain, objects they could easily nibble. We assessed time budget, behavioral reactions to a water throw, neuroendocrine responses to stress (ACTH challenge and catecholamine synthesis), health, and growth. Calves kept in isolation displayed more startled

reactions (16 isolated calves vs 5 non-isolated calves were startled by the throw, $P < .05$). Calves without objects spent more time nibbling at the feeding grille (5 vs 3% time, $P < .01$), licking their lips and tongue-rolling (7 vs 4% time, $P < .05$). Social contacts and the provision of objects had no incidence on neuroendocrine measurements and growth. Contacts with neighbors resulted in a slight but nonsignificant rise in disease. Depriving calves of social contacts increases behavioral reactivity, probably because there are no peer animals through which reactions can be moderated, and the lack of adequate objects to nibble promotes self-directed activities.

Key Words: Calves, Behavior, Neurohormones, Stress, Veal

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Introduction

The effects of social contacts between calves have been indirectly documented by comparisons of animals kept in individual stalls with those housed together in pens (Dantzer et al., 1983; de Wilt, 1985; Friend et al., 1985). Both social and physical factors vary between pens and stalls; even when animals have the same space, calves in pens can move more easily than those in stalls. We assessed the effect of interaction between calves in stalls that varied in the extent of contacts they allowed between neighbors.

The optimal stimulation theory postulates that individuals adapt their behavior to maintain optimal

levels of arousal, increasing their activity and reactivity when stimulus input is low (Zentall and Zentall, 1983). In addition, a bare environment produces a greater incidence of purposeless activities (Wemelsfelder, 1993). We thus focused our study on reactions to distracting stimuli, and on oral activities, which are extensively developed in veal calves (Webster et al., 1985; Wiepkema et al., 1987). To encourage nibbling, we gave tires and chains to the calves. Some calves did not have access to these objects and hence were expected to develop more self-directed activities (Dantzer, 1986).

The impact on welfare was also assessed on the basis of health, growth, and neuroendocrine responses to stress, changes that are due to stress greater than that which modifies behavior alone.

Materials and Methods

Animals and Management

Sixty-four Holstein or Montbeliard (a French dairy breed) calves were used in the experiment. They were reared in two batches of 32, one in 1993 and the other

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Table 1. Housing conditions and number of calves from each breed^a in the two batches

Treatment	Social contacts	Tire and chain	1993	1994
1	+ +	+	5 Ho + 3 Mo	5 Ho + 3 Mo
2	+	+	5 Ho + 3 Mo	5 Ho + 3 Mo
3	0	+	4 Ho + 4 Mo	4 Ho + 4 Mo
4	0	0	5 Ho + 3 Mo	5 Ho + 3 Mo

^aHo = Holstein, Mo = Montbeliard.

in 1994. They were trained to drink milk from a bucket before they entered the experimental building. From about 2 wk of age, they were housed in an air-controlled room (temperature, 12 to 15 °C; air turnover, 1,600 to 10,000 m³/h with air speed below 1 m/s; lights on from 0700 to 1730). The room contained 32 individual wooden stalls, .90 × 2.00 m, placed on a slatted floor and separated by a central alley. In each batch, eight calves (treatment 1) were placed in stalls with open partitions (125 cm high, slat and slot 10 cm), through which they could see and sniff their neighbors. Adjacent animals could also lick and suck the nose or ears of each other through the front of the stall. Another eight calves (treatment 2) were in stalls separated by solid partitions 125 cm high that prevented all lateral contacts. The remaining 16 calves (treatments 3 and 4) were in complete isolation flanked by partitions 150 cm high that extended beyond the feeding grille, in front of which there was a partition dividing the alley. In treatments 1 to 3, we provided the calves with a piece of tire and a chain, objects that they could easily nibble similar to those used by Kopp et al. (1986) and Dantzer and Mormède (1983) to measure oral activities of calves or pigs. We will refer to them henceforth as "objects." The two batches were matched for breed and housing conditions (Table 1).

The animals were fed with milk replacer (Crémunic Sanders) twice a day according to a feeding regimen

used to produce white veal meat (Toullec, 1988). Their health was monitored daily during feeding and again at a third visit.

