BEHAVIOURAL REACTIVITY AFFECTED BY CHRONIC STRESS: AN EXPERIMENTAL APPROACH IN CALVES SUBMITTED TO ENVIRONMENTAL INSTABILITY

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Abstract *Animal Welfare 2001, **10:*** S175-185

Whereas physiological and behavioural responses to acute stressors are well documented, chronic stress remains difficult to assess in farm animals. The aim of the present paper is to investigate whether calves' behavioural reactions to acute events are modified during chronic intermittent stress. Thirty-two calves housed in pairs were used. For half of the calves the partner and the pen were changed once a week for 14 weeks (regrouped calves) while the others remained unchanged (controls). Four behavioural tests were performed to assess calves' reactivity to novel or sudden events, to predator cues and to restraint. In the water spray test, regrouped calves were startled more often. In the umbrella test, regrouped calves took a longer time to feed in front of the closed umbrella but no differences between the two treatments were observed on opening the umbrella. In the dog test, regrouped calves moved more and looked at the dog more often. In the restraint test, regrouped calves were more agitated. These differences disappeared when the tests were repeated. In conclusion, repeated changes in the social and physical environment of calves enhances their behavioural reactivity to novelty. This is likely to make them more adaptive to potential changes in their environment.

Keywords: *animal welfare, cattle, novelty, predator, reactivity, social instability*

Introduction

Welfare can be impaired not only by acute aversive events but also by chronic stressors. Animals' emotional states in response to acute events can be inferred from observable adjustments, such as increased heart rate, elevated blood corticoid levels and behavioural agitation (Boissy 1998). However, chronic stress is usually considered to be more difficult to detect (Dantzer & Mormède 1983a; Rushen 1991). For instance, blood corticoid levels often return to initial levels after repeated exposures to the same stressor (Von Borell & Ladewig 1992). Nevertheless, the functioning of the hypothalamo-pituitary-adrenal axis remains altered, and this can be assessed by pharmacological challenges (Friend *et al* 1985; Klemcke 1994). Similar phenomena may also occur for behavioural responses to stressors. For instance, sows which are tethered for the first time react with vigorous movements but stay immobile after 1 day of tethering (Cronin 1985). However, when compared to sows in groups, sows confined in individual stalls become less reactive to external events, an alteration which Broom (1987) called apathy. Hence, states of chronic stress might be revealed by alteration of the reactivity to acute events.

Responses to acute events vary according to the characteristics of the threatening event. According to Gray (1987), negative emotion-producing events may be classified into five categories. The first category includes novelty. Novelty can be considered a comparative variable because the recognition of any stimulus situation as being novel requires a comparison between the present situation and stimuli experienced in the past. The second category concerns events which relate to the historical ecology of the species: the evolutionary persistence of some anti-predator behaviours is well known in domesticated animals despite generations of artificial selection (Coss 1991; Terlouw *et al* 1998). Thirdly, physical characteristics which are linked to the presentation of an event such as movement, intensity, duration, suddenness and proximity can cause stress: Russel (1979) considered that these aspects are associated with the normal context of predation. Fourthly, events which have been previously associated with aversive events can be stressful; learning plays a role in adaptive reactions by identifying new sources of danger very rapidly and durably. Finally, events arising from interactions with conspecifics, such as alarm calls, represent particular cases of the four previous categories. Researchers have sought to identify the specificity of the relationships between these stress-related events and stress responses but the findings have been complex, inconsistent and often contradictory (see Boissy [1998] for a review). The general conclusion is that emotional reactivity cannot be considered as a unitary concept and that its evaluation must be based on observations made using various threatening stimuli.

