# THE DEVELOPMENT AND SIGNIFICANCE OF ABNORMAL STEREOTYPED BEHAVIOURS IN TETHERED SOWS

To my wife Mary Anne,
our parents
and Michael

Promotor : dr. P.R. Wiepkema, hoogleraar in de ethologie
Co-promotor: dr. J.M. van Ree, wetenschappelijk hoofdmedewerker aan de Rijksuniversiteit te Utrecht

G.M. Cronin

# THE DEVELOPMENT AND SIGNIFICANCE OF ABNORMAL STEREOTYPED BEHAVIOURS IN TETHERED SOWS

Proefschrift
ter verkrijging van de graad van
doctor in de landbouwwetenschappen,
op gezag van de rector magnificus,
dr. C.C. Oosterlee,
in het openbaar te verdedigen
op vrijdag 14 juni 1985
des namiddags te vier uur in de aula
van de Landbouwhogeschool te Wageningen.

G.M. Cronin

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Thesis
submitted to fulfill the requirements for the degree of
Doctor in the Agricultural Sciences
on the authority of the Rector Magnificus,
Dr. C.C. Oosterlee,
to be defended in public
on Friday 14 June 1985 at 4 pm,
in the Auditorium of the
Agricultural University of Wageningen.

## THEOREMS

I

A high incidence of sow wastage indicates that the environment in which sows live is unfavourable.

I.J. Walker, 1982. Anim. Prod. in Aust., 14: 238-241.

II

A most urgent need of modern intensive pig production is to reduce the level of wastage amongst gilts and young sows. The culling of young breeding animals due to reproductive failure and, or leg weakness will be reduced if the "burdens" of large litters to suckle, and living on bare concrete floors, were eased.

III

A return to less restrictive and more family-oriented housing systems for sows and their litters will reduce the growth check experienced at weaning by piglets, and improve the number of litters per sow per year.

IV

While as little as 3% of sows die in intensive housing systems per year, most deaths are associated with the absence of straw bedding, high sow density and close proximity of units.

J.P. Tillon and F. Madec, 1984. Ann. Rech. Vét., 15: 195-199.

V

Organisms prefer to control events in their lives and do so because control modulates the affective value of the event.

J.B. Overmier, J. Patterson and R.M. Wielkiewicz, 1980. In: "Coping and Health". Plenum Press, N.Y.

VI

Animal welfare can be defined, and thus measured, in accordance with the biological responses of animals to changes in the level of control and prediction over their environment.

This thesis.

VII

As minimum welfare requirements, intensively housed sows should not be tethered, nor closely restrained during extended periods, should be able to socially interact with other sows, and should receive straw bedding and 2 feeds per day.

H.H. Sambraus and B. Schunke, 1982. Wien. tierartzl. Mschr. 60 Jahrgang Heft 6/7.
A. Stolba, N. Baker and D.G.M. Wood-Gush, 1983. Behaviour, 87: 157-182.
This thesis.

VIII

The performance of stereotypies should be regarded as a symptom of environmental inadequacy and severely disturbed welfare.

M. Kiley-Worthington, 1977. In: "Behavioural Problems of Farm Animals", Knight and Forster Ltd., Leeds.
A. Stolba, N. Baker and D.G.M. Wood-Gush, 1983. Behaviour, 87: 157-182.
This thesis.

IX

If anyone kept a dog in the conditions typical for individually housed/tethered sows, he would be prosecuted and looked upon with horror.

R. Harrison, 1979. In: "Animals' Rights - a Symposium". Centaur Press Ltd., Fontwell Sussex.

X

Good welfare and sound, profitable husbandry are 2 factors that go hand in hand and are rarely in conflict.

D.W.B. Sainsbury, 1984. Pig News and Inform., 5: 377-381.

XI

Grant unto sows the ability to control and predict the events in their environment, as we would have them to unto us.

XII

In Holland there is a positive relationship between the population density of pigs in a region, and the annual amount of change in the ground level. Expansion of the Dutch pig industry will keep the country above sea level.

XIII

Take care of your dijkes ... should your chooks ever turn into emus!

Old Australian Proverb.

Thesis; Gregory M. Cronin
The development and significance of abnormal stereotyped behaviours in tethered sows.

Wageningen, 14th June, 1985.

## Preface

The research reported in this dissertation was carried out while I was the recipient of a post-graduate scholarship from the Australian Pig Industry Research Committee, and on study leave from the Victorian Department of Agriculture. The financial contribution of the Dutch Farm Animal Welfare Fund (Fonds Welzijn) is also gratefully acknowledged.

It is indeed an encouraging sign, and one which emphasizes the progressive nature of the pig industry in Australia, that the national committee (the APIRC) is willing to sponsor research into the welfare of intensively-housed pigs. This is despite most conclusions from "welfare research" drawing attention to the relationship between the intensive housing of pigs and unacceptably lowered states of welfare. In Europe, the move towards ever-restrictive and more-intensive, housing systems has gone considerably further than existed in Australia in 1982 (at the time of my departure). By studying at first hand the situation in Europe, lessons can be passed on to Australian pig producers, who (hopefully) will not succumb to the same problems facing intensive pig producers in Europe. One of the worst areas, in terms of animal welfare, is the housing of dry sows. The fulfillment of the research reported here will only be achieved if researchers and producers alike work towards genuine, and not compromised, improvements in the housing and welfare of pigs. The responsibility for the welfare of pigs lies with the pig producers. As a spokesbody of Australian pig producers, the APIRC is thus to be commended for attempting to promote greater knowledge on pig welfare, and for their forethought in encouraging the present research.

Similarly, I am very much obliged to the Agricultural University of Wageningen, and the Vereniging Varkensproefbedrijf, Noord- en Oost-Nederland, Raalte for allowing me to perform this research.

I am extremely grateful to my 'promotor', Professor dr. P.R. Wiepkema, for his invaluable advice, constant encouragement and unfailing support for my research throughout the past 3 years.

I wish to thank particularly Dr. J.M. van Ree and Prof.dr.ir. M.W.A. Verstegen for their discussions and suggestions during the planning and writing of parts of the present work.

To Mr. Peter Mekking of the Ethology Section, I extend my warmest thanks for his assistance in matters ranging from language translation to computer operations. To Mr. Jan Veldhuis, I am similarly indebted for the unfailing support in organizing video equipment and construction of stalls, etc., and for his help with the sows and their piglets. The contributions of a number of colleagues and students are also acknowledged where appropriate throughout this thesis. The care and maintenance of my experimental sows, housed in the animal accommodation of the Agricultural University of Wageningen (De Haar), was carried out under the supervision of Mr. J. Hagens. I am also indebted to Mr. J.G. Plagge, Mr. J. Tuininga and the piggery staff in Raalte for their co-operation with the on-farm research.

I am grateful to the many people who helped with statistics, Ir. T. van der Lende, Drs. W.G.P. Schouten, Dr. M.K. Carlstead and Dr. G.A.A. Albers, but especially to Mr. P. Mekking, who can take credit for teaching me all I know about computers.

The patience and care of Mrs. G.J. Gijsbertse-Huiberts and Mrs. H.W. Vertregt-Fonhof in typing this thesis, and Mr. W. Heije in drawing many of the figures, is thankfully acknowledged. To Kathy Carlstead, with whom I shared the "foreigners' office" in the roof of the Zodiac Building during most of the past 3 years, I express my sincerest thanks for her support and discussions of my work, and her comradeship.

I have great pleasure in dedicating this dissertation to my parents, my wife Mary Anne and our son Michael.

To my parents I give special thanks for their constant support, not just during the past 3 years with their regular correspondence, but since my earliest years, when they not only tolerated my obsession with animals but willingly encouraged my interests.

To Michael, who at the age of 46 days was whisked away from his grandparents to live in Holland. His contribution is as great as anyone elses: on many occasions he served as a "guinea pig" for the study of the development of behaviour. But mostly, I am grateful to him for the never-ending enjoyment that he provided.

FINALLY, it is with great pleasure that I acknowledge the help of my wife Mary Anne for her assistance, encouragement and patience throughout the past three years.