Measurements

Time Budget. When the calves were 14 wk old, we recorded their behavior from 0700 to 1730 (i.e., when the lights were on). Two cameras on rail trays, one on each side of the central alley, were automatically moved from one stall to the next every 5 s. We scanned the calves' activities, which we divided into 22 classes, including sniffing objects, nibbling at objects (sucking/biting/licking as defined by Kooijman et al., 1991) and self-directed activities (Table 2). Intervals between scans were about 3.5 min. We calculated the percentage of time spent on each type of behavior and the frequency of behavioral changes between successive scans.

Reactivity Tests. When the calves were 16 wk old (1993 batch) and 20 wk old (1994 batch), we measured their reactions to a water throw, a device adapted from a windshield wiper, which was controlled from outside the experimental room. We performed the test twice when the calves were resting and twice when they were nibbling. We considered a calf as resting when it was lying, immobile and its head not supported for more than 2 min. This posture

Table 2. Activities of the calves scanned from video recordings from 0700 to 1730

Activity	Object
Nibbling (including licking, sucking, biting)	Partitions Floor Feeding grille Bucket rack Bucket Tire Chain Another calf
Sniffing	Same objects as for nibbling
Grooming	Self-directed
Lip-licking	Self-directed
Tongue-rolling	Self-directed
Miscellaneous activities (eating, walking, scratching, etc.)	
No activity	

corresponds to an intermediate state between sleeping and activity (Veissier et al., 1989). The procedure was repeated until the calf stood up. Each throw lasted for 1 s and the interval between throws was 1 s. When the calf was nibbling, we repeated the throws until it stopped nibbling. We recorded startled reactions to the first throw, the number of throws, and the time elapsed before nibbling was resumed.

Adrenal Blockade and Stimulation. We administered dexamethasone and ACTH to the calves when they were 17 wk old (1993 batch) and 21 wk old (1994 batch). Between 1700 and 1800 (i.e., after the evening meal), we injected 20 $\mu\text{g}/\text{kg}$ dexamethasone (DectancyND, Roussel) and the following morning .25 UI ACTH per animal (SynactheneND, Ciba-Geigy). We took blood samples by jugular puncture before dexamethasone and ACTH injections, and 30 and 180 min after ACTH injection. Cortisol levels at these two last intervals are highly correlated with the whole response to ACTH (Veissier and Le Neindre, 1989) and we chose them as indices of readiness to respond to ACTH and recovery. We determined plasma levels of corticoid by radioimmunoassay with an antibody produced by Y. Cognié and N. Poulin (INRA, Tours). The detection limit was .02 ng/mL. Within- and between-assay coefficients of variation were 11 and 22% for low (4 ng/mL) and 7 and 14% for high (32 ng/mL) controls.

Health, Growth, and Postmortem Measurements. Diseases were recorded over the whole rearing period and we expressed their occurrence as the number of days on which a calf received medical treatment. We estimated growth rates from the difference between weight at birth and that at the end of the fattening period. The calves were slaughtered when they were aged 22 wk (1993 batch) or 24 wk (1994 batch). We opened the abomasum to record the number, surface, and localization (fundus, pylorus except the torus, and the pyloric torus) of erosions, ulcers, and scars (as described by Wiepkema et al., 1987). The left adrenal was cut into slices, which were immediately frozen in liquid nitrogen and stored at -80°C . We determined the activities of tyrosine hydroxylase and phenyl N-methanolamine transferase in the medulla by methods adapted from Waymire et al. (1971) and Axelrod (1962). In 1994, the right adrenal and the thymus were weighed. We used the activities of these enzymes and adrenal and thymus weights as indicators of chronic activation of the sympathetic nervous system and of the adrenocorticotrophic axis (Lemaire et al., 1993).

Data Analyses

Because there was often no erosion, ulcer, or scar in the abomasum, we expressed the results as the proportion of calves having each type of lesion at each localization. In addition, we calculated an index of abomasal damage for each calf by adding 1 when we

recorded one to three erosions, 2 for four to six erosions and for each ulcer, and 3 for more than seven erosions and for each scar (Wiepkema et al., 1987).