The aim of the present paper is to analyse the modification of emotional reactivity of calves exposed to chronic stress. According to Ladewig (in press), a chronic stressor should not be considered to be the result of a constant situation, but better as a succession of repeated acute stressors leading to chronic intermittent stress. Social relationships based on agonistic and sociopositive behaviours play an important role in most mammalian societies, particularly in herbivores where the need for social experiences have been highlighted (Boissy & Le Neindre 1990; Veissier *et al* 1998). For instance, the abrupt breaking of social bonds associated with weaning can lead to stress reactions in calves (Veissier *et al* 1989). Moreover, repeated mixings are known to be stressful to animals living in organized groups (rats – Mormède *et al* [1990]; chickens – Siegel & Latimer [1975]; cattle – Friend *et al* [1977]). Hence, we subjected calves to a chronic intermittent stress by mixing them repeatedly with unknown peers and relocating them to new pens. Their reactions towards negative emotion-producing events were then compared to those of control calves kept in a stable social and physical environment. To this aim, a set of behavioural tests was used to evaluate the reactivity of calves to novelty, to suddenness and to cues from predators, covering the first three categories of stressful events listed by Gray (1987).

Materials and methods

Animals and rearing conditions

Thirty-two male calves of the French Montbeliard breed were used. Twelve were born on the experimental farm and the others were purchased from commercial farms. From the age of 3 ± 1 weeks until the age of 21 ± 1 weeks, they were housed as pairs in 1.8x2 m pens on a wooden slatted floor, in the same air-controlled room. They weighed 200kg at the end of the experiment. The housing conditions were in agreement with European legislation, which stipulates that calves must not be kept in individual crates from the age of 8 weeks and that the space allowance should be a least $1.7m^2$ $calf^{-1}$ (liveweight between 140 and 220 kg; EC Directive 97/2/CE). Pens were separated by solid wooden partitions 125cm high that extended beyond the front to prevent contact between calves in adjacent pens. Calves were bucket fed milk replacer (Cremunic, Sanders) in two meals at 0800h and 1630h. As the temperature in the barn did not exceed 15°C, no additional water was provided to the calves. A food supplement containing vitamins and minerals (Appevo, Celtic NA, 560ppm iron) was added to the milk replacer (5g calf^{-1} and meal^{-1} for 10 days then 1g). In compliance with European legislation, calves received a solid supplementation at 1300h, from 50g day^{-1} of a pelleted food at the beginning to 250g day^{-1} at the end of the experiment (Startivo Centraliments, Aurillac, France; fibre 7%; protein 16%). The health of the calves was checked by caretakers at each of the three daily meals.

Experimental treatments

From the age of 8 ± 1 weeks, the pairs of calves were allocated to the two treatments so that the age and the weight of the calves were similar between the two treatments. In the control group, the calves were kept in the same pairs and in the same pens until the end of the experiment (*control calves*, n = 8 pairs). In the other group, both the partner of each calf and the pen in which it was housed were changed once a week for 14 weeks (*regrouped calves*, n = 8 pairs). Pairs from each group were housed alternately next to each other, ie a pair of controls, a pair of regrouped calves, a pair of controls, etc. Every Friday, each calf was individually taken out of its pen to be weighed. Control calves were returned to their pen whereas each regrouped calf was moved to another pen (ie different from the one it had previously occupied) and was allocated an unfamiliar calf from the same treatment. The handling procedure took place between 1400h and 1600h. Within each pair, a collar was put on one calf's neck in order to identify the calves during observations.

One calf from the regrouped treatment had to be removed from the experiment 6 weeks after the beginning because of illness and was replaced by a female calf. The data from this female calf have not been included in the analyses.

Reactivity tests

The reactivity of calves to external events was assessed through four behavioural tests: the water spray, the umbrella, the dog and the restraint tests. Reactions to novelty were investigated through the umbrella and restraint tests, reactions to suddenness through the water spray and umbrella tests, reactions to cues from a predator through the dog test and reactions to unpleasantness through the restraint test. The behaviour was recorded on a hand-held Workabout computer (Psion plc, London, UK) using the Observer event recorder software version 3.0 (Noldus Information Technology, Wageningen, The Netherlands). In order to reduce the effects of repeated handling, each test was carried out at the same period on all the animals with at least 1 week between tests.