## Contents

# CHAPTER 1

## General introduction

With the movement towards intensive housing of livestock during the past 30 years, the term "factory-farm", which once described a farm organized on industrial lines (Oxford Dictionary, 1976), has changed its significance and now conjures up a deeply emotional meaning. "Factory-farming" adeptly describes the similarities that exist between the treatment, and performance expectations, of animals and machines used in the manufacture of a product. The analogy between animals and machines however, becomes uncomfortably realistic when the repetitive actions performed by sows in tethers or individual stalls of a commercial, intensive pig breeding farm are studied. These repetitive behaviours variously labelled abnormal, disturbed or neurotic (depending on which species performs them) are called stereotypies.

Stereotypies are reported to occur in many species including man (Hutt and Hutt, 1970; Thelen, 1979), chimpanzees (Davenport, 1979), monkeys (Berkson, 1968), dogs (Melzack, 1954), pigs (Sambraus and Schunke, 1982), voles (Ödberg, 1981), hens (Duncan and Wood-Gush, 1974), and so on. Stereotypy behaviour is a very interesting class of behaviour for a number of reasons: the behaviours may be performed for hours on end yet have no obvious goal. Furthermore, their performance is reported to reduce anxiety in frustrated animals (Dantzer and Mormède, 1983) but also to generate stimulation in "bored" individuals (Kiley-Worthington, 1977). It is known that stereotypies develop out of chronic stress situations. As such, ethologists amongst others, propose that they are indicative of past or current insoluble conflict, and therefore may be indicators of reduced welfare status (Wiepkema et al, 1983). Concern over the welfare of intensively-housed breeding sows has thus been expressed, since many such sows are reported to perform stereotypies (Sambraus,1981; Sambraus and Schunke, 1982; Stolba et al., 1983; and so on).

The proportion of sows in a husbandry system which perform stereotypies may therefore be a critical determinant of acceptability of housing systems in terms of animal welfare. As a practical rule, Wiepkema et al. (1983) suggest that an abnormality may not occur in more than 1% or 5% of the animals in a given system. Furthermore, it is reasonable to assume that animals experiencing lowered states of welfare will produce at sub-optimal levels. Unfortunately, insufficient quantitative data are available on the degree, and consequences of, welfare problems in intensively-housed sows.

In order to make progress in the understanding of animal welfare problems, we need to begin at a basic point. If stereotypies are indicators of lowered welfare, then we need to know why this should be so. It is of primary importance then to answer the following questions: 1) how do stereotypies develop, 2) how are they maintained and 3) what do they mean for the performer? Then maybe we can understand better their relationship with welfare. A practical consequence is that the association between welfare and productivity will become measurable.

The first problem encountered when studying stereotyped behaviour is one of definition. Ödberg (1978) set about to present a definition of stereotypies that incorporated the phenomenological characteristics. Thus stereotypies were behaviours that 1) consisted of morphologically identical movements, 2) which were regularly repeated and 3) had no obvious function or were unusual in the context of their performance.

While such a definition is acceptable in general terms, it does not allow for example, the occurrence of short-term, within-animal variability in the performance of the behaviour. Thus there is some difficulty with terminology.

The second problem is one of quantification. This may be approached by measuring the fixedness of an individual's actions, for example by calculating the repeatability of sequences of actions or performance times. Alternatively, other researchers have observed the differences in morphology of behaviours which developed as a result of rearing animals in environments offering a range of environmental complexity (barren to richly stimulating). From either approach an operational definition can be formed that allows the existence of stereotypies to be identified and their quantitative nature measured.

An excellent example of a mathematical approach was by Stolba et al. (1983). These authors quantitatively assessed the informational content of the behaviour performed by tethered and individually-stalled sows to determine the "redundancy" of their behaviour. Redundancy was described as the complement of the uncertainty or diversity in a sequence, i.e. the variability of behaviour.

Many examples exist in the literature of studies investigating the development of stereotypies in response to deprivation of key environmental stimuli, for example, Berkson (1968) with monkeys, Davenport (1979) with chimpanzees, Ödberg (1981) with voles, etc.

On the understanding that stereotyped behaviour can be quantified, a description and classification of the seemingly non-functional, repetitive behaviours performed by 36 tethered breeding sows is reported in the second chapter.

Chapter three presents a detailed description of how stereotypies develop in sows after tethering, and provides quantitative information about the stages of development and between-animal variability. An hypothesis is proposed which suggests a potential role for endogenous opioids (endorphins) in the development and performance of stereotypies. Evidence to support this hypothesis is presented in chapter four. The consequences of the hypothesis are discussed in relation to animal welfare.

In the experiments described in the 5th and 6th chapters, the effects of stereotypy performance level by tethered sows are assessed in relation to sow productivity, viz. piglet production and sow metabolic rate. Chapter five also presents survey information of the quantitative and qualitative characteristics of stereotypy behaviour performance, attentiveness and fearfulness of tethered sows in a commercial herd. The results of the research are discussed in relation to the probable association between sow welfare and productivity.

## References

Berkson, G. 1968. Development of abnormal stereotyped behaviours. Developmental Psychobiol. 1: 118-132.

Dantzer, R. and Mormède, P. 1983. De-arousal properties of stereotyped behaviour: evidence from pituitary-adrenal correlates in pigs. Appl. Anim. Ethol. 10: 233-244.

Davenport, R.K. 1979. Some behavioral disturbances of great apes in captivity. In The Great Apes (ed. D.A. Hamburg and E.R. McCown), pp. 341-357, The Benjamin/Cummings Publishing Co., Menlo Park, California.

Duncan, I.J.H. and Wood-Gush, D.G.M. 1974. The effect of rauwolfia tranquilizer on stereotyped movements in frustrated domestic fowl. Appl. Anim. Ethol. 1: 67-76.

Hutt, S.J. and Hutt, C. 1970. Stereotypies and their relation to arousal: a study of autistic children. In Behaviour Studies in Psychiatry (ed. S.J. Hutt and C. Hutt), pp. 175-204. Permagon Press, Oxford.

Kiley-Worthington, M. 1977. Stereotypies. In Behavioural Problems of Farm Animals, pp. 74-79, Oriel Press, Stocks field.

Melzack, R. 1954. The genesis of emotional behavior: an experimental study of the dog. J. Comp. Physiol. Psychol. 47: 166-168.

Ödberg, F.O. 1978. Abnormal behaviours (stereotypies). 1st World Cong. on Ethol. Appl. to Zootech., Editorial Garsi, Madrid, pp. 475-480.

Ödberg, F.O. 1981. Environmental and pharmacological determinants of pathological stereotypies in voles (Clethrionomys glareolus britannicus). Ph.D.Thesis, State University of Gent.

Oxford Dictionary 1976. *The Concise Oxford Dictionary of Current English*. 6th ed. Clarendon Press, Oxford.

Sambraus, H.H. and Schunke, B. 1982. [Behavioural disturbances in breeding sows kept in boxes]. Wien. tierärztl. Mschr. 69. Jahrgang Heft 6/7: 200-208.

Stolba, A., Baker, N. and Wood-Gush, D.G.M. 1983. The characterization of stereotyped behaviour in stalled sows by information redundancy. Behaviour 87: 157-182.

Thelen, E. 1979. Rhythmical stereotypies in normal human infants. Anim. Behav. 27: 699-715.

Wiepkema, P.R., Broom, D.M., Duncan, I.J.H. and Putten, G. van 1983. Abnormal behaviours in farm animals. A report of the Commission of the European Communities, Autumn, 1983.

# CHAPTER 2

# THE DEVELOPMENT AND SIGNIFICANCE OF ABNORMAL STEREOTYPED BEHAVIOURS IN TETHERED SOWS

## AN ANALYSIS OF STEREOTYPED BEHAVIOUR IN TETHERED SOWS

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## Introduction

The problems associated with the definition and discussion of stereotyped behaviour in man and animals have been elucidated by a number of authors (for example, Berkson, 1968; Kiley-Worthington, 1977; Ödberg, 1978; Thelen, 1979). Although Morris had emphasised the importance of investigations to quantify "abnormal behaviour rituals" in animals as early as 1966, there exists little quantitative data or analyses of stereotyped behaviour in the literature particularly for farm animals. Recently, authors such as Van Putten (1981), Sambraus (1981) and Wiepkema (1982a) have emphasized the significance of ethological criteria for the assessment of farm animal welfare, and in particular, the interpretation of stereotyped behaviours. However, without concrete quantitative data, the many questions being raised by scientists, producers and welfarists regarding the interpretation of stereotyped behaviours in animals housed under intensive conditions cannot be satisfactorily substantiated.