We used the SAS package for data analyses (SAS, 1988). When we could not exclude the hypotheses of a Gaussian distribution and homogeneous variances, we used the general linear model to assess the effects of breed, year, and housing conditions (including type of partition between stalls and presence or absence of objects). Breed had no effect on most of the data and never interacted with housing or year, and so we omitted it from subsequent analyses. We also analyzed the animals' reactions to the water throw when they were nibbling, taking their reactions at rest as covariates. We thus used three models:

$$\text{measurement} = \beta_0 + \beta_1 a_i + \beta_2 b_j + \beta_3 c_{ij} + \beta_4 d_k + \epsilon_{ijkl}, \text{ when breed had an effect}$$

$$\text{measurement} = \beta_0 + \beta_1 a_i + \beta_2 b_j + \beta_3 c_{ij} + \epsilon_{ijl}, \text{ when breed had no effect}$$

$$\text{number of throws received during nibbling} = \beta_0 + \beta_1 a_i + \beta_2 b_j + \beta_3 c_{ij} + \beta_4 e_m + \epsilon_{ijml}$$

where a_i , b_j , and d_k represent differences due to housing, year, and breed; c_{ij} represents interaction between housing and year, and e_m represents the number of throws received when resting. We performed appropriate comparisons of means using Duncan's test. We used repeated statements to analyze cortisol levels in response to ACTH and we analyzed paired data with Student's paired tests. When we could not assume normality or homogeneity, we performed Kruskal-Wallis and Mann-Whitney tests. To express the quantitative data, we will give the means for each housing condition, year, and breed, and the residual standard deviation (SEM) unless we could not use the general linear model, in which case we will give the SD within each level. Finally, we compared proportions by χ^2 calculations. We will focus on significant results ($P < .05$).

Results

Time Budget (Table 3)

Whatever their housing conditions, the calves spent most of their time inactive (about 53% of the daytime) and half of their active time nibbling. Housing affected the objects they nibbled at. When they were provided with objects, the calves spent less time nibbling at the feeding grille. Providing objects and allowing social contacts had a cumulative effect on partition nibbling, which was significantly more frequent in calves deprived of objects and of social contacts than in calves provided with both, whereas calves provided with objects but not with social

Table 3. Behavior of calves housed in individual stalls that varied in the extent of contacts they allowed between neighbors and in the provision of objects to nibble^a

	Trt. 1 ^b (n = 16)	Trt. 2 (n = 16)	Trt. 3 (n = 16)	Trt. 4 (n = 16)	1993 (n = 32)	1994 (n = 32)	SEM	F ^c treatment	F year	F trt. × year
Inactivity	55.7	50.7	53.4	51.4	52.1	53.5	9.43	.91	.40	.97
Nibbling	22.7	26.7	25.0	24.4	26.8	22.7	8.09	.69	4.09	1.61
Partitions	9.6 ^x	10.1 ^x	13.3 ^{xy}	15.3 ^y	12.9	11.2	5.40	3.97**	1.57	2.59
Floor	1.1	.7	.9	1.4	1.0	1.0	1.08	1.21	.00	.32
Feeding grille	2.2 ^x	3.0 ^x	3.4 ^x	5.1 ^y	3.8	3.0	2.22	4.95**	2.25	1.54
Bucket rack	1.5	2.2	1.7	1.8	1.8	1.8	1.61	.52	.01	1.71
Bucket	.5	.2	.5	.8	.7	.4	.62	2.36	3.51	.66
Tire	6.0	8.9	4.3	—	5.8	3.9	5.76	2.61	2.35	3.13*
Chain	1.1	.9	.9	—	.7	.8	1.55	.12	.14	1.23
Another calf	.7	.6	—	—	.1	.6	.86	.06	10.09**	.06
Self-directed activities	8.0 ^x	9.3 ^x	9.7 ^x	12.5 ^y	10.7	9.1	3.76	4.09**	2.71	2.04
Lip-licking	2.7 ^x	3.1 ^x	3.8 ^x	5.2 ^y	3.7	3.7	2.09	4.47**	.02	1.57
Tongue-rolling	.3 ^x	.8 ^x	.6 ^x	2.1 ^y	1.0	.9	1.76	3.40*	.01	1.56
Grooming	4.9	5.2	5.2	5.2	5.9	4.3	2.59	.04	5.90*	1.00
Sniffing	7.7	6.8	6.0	6.4	6.5	7.0	2.39	1.54	.58	1.29
Miscellaneous	5.0	5.1	5.6	4.7	2.8	7.4	9.43	.91	.40	.97

^aWe observed the animals every 3.5 min from 0700 to 1730.

^bTreatment 1: open partitions, treatment 2: solid partitions, treatments 3 and 4: solid and extended partitions; treatments 1 to 3: tire and chain, treatment 4: no object.