Water spray test

The water spray test was performed between 1000h and 1400h. A first test was carried out after the regrouped calves had been moved between pens and had had their partners changed eight times (hereafter called the 'eighth mixing'), and a second one 2 weeks later. The test was adapted from Veissier *et al* (1997) but a spray of water was used instead of a single throw. A device made of a 155cm pipe perforated with 11 holes (1.5mm diameter) fixed to the ceiling of each pen (height 2m) enabled cold water to be sprayed onto the calves. The reaction of the calves was monitored from a remote place. After the two calves from a pen had been observed lying with their heads down for more than 2min, a 1s spray was given. The reaction of the calves to this first spray was classified in one of three behavioural categories: no reaction; slight reaction (the calf remains lying down but with head up); and stand up. If the two calves did not stand up at the first spray, the procedure was repeated every 4s until the two calves stood up. The number of sprays was recorded. On each day of testing, two repetitions were run, at least 1h apart.

Umbrella test

The umbrella test was performed after the tenth mixing. This test was adapted from Boissy and Bouissou (1995). At 1200h, plywood partitions were placed in front of all calves to prevent them from seeing the umbrella before the test. On the day of testing, the calves did not receive their meal of solid food at 1300h. The test was carried out between 1300h and 1530h. An umbrella that could be opened from a remote place was placed 1m in front of the pen. Then the plywood partition in front of the pen of the calves to be tested was removed and two buckets containing pelleted foods were introduced to the calves. During the first part of the test, the umbrella was left closed. After each calf had eaten for at least 10s, the umbrella was opened (beginning of the second part of the test). The reaction of each calf to the opening of the umbrella was recorded as no reaction, slight reaction (ie the calf stops feeding without moving) or strong reaction (ie the calf moves at least two steps back). The time to resume eating was noted and truncated at 90s if calves did not resume eating by that time.

Dog test

The dog test was run after the eleventh mixing. A 3.8x3.8 m arena next to the experimental room was used. The walls were white and the floor was marked off into nine squares by white painted lines. A bucket containing 5.5l of milk replacer was placed in the arena along the wall opposite to the entrance. The calves could be observed from behind a one-way screen.

Two days before the dog test, a habituation session was run between 0940h and 1500h. The calves did not receive their morning milk meal. Each calf was taken out of its pen and carried in a cart to the test arena. It was left in the arena until it had drunk the milk, up to a maximum of 10min. All calves drank during the habituation session.

During the dog test, the procedure was the same as during the habituation session, except for the presence of a dog. After the calf had drunk milk for 15s, an adult shepherd dog was introduced into the arena through a trapdoor opposite the bucket. The behaviour of the dog was standardized by its owner, outside the arena. First, the owner ordered the dog to sit down to the right of the trapdoor. After 1min, the dog was ordered to sit on the left. The procedure was repeated twice. After 4min, the dog was ordered to get out of the arena using the trapdoor and the calf was returned to its pen. For the behavioural analysis, two categories of states were defined: the position of the calf (ie the number of the square on the floor as the calf moved from one square to another); and its activity. The activities were: walking, drinking, being startled (brief upward movement with all legs moving at the same time), mooing, sniffing and activities directed towards the dog – looking at the dog (the head of the calf is more than 30cm away from the dog and is orientated toward the dog) and sniffing the dog (head less than 30cm away from the dog, head and neck orientated toward the dog).

Restraint test

For the restraint test, each calf was taken out of its pen and restrained in a modified weighing crate for 4min. The weighing crate measured 58cm wide, 150cm long and 120cm high, and all the sides were plain. The test was performed four times, after the 4th, 7th, 10th and 13th mixing. The behaviour during the test was recorded (movement of the head or of the legs, vocalization and defecation). The calves were further classified as agitated or un-reactive (ie no movement, no vocalization, no defecation).

Statistical analyses

The data were analysed using the SAS package, release 6.11 (Statistical Analysis Systems Institute Inc, Cary, North Carolina, USA). For any data collected when the calves were in their pen, the pair of calves was considered as the experimental unit. The differences between control and regrouped calves were tested using analyses of variance when conditions were fulfilled, otherwise using Mann-Whitney analyses. Proportions were analysed using Fisher's exact probability.

Results

Water spray test

In reaction to the first water spray received in the first test, significantly more regrouped calves stood up than controls (Table 1). The number of water sprays necessary for the two calves of the same pair to stand up was not significantly different between the two treatments. The calves were less reactive when the test was repeated 1h later. There was no significant difference between the two treatments in the second test run 2 weeks later.