The aim of the present study was to record and analyse stereotyped behaviours in tethered sows in order to obtain a quantitative description of these behaviours. Such a quantification is necessary for a full understanding of the biological relevance of the phenomenon. Two aspects are immediately relevant: 1) the organization or structure of these behaviours - are there categories of these stereotypes? - is some classification of the different types possible? and 2) how do these classes or types of stereotypes occur in the individual animals per day and over longer periods of time? Such descriptions are absent in the existent literature. In order to assess the biological significance of stereotypes such a description is essential. With respect to tethered sows we may ask, which aspects are common and which are different in the various stereotypes performed by these animals. Moreover, how stereotyped are stereotypes; we really don't know!

Since it is apparent that some stereotypic behaviours have obvious functions e.g. predunging, agonistic, posture changing, etc., these behaviours will not be considered here.

The main aim of this paper therefore, is to present a description and classification of the seemingly "non-functional" stereotypes (stereotypies) of tethered sows. In this paper we shall also present a first use of this description. The description will be derived from sows which had been tethered for different periods of time. No attention will be paid to an equally important point, namely, how did these stereotypies develop.

## Materials and methods

Thirty-six Large White x Netherlands Landrace sows were studied at a 250-sow, intensive piggery in the Netherlands. The sows were neck-tethered in partial stalls with solid front panels, on a concrete floor which was slatted behind the sows. At the study piggery weaned sows were tethered in the dry sow accommodation within a week of being inseminated. Commercial sow diet at the rate of 2.75-3.0 kg per sow was fed once daily at 07.45 h. Water was available from nipple drinkers during 2, one hour periods: from 09.00 and 17.00 h. An equal number of sows from each of 6 parity groups (second to seventh pregnancy, inclusive) were chosen at random from the available dry sows for inclusion in the study. Each individual sow was only observed during one of the nine observation days.

In order to limit the potential range of stereotyped behaviours to those that seem to be non-functional, observations did not commence until feeding and drinking were completed. Some details of the experimental plan are shown in Fig. 3. On days when observations were made, four sows in turn were observed during eleven, 5 minute sessions commencing at about 10.00 h. After 7 sessions had been recorded for each sow, the observer quietly left the room, returning 20 min. later to complete the remaining 4 sessions per sow. During each session, the observer continuously recorded the behaviour of one sow via a numeric code scheme in an OS-3 event recorder (Observational Systems Inc., Seattle,Washington). Each code represented an element of behaviour and consisted of 4 digits, which simultaneously described 3 aspects pertaining to the sow: her posture, action and the substrate upon which the action was performed. The OS-3 stored the sequence and the time duration (tenths of seconds) of each behaviour element, and in association with a host computor, a hard copy of the data was obtained. From these data, it was possible to precisely identify the existence of some order, organization or structure in a sequence of elements.

After removing from the data all behaviour which was non-stereotyped (e.g. resting, random movements, etc.) and stereotypes that appeared to be functional (e.g. pre-dunging and urinating behaviours) or were performed rarely and for short durations (e.g., fighting), only 11 actions and 5 substrates were used by the sows in the performance of abnormal stereotyped behaviours. This is despite approximately 50 distinct actions being recorded and 9 different substrates being available to the sows. As described by Schmidt (1982) all "abnormal" behaviours were oral activities. In addition, since none of the six distinct postures (standing through to side lying) recorded for sows in the present study were associatied to a significant degree with the performance of the stereotyped behaviours under investigation, data relating to posture will not be included. The actions and substrates utilized in the performance of "seemingly non-functional" stereotyped behaviours are defined as follows:

**Actions:**

1) chewing/biting: continuous and rhythmical opening and closing of the mouth, including "biting".

2) sucking: apparent sucking and subtle jaw moving while the mouth was closed usually with the cheeks slightly involuted and the front of the lower lip drawn into a V-shape.

3) mouth stretching: continuous and rhythmical mouth opening and closing, however the emphasis is on stretching the lower jaw whilst open, in either the vertical, horizontal or both planes, rather than on chewing.

4) palate grinding: continuous and rhythmical opening and closing of the mouth, however a squeaking noise is emitted as the mouth is closed.

5) tongue flicking: the tongue appears to be moving rapidly about inside the mouth while the sow performs continuous and rhythmical chewing but without opening her mouth much.

6) licking: a continuous and rhythmical action in which the tongue protrudes from the mouth and is then withdrawn.

7) nibbling: continuous and rhythmical biting by the sow, using the extreme fore-part of the mouth and usually in a gentle manner.

8) nosing: pushing against or along an object with the bridge of the snout.

9) rooting: pressing and scraping the rooting disk against a surface.

10) pressing with rooting disk: pressing the rooting disk against a surface without rooting actions.

11) pause: fixed rest periods when no action was performed, for example between bursts of chewing actions.

**Substrates:**

1) trough: the feed trough, which occupied the entire width of the sow stalls and was 15 cm deep.

2) floor: the concrete surface under the sow.

3) bars and front panel: all the vertical fixed physical environment except for the trough and tether chain.

4) tether chain: the chain which attached the sow to her stall.

5) nil: used when an action was performed without an external substrate; e.g. sham chewing.

The combination of an action and a substrate was termed an element. Since these elements were performed in ordered sequences before being repeated, such a unique sequence of elements was called a cycle. A series of identical cycles therefore formed a bout of stereotyped behaviour.

The registration of an element, however, did not differentiate the actual components forming the element. For example, if a sow was standing (1) while biting (33) on a bar (4), her behaviour element was coded: 1433. Although the element may appear to be always performed in a fixed manner between cycles, there is no indication of this from the OS-3 record. The fixedness of components forming elements (e.g., the number and orientation of individual bites in an element such as chewing/biting) was assessed from video recordings made on other occasions for 20 sows performing abnormal stereotyped behaviours. Therefore, for the code 1433, it was possible to detect the variance of behavioural parameters of these components: e.g., the number of bites in the time recorded, which bar and at which location on a bar, the position of the bar in the mouth and the duration of the element.

The relationships between the performance and the characteristics of stereotyped behaviours, and parity number, stage of pregnancy (which was closely correlated with time spent tethered in the current pregnancy) and time of day were examined.

## Results

Although 11 distinct stereotyped actions were recorded for all sows, on average individual sows performed only 3.7 actions (range 1-7) on 2.0 substrates (range 1-4) in bouts of stereotyped behaviour (SB). These elements (combinations of actions and substrates) formed sequences which recurred in a cyclic manner. As a first approximation, the following criteria were used to define a stereotyped cycle:

1) the cycle contained a fixed number of elements (e.g. ABCD);
2) the elements occurred in the same order in successive cycles (e.g. ABCDABCDABCD....);
3) the time duration of elements, and therefore of cycles, was relatively constant; and
4) non-stereotyped elements did not occur between cycles.

A behaviour was considered to be stereotyped if it consisted of a sequence of such cycles. An inventory of these elements and their frequency of occurrence are shown in Table 1. In 55% of SB, all elements were performed without contact with the sows' external environment (nil substrate). These elements are termed sham actions. The remaining 45% of SB were formed of exclusively non-sham ele-

Table 1. Inventory of the actions performed and the substrates utilized by sows in abnormal stereotyped behaviours (frequency of combinations shown). (n = 36 sows)

| Actions | Substrates | | | | |
|---|---|---|---|---|---|
| | nil | trough | floor | bars/front panel | tether chain |
| Chewing/biting | 32 | 1 | | 7 | 9 |
| Sucking | 12 | | | | |
| Mouth stretching | 9 | | | | |
| Palate grinding | 2 | | | | |
| Tongue flicking | 2 | | | 7 | |
| Licking | 2 | 3 | 8 | | 2 |
| Nibbling | | | | 2 | |
| Nosing | | | | 2 | 2 |
| Rooting | | | | 8 | |
| Pressing with rooting disk | | | 1 | 2 | |
| Pause | 21 | | | | |

Table 2. Examples of segments of abnormal stereotyped behaviours in 3 sows showing differentiation into cycles and elements and the time duration of elements (*Element A: bar nibbling, B: bar biting, C: sham chewing, D: pause, E: sham sucking).

| Sow 577 | | | Sow 884 | | | Sow 1042 | | |
|---|---|---|---|---|---|---|---|---|
| cycle | element* | duration (sec) | cycle | element* | duration (sec) | cycle | element* | durati |
| 1 | A | 0.6 | 1 | C | 4.7 | 1 | C | 2.1 |
| | B | 2.2 | | D | 1.4 | | E | 2.4 |
| | C | 2.5 | 2 | C | 3.2 | 2 | C | 2.5 |
| 2 | A | 0.5 | | D | 1.8 | | E | 3.3 |
| | B | 2.6 | 3 | C | 5.5 | 3 | C | 2.4 |
| | C | 5.8 | | D | 2.0 | | E | 2.6 |
| 3 | A | 2.4 | 4 | C | 3.5 | 4 | C | 3.5 |
| | B | 2.3 | | D | 5.2 | | E | 2.0 |
| | C | 4.6 | | etc. | | | etc. | |
| | etc. | | | | | | | |

ments (9%) and combinations of sham and non-sham elements (36%). As an example, segments of SB in 3 sows are presented in Table 2.