^cWe performed ANOVA to compare percentage of time.

^dGeneric classes detailed below.

^{x,y}Within each row and main effect, means with uncommon superscripts differ ($P < .05$).

* $P < .05$.

** $P < .01$.

contacts were in between. The calves deprived of objects also spent more time licking their lips and tongue-rolling. The time spent on sniffing objects or parts of the stalls and on miscellaneous activities did not vary with housing, nor did the frequency of behavioral changes (the probability that a calf would change activity between successive scans was .49, .51, .49, and .52 in treatments 1 to 4, SEM = .07 $F(3,63) = .66$ $P > .05$).

There was a significant interaction between year and housing for nibbling at the tire. We therefore analyzed the effect of housing separately in the two batches. In 1993, calves exposed to limited social contacts (treatment 2) nibbled at the tire more often than the others (7.3, 12.7, 3.0% time for treatments 1, 2, and 3, SEM = 6.3 $F(2,23) = 4.78$ $P < .05$). These differences disappeared in 1994.

In 1994, the calves spent more time in self-grooming and less time licking their neighbors than in 1993. They also changed activity more often in 1994 than in 1993 (probability of behavioral changes between successive scans: .46 in 1993 vs .54 in 1994, SEM = .07 $F(1,63) = 19.45$ $P < .01$).

Time budget did not vary between the two breeds.

Behavioral Reactivity (Table 4)

The number of water throws was reproducible when the calf received them during a given behavioral state (Spearman correlation between tests 1 and 2: .53

during resting and .52 during nibbling, $P < .01$) but not between the two behavioral states (Spearman correlation: between .02 and .14, $P > .05$).

When they were resting, calves deprived of all social contact had startled reactions to the water throw more often than calves allowed full contact, whereas those provided with only limited social contact were in between (significant on test 2 between treatments 3–4 and 1). When the calves were nibbling, housing affected neither their reactions to the first throw nor to the number of water throws, even when reactions during resting were taken into account (for example, the number of throws received during nibbling in test 1 with the number of throws received during resting in test 1 as the covariate, SEM = 1.39 $F(3,62) = .42$ $P > .05$). A significant interaction between year and housing was observed in time taken for nibbling to resume in test 1. In 1993, this time was longer for calves allowed full social contacts (142 ± 112 , 51 ± 71 , 30 ± 32 , 32 ± 24 s for treatments 1 to 4, Kruskal-Wallis test $P < .05$, with treatment 1 different from any of the others).

We recorded more startled reactions in 1993 than in 1994 (significant for test 1 when the calves were resting and test 2 when they were nibbling) and fewer water throws necessary to end resting or nibbling (significant in tests 1 when animals were resting or nibbling).

When they were resting, Montbeliard calves received more water throws than Holstein calves (test 2: 7.4 vs 5.3, SEM = 4.2 $F(1,63) = 4.77$ $P < .05$).

Table 4. Behavioral reactions of calves housed in individual stalls that varied in the extent of contacts they allowed between neighbors and in the provision of objects to nibble^a

Item	During rest								SEM	F/ χ^2 /Z ^c treatment	F/ χ^2 /Z year	F/ χ^2 /Z rt. × year
	Trt. 1 ^b (n = 16)	Trt. 2 (n = 16)	Trt. 3 (n = 16)	Trt. 4 (n = 16)	1993 (n = 32)	1994 (n = 32)	During nibbling bout					
First test												
Animals with a startled reaction ^d	4	5	7	8	7	17			2.67	6.67**		
No. of throws ^e	4.63	5.50	4.44	6.94	6.84	3.91			1.23	8.15**		.50
Second test												
Animals with a startled reaction ^d	2 ^x	3 ^{xy}	8 ^y	8 ^y	9	12			8.72*	.64		
No. of throws ^e	7.13	5.81	5.00	6.75	7.00	5.34			.83	2.49		2.04
First test												
Animals with a startled reaction ^d	8	5	4	6	8	15			2.37	3.23		
No. of throws ^f	1.19 ± .40	1.25 ± 1.00	1.19 ± .54	1.67 ± 2.58	1.59 ± 1.90	1.03 ± .18			1.28	-1.97*		
Time to resume nibbling, s ^e	88.25	47.00	57.94	59.40	63.78	62.61			1.08	0.00		5.25**
Second test												
Animals with a startled reaction ^d	5	1	4	5	1	14			3.74	14.72***		
No. of throws ^f	1.13 ± .34	1.00 ± 0.00	1.00 ± .00	1.67 ± 2.58	1.38 ± 1.77	1.00 ± 0.00			3.69	-1.71		
Time to resume nibbling, s ^e	60.56	52.44	73.63	59.47	57.44	65.81			.24	.19		2.49

^aThe animals received water throws until they stood up if they were resting and until they stopped nibbling if they were doing so.