Table 1 Effect of environmental instability on the reactivity of calves to the water spray test. A spray of water was thrown at a pair of calves lying down in their home crate. The test was performed twice, 2 weeks apart; for each test, two series of sprays were given at least 1h apart.

	Control pairs (n = 8)	Regrouped pairs (n = 7)	P	$F_{(1,15)}$
First test (after 8 mixings)				
Series 1				
Animals standing up (n)	2/8	6/7	0.03	
Number of sprays necessary for the 2 calves to stand up	1.9 ± 0.4	1.5 ± 0.5		2.32 (ns)
Series 2				
Animals standing up (n)	7/8	7/7	0.53	
Number of sprays necessary for the 2 calves to stand up	2.5 ± 3.0	1.4 ± 0.7		0.91 (ns)
Second test (after 10 mixings)				
Series 1				
Animals standing up (n)	2/8	3/7	0.43	
Number of sprays necessary for the 2 calves to stand up	2.6 ± 1.7	2.1 ± 0.9		0.55 (ns)
Series 2				
Animals standing up (n)	4/8	6/7	0.30	
Number of sprays necessary for the 2 calves to stand up	3.0 ± 2.4	2.0 ± 1.0		0.83 (ns)

P: Fisher's exact probability – comparison between proportions of pairs of animals
F: analysis of variance (level of significance), except Mann-Whitney test for series 2 of the second test

Umbrella test

During the first part of the test, ie when the umbrella was closed, regrouped calves took a significantly longer time to start feeding than controls (Table 2). In reaction to the opening of the umbrella, almost all calves reacted strongly by running away. The reactions did not differ significantly between regrouped and control calves. Likewise, there was no significant difference in the time taken to resume eating after the opening of the umbrella.

Table 2 Effect of environmental instability on the reactivity of calves to the umbrella test. The test was performed on pairs of calves in their home crate during feeding after 10 mixings.

	Control pairs (n = 8)	Regrouped pairs (n = 7)	*P*	$F_{(0,15)}$
Closed umbrella				
Feed latency (s)	2.6 ± 1.6	6.1 ± 4.5		4.75 (0.05)
Opened umbrella				
Flight response *	8/8	6/7	0.47	
Feed latency (s) **	27.5 ± 18.7	41.8 ± 31.0		0.41 (ns)

P: Fisher's exact probability – comparison between proportions of pairs
F: analysis of variance (level of significance)
* number of pairs in which at least one calf reacted strongly to the opening of the umbrella
** time to resume eating after the opening of the umbrella

Dog test

During the dog test, regrouped calves moved more, crossed more squares and spent more time moving. They also looked at the dog more often than controls (Table 3). There was no significant difference for the other behavioural items.

Table 3 Effect of environmental instability on the reactivity of calves to the proximity of a dog. The test was performed after 11 mixings on calves taken individually to a remote arena for 4min.

	Animals from control pairs (n = 16)	Animals from regrouped pairs (n = 15)	$F_{(1,15)}$	*U*
Volume of milk drunk (l)	3.8 ± 1.2	3.4 ± 1.8	0.79 (ns)	
Locomotion (no squares crossed)	12.7 ± 1.9	19.6 ± 5.4	7.24 (0.01)	
Looking at the dog (n) *	8 ± 2	10 ± 2		1.86 (0.10)
Latency to sniff the dog (s)	117 ± 53	91 ± 89		1.02 (ns)
Sniffing the dog (n) **	3.0 ± 3	3.8 ± 2.9	0.27 (ns)	

F: analysis of variance (level of significance)
U: Mann-Whitney test (level of significance)

* head of the calf is orientated towards the dog and is more than 30cm from the dog
** head of the calf is orientated towards the dog and is less than 30cm from the dog

Restraint test

The first time the calves were restrained, regrouped calves were more agitated than the controls (Figure 1). There was no difference in the three other sessions.

Discussion

Submitting calves to an unstable physical and social environment, by repeatedly relocating and mixing them, resulted in modification of their reactivity to potentially negative emotion-eliciting events.