Based on the previously mentioned criteria, 94 different SB were identified for the 36 sows. These behaviours were each unique in their composition, and were performed during 38.7% of the observation time. In many sows, bouts of SB were observed which were identical in all respects apart from the consistent omission of one or more elements. However, because the elements of these shorter cycles were all present in the longer ones, and the elements in both cases exhibited organization into fixed sequences, they were considered to be separate but related classes of SB: fixed complete routines (FCR) and fixed subroutines (FSR), respectively: e.g.,

FCR: ABCDABCDABCD........
FSR: ACACACAC......

On average, each sow performed 1.7 FCR and 0.9 FSR SB over the 11 periods of observation. These contained a mean of 2.3 and 1.3 elements per cycle, respectively, and were performed during 25.8 and 12.9% of observation time, respectively.

It is of further interest to note that two other forms of patterned behaviour were recorded, in which recognizable but less-fixed cycles were evident. In the first form, a gradual substitution of some elements occurred over a sequence of cycles. As a first approximation to quantify and classify stereotypies in tethered sows, we have termed these "transitory" stereotypies, since they were found to occur between two different fixed SB: e.g.,

FCR Transitory FCR
ABCABCABC...ABCABCABDABCABCABDABCABDABCABDABD...ABDABDABD

The second form ("loose" stereotypies) were bouts of behaviour in which the cycles, although less-fixed, contained some fixed elements, but one or more varied elements occupied the non-fixed element space(s): e.g.,

........ABCDABCEABEFABDGABCFABGDABDCABEG........

Not more than 6 varied elements were recorded for individual sows in "loose" stereotypies. The "transitory" and "loose" SB were only recorded during 4.9 and 2.7% of observation time, respectively, and were not observed in all sows.

While there was no clear indication that parity of the sows influenced the incidence, performance time or number of cycle elements of the fixed SB, there were effects due to stage of pregnancy. The mean number of FCR and FSR SB increased with advance in the stage of pregnancy (Fig. 1). The percentage of observation time that sows performed fixed SB increased until day 80 of pregnancy, after

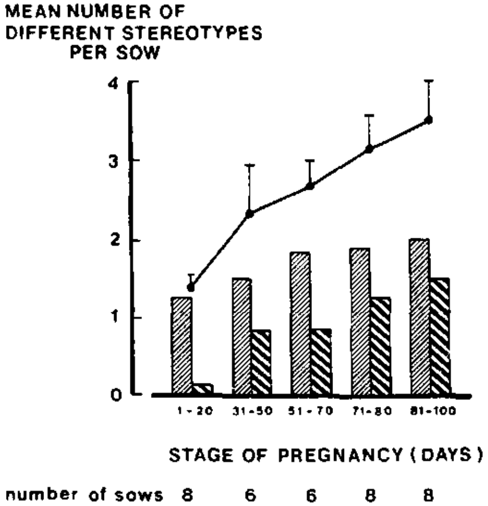

*Fig. 1.* — The number of different FCR and FSR stereotypes per sow (fine and heavy hatched columns) and the total of both classes (●) in relation to pregnancy stage. Vertical lines represent + S.E.

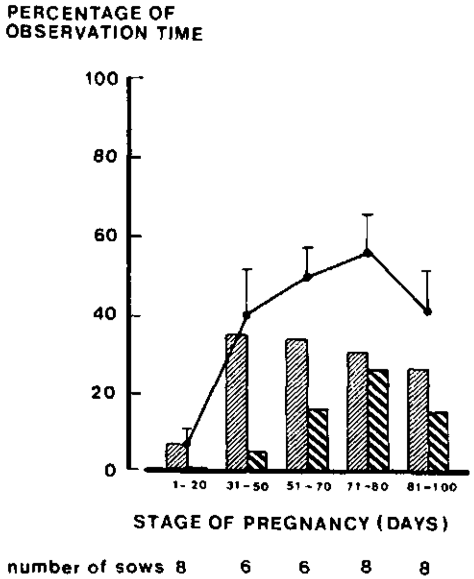

*Fig. 2.* — Percentage of observation time that sows performed FCR and FSR stereotypes (fine and heavy hatched columns) and the total of both classes (●) in relation to pregnancy stage. Vertical lines represent + S.E.

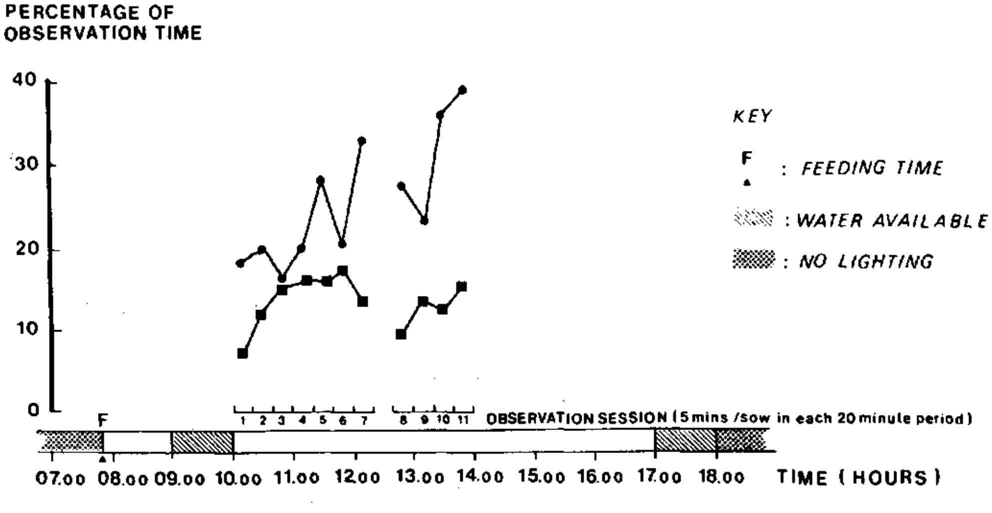

*Fig. 3.* — Changes in the percentage of time spent performing FCR (●) and FSR (■) stereotypes in relation to observation session, time of day and the availability of food, water and lighting.

which there was a marked decrease (n.s.) (Fig. 2). While the sows tended to perform FCR more than FSR in the first half of pregnancy, around the time of maximum performance there was little difference between the 2 classes. After day 80 of pregnancy, there was a tendency for the sows to perform continually less FCR SB. Over the period of the day when observations were made, the mean proportion of time that sows performed FCR SB tended to increase (Fig. 3). The performance of FSR SB, however, tended to increase over the first few sessions, when the FCR SB were performed at a relatively constant level, but in the last sessions of the day, both classes of SB were performed at increasing levels with time. The number of elements per cycle of FCR SB was lower, but not significantly lower, for sows in the day 1-20 pregnancy stage compared with sows in the remaining stages of pregnancy (1.9 and 2.4, respectively).

## Discussion

The quantitative approach taken in the present study to measure stereotypies in tethered sows revealed a quantifiable rigidity and flexibility in performance of these behaviours. For example, a sow might perform a FCR in a rigid manner: the sequence of cycles contains identically-ordered elements and components performed for characteristic durations and in specific orientations. Alternatively, she may be flexible in some of these aspects and perform FSR, transitory or loose stereotypies. The measurability of these cycles, elements and components is a prerequisite for the quantitative and qualitative analysis of cause and function of stereotypies. Once the causation and function have been satisfactorily described, adequate measures can be taken to improve welfare status of the animals involved, and by this, a better control over their production and reproduction.