^bTreatment 1: open partitions, treatment 2: solid partitions, treatments 3 and 4: solid and extended partitions; treatments 1 to 3: tire and chain, treatment 4: no object.

^cWe performed ANOVA when we assumed a Gaussian distribution and homogenous variances, otherwise Mann-Whitney analyses.

^dNumber of animals, χ^2 .

^eANOVA: F.

^fMann-Whitney: Z.

^{x,y}Within each row and main effect, means with uncommon superscripts differ ($P < .05$).

* $P < .05$.

** $P < .01$.

Neuroendocrine Measurements (Figure 1 and Table 5)

Plasma levels of cortisol did not decrease after injection of dexamethasone in the 1993 batch, whereas they did in the 1994 batch (paired *t*-test for Δ (after – before dexamethasone) in 1994: $t = 4.44$ $P < .01$). Cortisol levels always increased by about 10-fold 30 min after ACTH injection (paired *t*-test for Δ (after – before ACTH): $t = 15.1$ $P < .01$). After 180 min, they still had not returned to basal levels (paired *t*-test = 3.7 $P < .01$). Despite a tendency for cortisol levels 30 min after ACTH to vary inversely with social contacts and the provision of objects, housing had no significant effect (repeated measures ANOVA: $F(3,59) = .68$ $P > .05$). Cortisol levels were higher in 1993 than in 1994 ($F[1,59] = 9.45$ $P < .01$). Breed had no effect on cortisol levels.

The activities of tyrosine hydroxylase and of phenyl N-methanolamine transferase were about 3 and .25 nmol·h⁻¹·mg⁻¹ of protein content of the adrenal medulla. Housing and breed affected neither enzyme activity nor thymus and adrenal weights.

Health and Growth Rate (Table 6)

Although the medical treatments of calves that were allowed the most social contacts lasted longer than those of the other animals, the differences were not statistically significant. More of the calves that were isolated but provided with objects had erosions on the pyloric torus than calves that were either allowed limited social contacts or deprived of an object; erosions in calves allowed the most social contacts were in between. Housing did not affect other abomasal lesions or growth rate.

Many more calves had pyloric scars in 1994 than in 1993. This gave a much higher index of abomasal damage in 1994.

Montbeliard calves had pyloric scars more often than Holstein calves (25 out of 26 Montbeliard vs 29 out of 38 Holstein, $\chi^2 = 4.6$ $P < .05$) and grew faster

(weight gain = 1.33 vs 1.27 kg/day, SEM = .13 $F[1,61] = 5.06$ $P < .05$).

Discussion

We will discuss the results in regard to the four hypotheses mentioned in the Introduction.

First Hypothesis: Social Deprivation Enhances Behavioral Reactivity and Spontaneous Activity

The most striking result was that calves reared in isolation reacted more intensively to the water throws than calves that could interact with their neighbors. Without quantifying the reactions, de Wilt (1985) also noted that calves reared in stalls separated by solid partitions were more easily distracted by unusual stimuli than calves reared in groups, and Webster et al. (1985) attributed fear reactions of calves reared in poorly-lit stalls to their being cut off from the normal sights of farm activity. According to the optimal stimulation theory, “there exists for all organisms a biologically determined optimal level of stimulation” (Zentall and Zentall, 1983). In sensory overload or deprivation, organisms react either by stimulus withdrawal or by stimulus seeking. Experiments made with different species have shown that animals reared in poor environments display more fear reactions, as measured by behavioral excitement to threatening stimuli (Melzack, 1954 in dogs), defecation in open-fields (Taylor, 1969 in rats; Ardila et al., 1977 in mice), or failure to habituate to testing situations (Joseph and Gallagher, 1980 in rats). Similarly, pigs reared in total darkness display more fear reactions to humans, whereas those given rubber hoses are tamer (Grandin, 1989, 1993). The hyper-reactivity observed in isolated calves is thus an indication that social stimuli play a large part in defining the level of stimulation provided by the environment. Hence, reducing social stimuli is likely