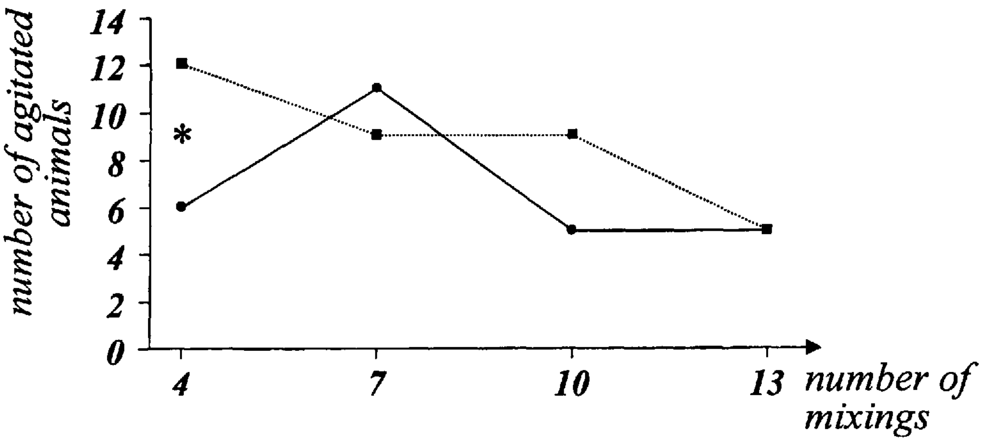

Figure 1 **Effect of environmental instability on the behavioural reactivity of calves to the restraint test. The test was performed individually in a crush after the 4th mixing and repeated four times 3 weeks apart (—●— animals from control pairs and ····■···· animals from regrouped pairs; * $P < 0.05$).**

Firstly, in the initial part of the umbrella test, designed to assess reactions to novelty, regrouped calves had a more disturbed feeding behaviour than control calves: when the closed umbrella was placed in front of the calves, the latency to start eating was longer for the former. Secondly, in the water spray test, designed to assess responses to suddenness, more startle responses were observed in regrouped calves than in controls. Thirdly, in the restraint test, regrouped calves were more agitated than controls. Finally, in the dog test, which was designed to assess fear-related reactions to a predator, regrouped calves were more agitated and looked at the dog more often. All these results indicate that living in an unstable environment makes calves more reactive to various potentially aversive events.

However, when the umbrella was opened suddenly, all calves reacted by stopping eating and stepping back in the pen, with no differences between treatments. The lack of differences between the regrouped and control calves may be due to a ceiling effect since the responses to the opening of umbrella were very high for all the animals. Alternatively, the lack of differences between calves might be due to the fact that the calves did not differ in their responses to suddenness. This hypothesis is confirmed in the water throw test where the two groups of calves no longer differed on the second, third and fourth occasions, ie when the stimulus was still sudden but no longer novel. Again, when the restraint test was repeated, the difference between the two treatments disappeared. Hence, the main difference in reactivity between regrouped and control calves is likely to have been due to the former reacting more intensely to novelty.

More evidence will be provided that calves which were submitted to a social and physical instability of the environment, were experiencing chronic stress. Actually, Veissier *et al* (unpublished data) have found that cortisol responses to an injection of ACTH in regrouped calves were higher than those of the control calves, showing that the sensitivity of their adrenal glands was enhanced. According to Dantzer *et al* (1983) and Friend *et al* (1985), who both compared calves kept in small crates to calves living in groups, chronic stress leads to an increased release of cortisol following ACTH challenges. Hence, the fact that the adrenal sensitivity to ACTH was enhanced in calves subjected to social and physical instability supports the hypothesis of a long-term state of stress. In our experiment, repeated regrouping seems to have played a large part in the aversiveness of the treatment. Young domestic ungulates develop a network of social relations early in life (Bouissou & Andrieu 1978; Reinhardt & Reinhardt 1981; see Veissier *et al* [1998] for a review) and a temporary disruption of social bonds elicits distress responses in calves characterized by heightened physiological and behavioural arousal (Boissy & Le Neindre 1990). Therefore, the hyper-reactivity to novelty observed in regrouped calves could result from the chronic stress they had experienced during the treatment.