The present study further showed that stereotypies in tethered sows are less fixed or stereotyped than has been suggested for other animals (Hediger, 1950; Morris, 1966; Ödberg, 1978). It is of interest to briefly speculate on this variability. However, one must not lose sight of the fact that the rigid, fixedness of the stereotypies was the most preponderant feature of the sows' behaviour. Compared with the situations in which very stereotyped behaviours have been described, the situation of the tethered sows differs from that described for studies reported in the literature in 2 important aspects: 1) the environment of tethered sows potentially contains an unexpected high level of "natural" variation, certainly more than presumably exists for wild-captured animals in the classic zoo environment. For example, while sows may remain continuously tethered in the same stall for 15 weeks, neighbouring sows may be removed or replaced, or the herdsman may perform other non-routine activities. In addition, the management of breeding sows involves movement to farrowing crates or weaning pens, and interaction with piglets and boars in these environments. Exposure to this environmental variability may contribute to the variability observed for stereotypies in the present study. 2) By comparison with the present study, the studies described in the literature mostly concern wild or zoo animals in confinement. Sows are less likely to be disturbed in confinement than wild animals, since sows have been selected for, and are more adapted to, confinement. If we speculate that the eventual rigidity of a stereotypy reflects the level of original or current conflict due to confinement (e.g. caging a wild bear or tethering a domestic sow), then it is probable that the degree of variability in the stereotypy of a tethered sow will be greater than that of a wild animal. If this is true, then it would be worthwhile to relate the eventual degree of stereotypy rigidity with the level of conflict experienced by sows, for instance at the beginning of confinement, demonstrated by the amount of conflict behaviour shown in that period. Integration of both these points may substantially improve our understanding of the biological significance of abnormal stereotyped behaviour.

Most authors consider that stereotypies develop in animals as a response to, and therefore are indicative of, a suboptimal environment (see reviews by Kiley-Worthington, 1977; Ödberg, 1978). Other authors such as Sambraus (1981), Van Putten (1981) and Wiepkema (1982a) extrapolate on this theme to suggest that stereotypies are ethological indicators of welfare status. However, the functions of the behaviours remain obscured through lack of quantitative data. Unlike behaviours such as feeding, drinking or comfort behaviours, which may also be performed in a stereotyped manner, the stereotypies described in the present study seemingly lacked function. Kiley-Worthington (1977) suggests that stereotypies may act as coping behaviours to buffer the level of incoming stimuli and thus maintain a balanced Umwelt under adverse conditions (Wiepkema, 1982b) or frustration (Duncan and Wood-Gush, 1972, 1974). Alternatively, they may initially be learning behaviours, as suggested by Wolff (1968) and Thelen (1979), in subjects which fail to progress to the next level of behavioural development. Further, Garrigues et al. (1982) suggest that some stereotypies may serve as means of non-verbal communication, while Fentress (1976) argues that their repetitive nature will lead to fixation by which an overloading of the neural processing mechanisms may be avoided.

The observation that different classes of stereotyped behaviour exist may help in determining some aspects of their function. "Loose" stereotypies, for example, may be learning behaviours, in which the sow tests the suitability of new elements or sequences in order to establish, or improve the level of, contingency over her environment (Mason, 1978). The performance of FSR, being a reduction of FCR stereotypies, by sows may be a strategy to conserve energy use and, or neural processes underlying these stereotypies. In the latter case, the performance of shorter-cycle routines may allow additional mental processes to occur simultaneously with the performance of stereotypies.

The high proportion of stereotyped behaviours and elements which were sham behaviours, that is, behaviours not directed at the sow's external environment, is an interesting finding. Substrates in the external environment may be less attractive (e.g. side bars) in that they are also accessible to neighbouring sows or may be included in the "personal" space of neighbours, whereas sham substrates (teeth, tongue, saliva, etc.) remain under the sole control of the individual. The interpretation of sham behaviours in relation to welfare status is as yet not possible, but further research may enable grading on the basis of the elements involved. Different elements or stereotyped cycles may have different functions, but until more data are gained, such general preferences may not be recognized. Unpublished data from observations in our stables suggest that chains are attractive substrates for tethered sows, and are utilized post-feeding but not prefeeding. In addition, thin rather than heavy gauge chains are preferred for chewing, an observation which may explain the low proportion of tether chain stereotypes recorded at the study piggery.

In the present study, the number of different stereotypies per sow, and their performance time, increased with time spent tethered. After day 80 of pregnancy, however, there was a negative association with the proportion of time that sows spent performing stereotyped behaviour, but not with the number of stereotypies per sow. It is feasible that the longer a sow remains confined in the same environment, the more adversive the situation becomes, producing a positive relationship therefore between the increased adversity and the number and duration of stereotypies performed. If this is so, this strongly supports the suggestion that abnormal stereotyped behaviours are indicative of negative welfare or negative environmental aspects. By seeking a balance with their adversive environment, sows increase the number of behaviours which are stereotyped.

In conclusion, through the use of quantitative measurement techniques, advances in the study of stereotyped behaviours in tethered sows can be achieved. Classical stereotyped behaviour, however, may only exist under real stereotyped conditions.

## Summary

The behaviour of 36 Large White x Netherlands Landrace sows was individually and continuously recorded during eleven, 5-minute periods commencing at 10.00 h. The sows were neck tethered in partial stalls in the dry sow accommodation of a 250-sow, commercial herd. The recorded behaviour data were analysed for cycles of repetitive behaviour which appeared to be non-functional. Four classes of non-functional stereotyped behaviour (stereotypies) were recognized: fixed complete routines, fixed subroutines, transitory and loose. These were performed during 25.8, 12.9, 4.9 and 2.7% of the observation time, respectively.

Some aspects of the two fixed-class stereotypies were found to be related to stage of pregnancy, that is, time spent tethered in the current pregnancy. The proportion of observation time that sows performed fixed stereotypies, and the number of fixed stereotypies, increased per sow with increase in stage of pregnancy, although in the former instance, less time was spent performing the stereotypies after day 80 of pregnancy.

Considerable variability was recorded in the stereotypies in terms of use of particular elements, duration of element use, etc., suggesting that the classical definition of stereotyped behaviour may only hold in situations where the environment is totally unchanging. The use of a quantitative approach to measure stereotypies in tethered sows provides the basis for investigation of cause and function of these behaviours, and therefore the interpretation of stereotypies in terms of sow welfare.

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## References

Berkson, G., 1968. Development of abnormal stereotyped behaviours. Developmental Psychology 1, 118-132.

Duncan, I.J.H., and Wood-Gush, D.G.M., 1972. Thwarting of feeding behaviour in the domestic fowl. Animal Behaviour 20, 444-451.

Duncan, I.J.H. and Wood-Gush, D.G.M., 1974. The effect of a rauwolfia tranquillizer on stereotyped movements in frustrated domestic fowl. Appl. Anim. Ethol. 1, 67-76.

Fentress, J.C., 1976. Dynamic boundaries of patterned behaviour: interaction and self-organization. In Growing Points in Ethology, ed. P.P.G. Bateson and R.A. Hinde, pp. 135-169. Cambridge: Cambridge University Press.

Garrigues, P., Peterson, A.F., De Roquefeuil, G., and Gourdon, N., 1982. On behavioural similarities between animal and human stereotypies, with a note on a preliminary analysis of stereotypic movements in psychotic children. Appl. Anim. Ethol. 9, 197-198 (Abstract).

Hediger, H., 1950. Wild Animals in Captivity. New York: Dover Publication Inc.

Kiley-Worthington, M., 1977. Stereotypies. In Behavioural Problems of Farm Animals, pp. 74-79. Stocksfield: Oriel Press.

Mason, W.A., 1978. Social experience and primate cognitive development. In The Development of Behavior: Comparartive and Evolutionary Aspects, eds. G.M. Burghardt and M. Bekoff, pp. 233-251, New York: Garland Press.

Morris, D., 1966. Abnormal rituals in stress situations. The rigidification of behaviour. Philosoph. Trans. Roy. Soc. London B251, 327-330.

Ödberg, F.O., 1978. Abnormal behaviours: stereotypies. Proc. First World Congress on Ethology Applied to Zootechnics. Madrid, 23-27 Oct., 1978. Section B.

Sambraus, H.H., 1981. Abnormal behaviour as an indication of immaterial suffering. Int. J. Study Anim. Prod. 2, 245-248.