Table 5. Physiological data from calves housed in individual stalls that varied in the extent of contacts they allowed between neighbors and in the provision of objects to nibble^a

Item	Trt. 1 ^a (n = 8)	Trt. 2 (n = 8)	Trt. 3 (n = 8)	Trt. 4 (n = 8)	SEM	F/Z ^b
Catecholamine synthesizing activities, ng product·hour ⁻¹ ·mg protein content ⁻¹						
TH ^c	3.24	3.53	4.83	4.01	1.61	1.48
PNMT ^c	.23	.25	.23	.26	.14	.10
Organ weight, g						
Adrenal ^d	4.70 ± 1.08	5.18 ± 1.24	6.24 ± 4.66	5.85 ± 2.57		2.49
Thymus ^c	373.00	353.00	299.00	392.00	161.00	.48

^aTreatment 1: open partitions, treatment 2: solid partitions, treatments 3 and 4: solid and extended partitions; treatments 1 to 3: tire and chain, treatment 4: no object.

^bWe performed ANOVA when we assumed a Gaussian distribution and homogenous variances, otherwise Mann-Whitney analyses.

^cANOVA: *F*.

^dMann-Whitney: *Z*.

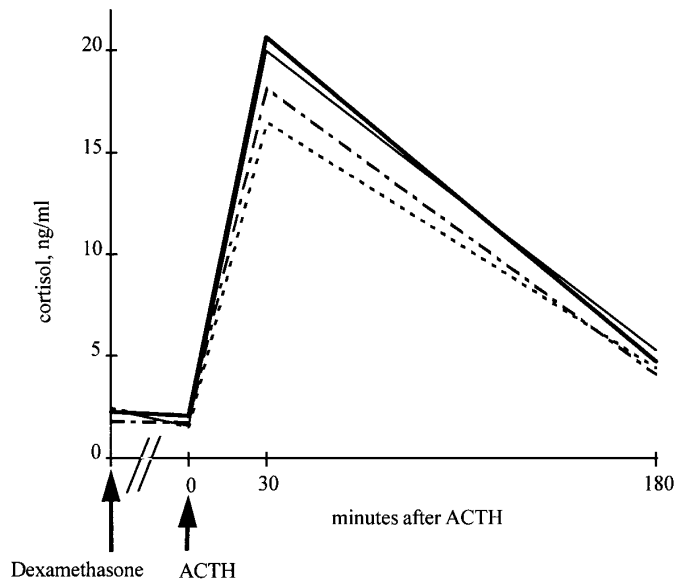


Figure 1. Adrenal blockage and stimulation. We took blood samples before dexamethasone injection, 17 h after, then 30 and 180 min after ACTH injection. We compared calves that were not provided with a tire and a chain and were separated from each other by solid and extended partitions (—) with calves provided with these objects that were separated either by solid and extended partitions (— · —), by solid partitions (— · · —) or by open partitions (---). We performed a repeated measures ANOVA. The changes over time were highly significant (within SEM = 5.6 $F(3,118) = 166$ $P < .001$) but the differences between treatments were not significant (between SEM = 6.7 $F(3,59) = .68$ $P > .05$).

to increase the impact of extra-stimuli the animal can receive. Compared to calves in groups, those housed in individual stalls are also more reactive to handling and transport (Trunkfield et al., 1991).

The optimal stimulation theory also postulates that "activity can serve as a homeostatic regulator" (Zentall and Zentall, 1983). Calves reared in social isolation should thus be more active in order to maintain a continuous level of stimulation during the day. This was not the case in the present experiment; whether the calves had contacts with their neighbors or not, the time they spent resting was comparable.

An alternative explanation for the hyper-reactivity observed in isolated calves is that they have no social partner to moderate their reactions to external events. The presence of mates can reduce fear in cattle exposed to novel environments (Boissy and Le Neindre, 1990; Veissier and Le Neindre, 1992), and concordant results have been reported in primates (Hennessy, 1984). The work of Harlow and Zimmermann (1959) on infant monkeys reared with surrogate mothers showed that reactions toward fear-eliciting stimuli vary inversely with the strength of

the bond with the surrogate. This finding supports the idea that the effect of the presence of partners during a test is not due to the physical enrichment of the test situation but rather to the social component. Hence, we suggest that the hyper-reactivity observed in calves reared in isolation arises from the absence of the tempering effect of the presence of peers at the time they experience an external event. Allowing contacts through partitions seems sufficient to achieve this tempering effect.