Our results showing a hyper-reactivity to novelty in chronically stressed calves seem to contradict previous results. In particular, Broom (1987) found a decreased reactivity to a water test in sows confined in individual stalls. In order to understand why some authors have observed a decreased reactivity and others have reported the opposite effect, several hypotheses can be raised. The first one is the differences in social housing. The confined sows observed by Broom were housed individually, whereas our calves were kept in pairs. Another hypothesis is that cattle and pigs have different strategies for coping with stressful situations. We want to point out that the discrepancy between results may also be due to the difference in the informative value of the stressful environments that were applied to the animals. Since the work of Lazarus (1968), it has been widely suggested that an organism's emotional response to an external event results from cognitive processes. More particularly, the evaluation of an event with respect to its relevance for the organism is responsible for the elicitation and differentiation of emotion (Scherer 1993). In animals, impressive support was provided by the classical research conducted by Weiss (1972). In restrained rats submitted to electric shocks, some rats were given the possibility of terminating the shocks by a learned behaviour (avoidance-escape rats) while others were denied this possibility (yoked rats). Each time the avoidance-escape rats received a shock, the yoked rats received exactly the same shock. Yoked rats developed much more gastric ulceration than the avoidance-escape rats did. This result has been confirmed many times. In addition, the mere possibility of doing something in a stressful situation can reduce stress responses even if the action has no effect on the stressor. For instance, in food-deprived pigs submitted to an intermittent food delivery, the pituitary-adrenal arousal is reduced when pigs can pull a chain (Dantzer & Mormède 1983b). Therefore, it is now well established that emotion depends less on the physical characteristics of the potentially emotion-eliciting event than on the cognitive evaluation of the situation by the animal and of the possibility for action.

Depending on such cognitive processes, both a decrease or an increase in behavioural reactivity can be interpreted as specific coping strategies. When calves are mixed, they normally react by increasing social interactions such as sniffing, threatening or attacking (reviewed by Bouissou *et al* [in press]). It is likely that, when a change occurs in the environment, animals increase their general reactivity in order to be ready to react actively, such as by attacking or fleeing. In the case of our study, calves that were exposed to frequent social and environmental changes could have come to expect these changes and thus might have been more aware of any potential change in their environment. This would explain why they were more reactive to novel situations. By contrast, in Broom's experiment (1987), the stressful environment to which sows were subjected (isolation and confinement in a stall) did not change, and the animals' possibility of action was limited. In an uncontrollable situation, it seems more adaptive to adopt a passive strategy (Henry *et al* 1995). This has been observed in animals which are subjected to unavoidable electric shocks: they are no longer able to learn to avoid shocks when given the possibility to do so (Maier & Seligman 1976).

This phenomenon called learned helplessness has been put forward by Broom (1987) to explain the apathy developed by confined sows. In contrast, repeatedly regrouped and relocated calves may come to expect changes within their complex and unpredictable environment, and become sensitized to novelty.

In conclusion, repeated changes in the physical and social environment of calves enhance their reactivity to novel events. In addition, it is likely that the effect of chronic intermittent stressors on the animals' emotional reactivity depends on the strategies the animal can develop in response to the stressor. Whereas unavoidable stressful events are known to lead to passive coping and apathy, stressful events to which animals can respond actively are likely to make them more ready to react to further changes in their environment. This hypothesis must be further tested by subjecting the animals to the same repeated stressful events but in a more or less controllable environment, and by observing their reactivity to novelty.

Animal welfare implications

Whereas some acute aversive events can be tolerated because their effects are limited in time, repeated aversive situations leading to chronic stress should be banished in farmed or captive animals. However, states of chronic stress are difficult to detect. Alteration of the behavioural functioning of animals is likely to occur under chronic stress. Similarly to pharmacological changes which are used to detect alteration of the functioning of the hypothalamo-pituitary-adrenal axis in animals under chronic stress or in depressive humans (Caroll *et al* 1981; Friend *et al* 1985; Klemcke 1994; O'Toole *et al* 1998), the assessment of behavioural reactivity could help to detect chronic stress in farm animals. Such an approach could help to understand the coping strategy developed by an animal when facing stressful conditions: a decrease in reactivity may reflect a lack of control over the stressor and an increase in reactivity may reflect the engagement of the animal in an active strategy.

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