Schmidt, M., 1982. Abnormal oral behaviour of pigs. In Disturbed Behaviour of Farm Animals, ed. W. Bessei, pp. 115-121. Stuttgart: Verlag Eugen Ulmer.

Thelen, E., 1979. Rhythmical stereotypies in normal human infants. Anim. Behav. 27, 699-715.

Van Putten, G., 1981. Quantifying well-being in farm animals. Pig News and Inform.2, 372 (Abstract).

Wiepkema, P.R., 1982a. On the significance of ethological criteria for the assessment of animal welfare. Paper presented at CEC-Conference: Indicators Relevant to Farm Animal Welfare, 8th Nov., 1982. Mariensee, Western Germany.

Wiepkema, 1982b. On the identity and significance of disturbed behaviour in vertebrates. In: Disturbed Behaviour in Farm Animals, ed. W. Bessei, pp. 7-17. Stuttgart: Verlag Eugen Ulmer.

Wolff, P.H., 1968. Stereotypic behaviour and development. The Canadian Psychologist 9, 474-484.

# CHAPTER 3

# THE DEVELOPMENT AND SIGNIFICANCE OF ABNORMAL STEREOTYPED BEHAVIOURS IN TETHERED SOWS

## THE DEVELOPMENT OF ABNORMAL STEREOTYPED BEHAVIOURS IN SOWS IN RESPONSE TO NECK TETHERING

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## Abstract

Cronin, G.M., Wiepkema, P.R. and Hofstede, G.J. The development of abnormal and stereotyped behaviours in sows in response to neck-tethering. Appl. Anim. Beh. Sci.

The manner in which abnormal stereotyped behaviours (stereotypies) develop was closely studied in 9 parity-one sows during the first 12 weeks after neck-tethering. Stereotypies developed after the sows passed through a number of behavioural stages, termed stages 1-4. The stages can be summarily labelled: 1) attempted escape; 2) inactivity; 3) outward-directed activity and 4) basic stereotypy. The median duration (and ranges) that the sows spent in stages 1-3 were 45 min. (10-180 min.), 1 day (140 min - 16 days) and 15.7 days (7.8 - 55 days). Once a basic stereotypy was formed, random aggressive-like acts were rarely observed, and sows spent the majority of their active time in the performance of the stereotypy. Most sows built onto their basic stereotypy in stage 4, with the addition of extra components. The stereotypies which developed after tethering were almost exclusively environmental-directed. These were derived from redirected aggressive acts resulting from the conflict/frustration experienced by loss of controllability due to restraint in a socially-imbalanced, barren environment.

In the light of recent evidence suggesting that endorphins (endogenous opiates) may be the factor underlying the continued performance of stereotypies in tethered sows, the authors present an hypothesis to describe the potential role of endorphins in the development of stereotypies. The study concludes that stereotypies are behavioural responses to chronic stress in adult female pigs. The development of stereotypies in breeding sows may be avoided by providing less restrictive housing systems that allow for social interaction and which present variation in the quantity and quality of environmental stimulation.

## Introduction

Routine acts like walking, eating, etc., are often so well-learned by an animal, that when observed at a later time, the actions may be considered stereotyped behaviours. Indeed it is to the animals' advantage to assign commonly-performed actions to automatic control, as this allows for other possibly creative or vital processes to occur simultaneously (Fentress, 1976). Analysis of the behaviour sequences of individually-housed sows by information theory showed that almost all behaviour sequences became less variable, i.e. more stereotyped, with increasing age of the animal (Stolba et al., 1983). Furthermore, these authors compared their results with the variability of behaviour sequences performed by sows in a natural environment. Here also, the animals sometimes performed behaviour sequences with low variability by engaging in very long sequences containing only a few investigatory elements.

Psychologists and ethologists however, do not always consider stereotyped acts to be signs of normality. Infant monkeys and chimpanzees raised without their mothers developed abnormal stereotyped behaviours (Berkson, 1968, Davenport, 1979). Berkson assumed that the abnormal acts were in fact normal behaviours derived via normal learning processes, but which were functioning in an abnormal situation and were gradually conditioned by the animal's environment.

In probably all cases, the existence of abnormal stereotyped behaviours in an individual's ethogram can be related to a serious conflict of some sort experienced by the animal (Maier, 1949; Duncan and Wood-Gush, 1972). Because the conflict was insoluble via "conventional" strategies, seemingly non-functional solutions were invented. However, since the development and performance of behaviour is dynamic, the morphology of stereotyped acts may alter over time. Thus the form of an abnormal stereotyped behaviour (stereotypy) in an older animal may provide little insight into 1) the nature of the original conflict; 2) the approach taken to find a solution and, or 3) even what the earlier forms of the stereotypy looked like.

By definition, stereotypies are morphologically invariable actions which are regularly repeated and seemingly purposeless, or at least unusual, for the situation in which they are performed (Ödberg, 1978). Such behaviours have been commonly noticed amongst zoo, pet-shop and circus animals (Holzapfel, 1938; Hediger, 1950; Morris, 1964), and also in certain circumstances amongst humans (e.g. Kravitz et al., 1960; Berkson and Davenport, 1962). Their occurrence is plainly associated with conflict: for example, restraint and, or confinement in an unstimulating, and possibly socially-imbalanced, environment. The degree of environmental enrichment influenced the proportion of chimpanzees (Davenport, 1979) and captive voles (Ödberg, 1981) which developed stereotypies: as the quality of the environment decreased, so the proportion of stereotyping animals increased. Similarly, Berkson (1968) showed that monkeys, isolated from their mothers at different ages in their first year of life, commonly developed stereotypies. The age at isolation modified the frequency of the behaviour. Thus, lack of certain factors in the environment or loss of the ability to control the environment with one's own actions (Mason, 1978), and other forms of stress/conflict would seem to have important consequences for stereotypy development.

In animal husbandry, modern trends towards highly intensive housing systems have been reflected in altered behaviour patterns of the domestic species so housed (Wood-Gush et al., 1975; Ekesbo, 1977). Recent studies have clearly indicated that a considerable proportion of the behaviour of individually-housed and tethered breeding sows, respectively, was in the form of stereotypies (Sambraus, 1981; Stolba et al., 1983; Cronin and Wiepkema, 1984). Although these disturbed behaviours have been interpreted to indicate a state of suboptimal welfare for the performer (Stolba et al., 1983; Wiepkema et al., 1983), the precise nature of development, or the underlying mechanisms, are not clearly known. However, it would appear to be very important to know how such behaviours develop in individual situations, as this may indicate more clearly why the behaviours developed and why they did so in the form observed. Furthermore, such an approach may reveal information about the nature of the underlying mechanisms, and thus why animals would continue to perform stereotypies. Ultimately, such knowledge would allow us to suggest methods for the prevention of these disturbed behaviours.

The aim of the present experiment was to follow in detail the precise manner of development of stereotypies in individual animals. Since it is well documented that tethering of adult female pigs (sows) often leads to the development of stereotypies, and because of the important consequences which these behaviours have for the welfare of farm animals, it was decided to study the process in a limited number of animals, first tethered in the second pregnancy.

## Material and methods

### Animals

Nine physically-sound, nulliparous pigs were selected at random from available 42-week old animals for use in the present experiment. The pigs were reared in the manner previously described by Van der Steen (1983), and were either purebred Dutch Landrace (DL) or Yorkshire-DL crossbred animals. At 42 weeks of age the pigs were transferred to other accommodation, but were still kept in groups and with straw bedding. At regular intervals from this time the behaviour of the pigs was recorded. On day 112 after insemination, the pigs were weighed and placed in standard farrowing crates with or without straw. After farrowing, all animals received straw during the subsequent 28 day lactation period.

### Tether housing and treatments

Within 4 weeks of weaning, the sows were neck-tethered in partial stalls in dry sow accommodation (see Cronin et al., 1985, for diagrammatic descriptions of the tether stalls and dry sow accommodation. The average age of the sows at neck tethering was 63.0 weeks (SD = 2.2 weeks). Three sows were tethered on each of 3 occasions: on 2 occasions in November 1982 7 days apart and in April 1983. The physical features of the tether stalls were similar to those provided for tethered sows on commercial breeding farms (see Daelemans, 1984). Six sows, however, also had access to a 40 cm length of medium gauge chain (the "extra" chain) suspended in the front of their tether stalls above the feed trough. These chains were provided in the hope that sows would direct their stereotypies on these chains, and thus allow a clearer view for the purposes of observation and video recording of the fine details of the behaviours. With this in mind, three of these sows were introduced to similar chains during 4 weeks of their rearing (from 42 weeks of age).