Second Hypothesis: Oral Activities Become More Rigid in Calves Deprived of Social Stimuli

Stereotypies, activities that are repetitive, invariant, and have no obvious function (Ödberg, 1978), are promoted in poor environments (jumping in bank voles, Ödberg 1986; pacing and rearing in minks, Mason, 1993). Veal calves commonly exhibit non-nutritive oral activities (Webster et al., 1985; Kooijmann et al., 1991). Certain authors, such as Wiepkema et al. (1987), consider them to be stereotypies. Social contacts did not affect the proportion of time the calves spent nibbling, but this behavior was disrupted for longer in calves that had contacts with their neighbors, as shown in 1993 by the longer time taken to resume nibbling after the water throw. However, the number of throws required to end nibbling was just as great in calves exposed to social contacts. This may have resulted from the reactivity of the calf (as assessed when it was resting) and its continuance in oral activities. If reduction of social contacts enhanced reactivity and continuance, it would have no effect on reactions to a distracting stimulus imposed on a calf nibbling. Hence, we cannot rule out the hypothesis that preventing social contacts makes nonnutritive oral activities less easy to interrupt. Nevertheless, during the day, isolated calves did not change activity less often than calves allowed social contacts. Hence, there is little evidence that isolated calves behave in a more rigid way. Moreover, according to Webster et al. (1985), nibbling in calves cannot be considered as a stereotyped behavior. Even in the most confined stalls, we often saw a calf nibbling at an object move toward another object, alternately licking or biting it.

Third Hypothesis: Self-Directed Behavior Takes Place When the Calves are Deprived of Easily Nibbled Objects

The items that the calves nibbled at most were the walls, the tire, and the feeding grille. Because the tire had a surface at least 60 times as small as that of the walls and about five times as small as that of the feeding grille, we concluded that it had a particular appeal. Calves that had been given a tire nibbled at the feeding grille and the walls less often than those without a tire. The latter spent more time licking their lips and tongue-rolling. This is consistent with the hypothesis that very restrictive environments promote

Table 6. Health and growth of calves housed in individual stalls that varied in the extent of contacts they allowed between neighbors and in the provision of objects to nibble^a

	Trt. 1 ^a (n = 16)	Trt. 2 (n = 16)	Trt. 3 (n = 16)	Trt. 4 (n = 16)	1993 (n = 32)	1994 (n = 32)	SEM	F/ χ^2 /Z ^b treatment	F/ χ^2 /Z year	F/ χ^2 /Z trt. \times year
Medical treatment ^c	5.56	2.88	2.56	3.06	2.88	4.16	3.47	2.53	2.18	.16
Abomasum lesions ^d										
Erosions										
Pylori	6	2	2	3	6	7		1.41	.10	
Pyloric torus	2 ^{xy}	0 ^x	4 ^y	0 ^x	3	3		8.09*	.00	
Fundus	4	3	2	4	6	7		1.06	.10	
Ulcers										
Pylori	0	2	3	2	5	2		3.05	1.44	
Pyloric torus	3	4	3	4	8	6		.37	.37	
Fundus	0	0	1	0	1	0		3.05	1.02	
Scars										
Pylori	3	1	4	2	1	9		2.37	7.58**	
Pyloric torus	5	4	2	3	2	12		1.83	9.14**	
Fundus	0	0	1	1	1	1		2.06	.00	
Synthetic index ^e	4.62 \pm 5.23	4.06 \pm 3.71	6.69 \pm 12.7	3.67 \pm 2.99	4.25 \pm 9.35	5.32 \pm 4.17		.09	3.39***	
Daily growth rate, kg	1.29	1.32	1.28	1.27	1.23	1.36	.12	.56	17.03***	.73

^aTreatment 1: open partitions, treatment 2: solid partitions, treatments 3 and 4: solid and extended partitions; treatments 1 to 3: tire and chain, treatment 4: no object.

^bProportions were compared with χ^2 calculations. Quantitative data were analyzed by ANOVA when we assumed a Gaussian distribution and homogenous variances, otherwise with Mann-Whitney analyses.

^cNumber of days on which a calf received medicine, ANOVA: *F*.