On the morning of tethering (day 1) the sows were weighed, and at about 10.30 h were individually brought to the tether stalls. Prior to 10.30 h however, 0.5 kg of sow feed had been placed in the feed troughs of the appropriate tether stalls. This provided enough distraction to facilitate ease of tether application. The neck tethers (model 2013 Brouwers, Holland) were fitted according to the individual neck sizes of the sows.

In order to reduce the possibility of leg and foot injuries, as observed in other studies involving tethered sows (e.g. Barnett et al., 1984), the concrete floor in the area where the sows stood was covered with grooved rubber matting. No straw bedding was supplied whilst the sows remained tethered in the dry sow accommodation

A semi-automatic feeding system delivered 1.4 kg of commercial sow diet into the sows' troughs at 08.45 and 15.30 h daily, following the sounding of a warning bell. This warning signal was incorporated so that the presence of the observer would not be associated with feeding. Water was available at all times from nipple drinkers. Although some natural light entered the sow room, this was supplemented between 06.30 and 18.30 h by illumination from fluorescent lights.

### Behaviour observations

The behaviour of the sows was recorded on 27 observation days during the first 12 weeks of neck tethering. In weeks 1-3, 4-9 and 10-12, respectively, there were 4, 2 and 1 observation days per week. An observation day contained 4 observation sessions, which commenced at 08.15, 10.30, 13.30 and 15.15 h, respectively. The first and last observation sessions incorporated feeding. Since it was apparent that the events surrounding the 2 feeding times per day were identical, the behavioural data from the 08.15 and 15.15 h observation sessions were combined on the basis of pre- and post-feeding times. Thus there were 4 observation sessions per day, simply referred to as the pre-feeding, post-feeding, 11.00 h and 14.00 h observation sessions, respectively.

An experienced observer seated 2 m above and to the fore of the sows, continuously recorded the behaviour of individual sows during 5-min periods (trials) via a 4-digit code scheme in an OS-3 event recorder (Observational Systems Inc., Seattle, Washington). The behaviours performed were considered to be combinations of a posture, an action or vocalization and a substrate upon which an action was directed, as previously outlined by Cronin and Wiepkema (1984). A list of the 7 postures, 8 substrates, 36 actions and 3 vocalizations recorded for the sows in the present experiment are presented in Table 1. Grunting was not included in the list of vocalizations due to its frequent occurrence, and idling/resting/sleeping were recorded as inactivity.

Apart from day 1, when 4 trials were recorded per sow per session, each sow was observed in turn during two 5-min trials per session. For each observation day therefore, there were 8 observation trials of 5 min. each recorded per sow. Thus each sow was individually observed during 220, five-min. trials over the period of the experiment. The OS-3 event recorder stored the sequence and the time duration (tenths of seconds) of each behaviour code per trial. The data were later dumped into a host computer for further processing.

In addition, written notes were made on the behaviours of the individual sows on most observation days and especially on day 1. During the first 6 hours of day 1 of the experiment an observer remained seated in the sow room during most of the time. Time-lapse and normal speed video recordings were also made at intervals during the experiment to aid in the description of stereotypied sequences which developed.

These sows were/are part of a small experimental herd under regular observation in an ethological project investigating the development and significance of abnormal stereotyped behaviours in tethered sows. As such, detailed behavioural records are also available for the sows from at least the time of the first farrowing. Similarly, observations have continued on the sows in subsequent pregnancies (tethering periods) resulting in the formation of a bank of detailed historic behaviour data on individual sows.

## Results

The quantitative behaviour records for each of the 9 sows in the present experiment were studied over the 27 observation days. The individual behaviours (see Table 1) in each 5-min. observation trial were noted for their duration and occurrence in sequences of activity. The individual behaviours and sequences were then classified where possible on the basis of apparent function. For example, pulling against the tether was assumed to indicate an escape attempt; licking the floor and trough after feeding reflected food-seeking activity; and so on. The functions of other behaviours and sequences, however, were less obvious. These acts (such as continuous chewing on sham or non-nutritive substrates) were simply classified as repetitive, seemingly non-functional behaviours.

By working backwards through the data records of each sow, we were able to identify behaviours that conformed to our definition of a stereotypy. Thus we could determine when and how the stereotypies emerged in individuals by examining relevant behaviour sequences which occurred before stereotypy formation.

## Stages of development of a stereotypy

Most sows developed a number of new behaviour sequences in response to tethering that were clearly recognizable as stereotypies (see Table 2). It was apparent that these behaviours developed as a result of the sows passing through a number of consistent behavioural states (stages). Thus it is necessary to provide general descriptions of these stages, with some indication of the time scale involved and boundary definitions. The four behavioural stages can be summarily labelled: 1) attempted escape; 2) inactivity; 3) outward-directed activity and 4) basic stereotypy, and are referred to as stages 1 to 4 respectively (see Fig. 1).

**Stage 1** was characterized by a high frequency and duration of escape attempts, aggressive acts, conflict and frustration. Once sows had eaten the feed in their troughs they began to reverse out of the tether stall. Following a brief and gentle tug on the tether chain, the sows threw themselves violently backwards, straining against the tether. This first and long escape attempt lasted from about 2 to 13.5 min. (median 7 min., see Table 3). Sows thrashed their heads about as they twisted and turned in their struggle to free themselves. Often loud screams were emitted and occasionally individuals crashed bodily against the side bars of the tether stall. This sometimes resulted in sows collapsing to the floor.

Subsequent escape attempts were shorter and less vigorous with the sows simply pulling backwards on the tether or trying to turn around in the tether stall. In this latter action, but also at other times in stage 1, the sows forced their snouts between the side bars or into a corner in the manner previously described by Fraser (1975), or pressed their rooting disk hard against the floor. The sows often remained in this position for many minutes. In addition, spasmodic

Table 1. Individual behaviours (combinations of a posture, a substrate used and an action/ vocalization) recorded during the experiment.

Postures

- stand
- kneel
- sit
- sit with front legs in kneel posture
- belly lie
- side lie
- lying in between belly and side postures

Substrates

- trough
- drinker
- floor
- bars
- self
- other pig
- extra chain
- tether

Actions

- feed
- lick
- root
- nose
- nibble
- chew
- bite
- attempt to bite
- agonistic acts
- sniff
- touch with rooting disk
- hold in mouth
- suck
- paw(fore leg)
- drink water
- splash water
- rub head or body
- scratch(hind leg)
- stretch
- yawn
- mouth stretch (repetitive action)
- head shake
- body shake
- body sway
- pre-dung hind leg "stepping"
- urinate
- defaecate
- look "alert"
- snout pressed between bars or in corner
- rapid sideways head movements
- move back and forth
- adjust lying position
- tongue flick inside mouth
- palate grinding
- pull against tether
- try to turn around

Vocalizations

- quiet groan
- whine
- scream

Table 2. Main stereotypies developed by the sows (denoted by capitals) and the sequence of performance from basic to complete routine of the stereotypy (denoted by Roman numerals). Components that *are underlined were repeated within sequences. Unless indicated,* sequences were performed whilst standing. (EC = extra chain, TC = tether chain, B = bars, T = trough, D = drinker, F = floor, SC = sham chew and MS = mouth stretch).

| Sow | | | Stereotyped sequences |
|---|---|---|---|
| 19 | A | I) | chew EC/SC |
| | | II) | chew EC/SC/lick T |
| 36 | A | I) | press D/drink/MS over D |
| | | II) | press D/drink/MS over D |
| | | III) | press D/drink/MS over D/drink/MS away from D |
| | | IV) | press D/drink/MS over D/lick T/MS away from D |
| | | V) | press D/drink/MS over D/drink in T/lick T/MS away from D |
| | | VI) | press D/drink/MS over D/drink/spray water/drink in T/lick T/MS lick T/MS away from D |
| 37 | A | I) | continuous chew EC |
| | | II) | long bouts of I) joined by short bouts of SC |
| 54 | A | I) | SC/sham suck, in left front corner of stall |
| | | II) | SC/sham suck, while head moves back and forth along front B, head tilts, B nosed and "kissed", body sways. |
| 63 | A | I) | tongue flick inside mouth/SC, while head moves back and forth along front bars. |
| 64 | A | I) | continuous chew TC |
| | | II) | long bouts of I) joined by brief SC |
| | | III) | long bout of I)/SC/lick T |
| | B | I) | chew TC/pause |
| 77 | A | I) | press D/root D/SC/drink |
| | | II) | press D/root D/drink/SC |
| | | III) | press D/root D/SC/drink/SC |
| | B | I) | root F in one location |
| | C | I) | sit idle with head drooped, occasionally body sways |
| 78 | | A) | before day 40 |
| | | I) | continuous chew EC |
| | | II) | long bouts of I) joined by brief root at EC attachment point on B |
| | | B) | after day 40 |
| | | I) | lie: SC/sham suck |
| 79 | A | I) | sit/stand: continuous chew EC |
| | | II) | sit/stand: chew EC/drink/MS over D |