^dNumber of animals, χ^2 .

^eCalculated by adding 1 when we recorded 1 to 3 erosions, 2 for 4 to 6 erosions and for each ulcer, 3 for more than 7 erosions and for each scar; Mann-Whitney: *Z*.

^{xy}Within each row and main effect, means with uncommon superscripts differ ($P < .05$).

* $P < .05$.

** $P < .01$.

*** $P < .001$.

self-directed activities, as in a final stage of behavioral fixation (Dantzer, 1986). Whether such activities would also develop in calves allowed social contacts is open to conjecture because the experimental design partly confounded the two factors owing to the limited number of stalls in the barn. Nevertheless, social facilitation between calves is likely to encourage nibbling rather than lip-licking or tongue-rolling, as shown in 1993 by the higher frequency of nibbling at the tire in calves allowed contacts only through the front of the stalls. We made no precise assessment of the temporal relation between the two activities but sporadic observations indicated that calves often licked their lips before tongue-rolling. It is likely that these behavioral patterns are closely linked. Self-grooming is probably triggered by another drive and so the absence of tire and chain had no incidence on its occurrence. When grooming, veal calves may shed to minimize heat stress caused by high metabolic rate (Webster et al., 1985).

Fourth Hypothesis: Deprivation of Social Contacts and of Easily Nibbled Objects Decreases Welfare

Because welfare cannot be evaluated from a single type of measurement (Dantzer et Mormède, 1979; Rushen et de Passillé, 1992; Broom and Johnson,

1993), we decided to draw our conclusions from a wide range of indices of discomfort, including occurrence of disease, growth, neuroendocrine responses to stress, and behavior. Whereas providing social contacts and objects modified the calves' behavior, it had no impact on neuroendocrine measurements of stress. Dantzer et al. (1983) and Friend et al. (1985) found that calves reared in groups had lower corticotropic responses to ACTH than calves reared in individual stalls. Both social and physical factors vary between calves reared in groups or in individual stalls. Calves can move more easily when they are housed together in a pen than when they are in individual stalls: they can walk together round the pen and lie down close to one another, leaving space for those that remain standing. Moreover, in the comparisons cited above, the space per animal and the type of floor varied between the two rearing systems. Taken together with ours, these results suggest that physical factors affect the stress reactions of calves more strongly than social factors. The absence of any recorded effect of social factors in our study may have been due to the small number of blood samples taken (only two, as against three and six by Dantzer et al., 1983, and Friend et al., 1985, respectively). In addition, all of the systems we tested might have been stressful because all the stalls limited the calves' movements and their social behavior.

Social contacts facilitate the spread of disease (Laval, personal communication), as shown in our experiment by the higher, but not significant, frequency of medical treatments in calves allowed contacts. Rearing calves in groups increases the incidence of disease compared to rearing them in stalls (deWilt, 1985; Smits and Ham, 1988; Webster, 1991; van de Braak and Kleinhout, 1991). More extensive work is needed to confirm the effect of open partitions between stalls on the health status of calves.

Finally, there were variations between the two replicates of the experiment and breed. In 1993, the calves were more reactive to the water throws, and housing conditions had a greater effect on cortisol responses. At the time these measurements were taken, the calves were also 4 wk younger than those of 1994. With increasing age, the animals might have adapted to their environment. Friend (1980) reported that responses to ACTH initially increased and then decreased after a few weeks of chronic exposure to stressors. As routinely observed in meat production, the Montbeliard calves grew faster than their Holstein counterparts; their greater weight may have made them less reactive. Montbeliard calves also had more abomasal lesions, which might have been due to a higher intake of milk.

Conclusions

The comparison of calves provided or not provided with objects that are easily nibbled and housed in individual stalls that varied in the amount of social contacts they allowed yielded the following results: 1) preventing social contacts increases behavioral reactivity, probably because peer animals are not present to allay reactions; 2) although isolated calves may be more motivated for nibbling, there is little evidence that they behave in a more rigid way; and 3) when the environment limits nibbling, the calves exhibit more self-directed activities (lip-licking and tongue-rolling).

Implications

Whereas contacts with neighbors and the provision of objects to nibble have positive effects on the behavior of calves reared in individual stalls, their impact on welfare is slight because they do not affect other indices of stress. However, the higher reactivity of isolated calves could lead to greater stress during transport and handling at slaughter and thereby to lower meat quality.

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