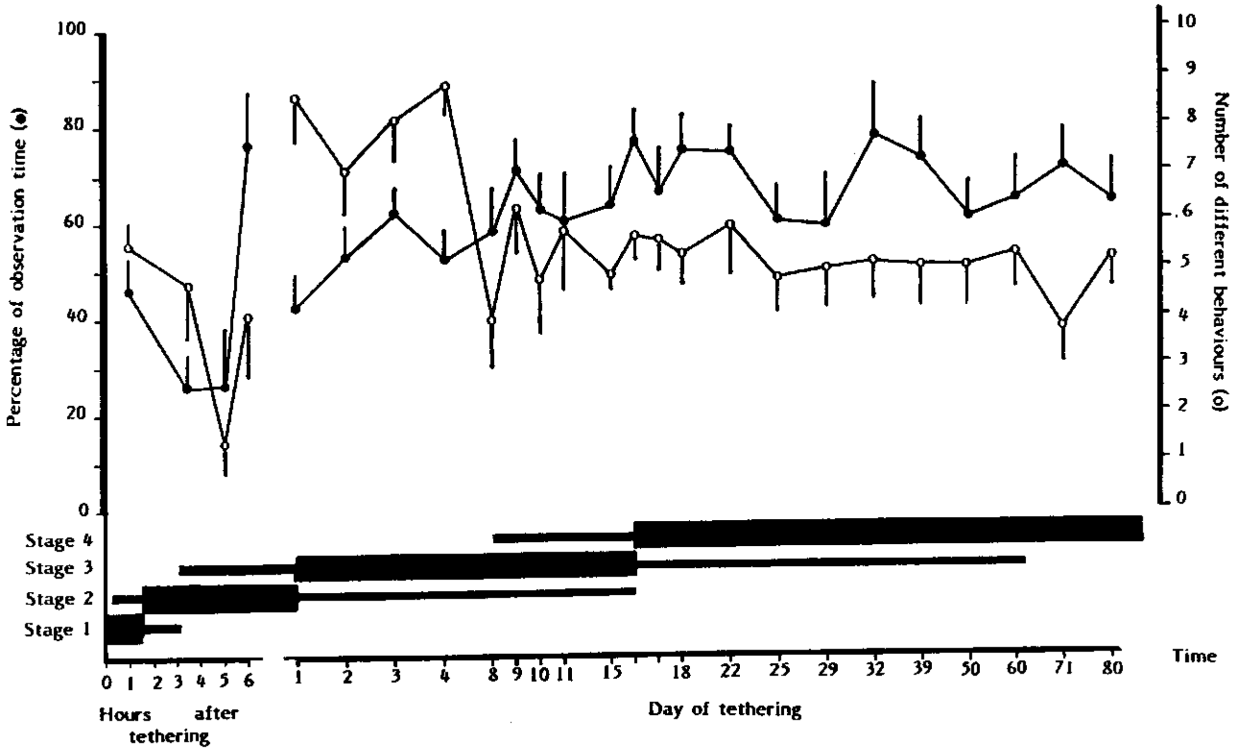

Figure 1. Changes in the mean proportion of observation time that the 9 sows were active (solid dots) and the mean number of different behaviours performed that were directed at the floor, bars, tether or extra chain (open circles). Vertical lines represent the standard error of the means. Horizontal bars and lines, respectively, indicate the median duration and range of the stages of stereotypy development by the sows.

but nevertheless violent attacks were directed at any accessible part of the environment (bars, floor, trough or neighbouring sow) and especially the tether chain. Sows, however, sometimes disrupted these foregoing activities to briefly lick the floor or trough, or to use the drinker. After some time, sows seemed to be unsure as to whether they should pull back on the tether. In these circumstances, the sows adopted a foot stance which reflected imminent flight, but instead rocked back and forth. Stage 1 was considered to have ended when the sows lay down and remained inactive for at least the subsequent 10 min. The median duration of stage 1 was 45 min. (range = 10 to 180 min, Table 3). The duration of the first long escape attempt was inversely correlated with the total duration of stage 1 (Spearman's rank correlation $r_s = -0.73$, $P < 0.05$, $n = 9$), probably reflecting that the most vigorous resisters were most rapidly exhausted.

In **stage 2** the sows remained lying idle, initially immobile, for long periods. Occasional quiet groans and whines were emitted, and often sows lay with their snouts thrust under the bars. All sows displayed a period of rigid immobility on the day of tethering during about 25 to 160 min. (median = 120 min.). In most cases this was terminated by the sow standing, briefly pulling on or biting the tether chain, before simply becoming inactive. As illustrated in Figures 2b and 3b, a considerable proportion of the activity which did occur during observation sessions was in the form of aggressive acts. Sows that were in stage 2 when feeding occurred spent little time in activities like licking the trough or floor following feeding, before resuming a lying posture.

Three of the 9 individuals performed sham oral activities, such as sham chewing, which had been previously recorded for those animals before tethering. These activities were mostly performed after feeding. Short bouts of other activities were also performed in stage 2 and although they were random in nature, they generally contained aggressive-like, environment directed acts.

Stage 2 was considered to have ended from the first observation session after which the sow remained idle during less than 50% of the observation time per day on 3 of 4 consecutive days. The stage had a median duration of 1 day (range = 2¼ h. to 16 days). The Spearman's rank correlation coefficient for the relationship beween time spent in stage 1 and stage 2 was $r_s = 0.53$ ($n = 9$, n.s.).

**Stage 3** was characterized by an increase in the level of activity compared with stage 2 and over time (as suggested by Fig. 1) and fewer long bouts of inactivity during observation sessions. With time, there was a gradual organization of random behaviour into sequences, a reduction in the number of different environment-directed acts performed by individual sows (e.g. after day 4, see Fig. 1)

Figure 2a. Changes in the proportion of total time spent active that sow 19 performed her "old" stereotypy - sham chewing (open circles) and new stereotypy-extra chain-directed (solid dots) after tethering. Horizontal lines indicate the stages of stereotypy development.

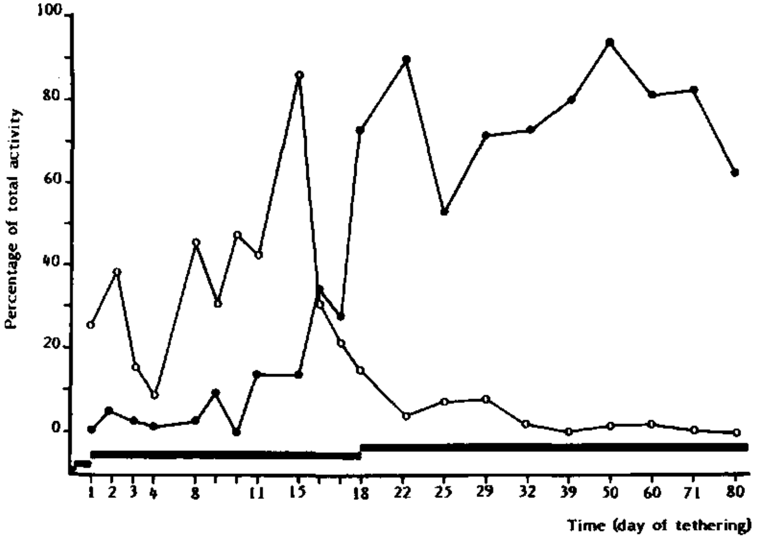

Figure 2b. Changes in the proportion of total time spent active that sow 19 performed aggressive-like, non-stereotyped behaviours directed at the extra chain (o—o), the tether (●—●), floor (*---*) and bars (+---+). Horizontal bars indicate the stages of stereotypy development.

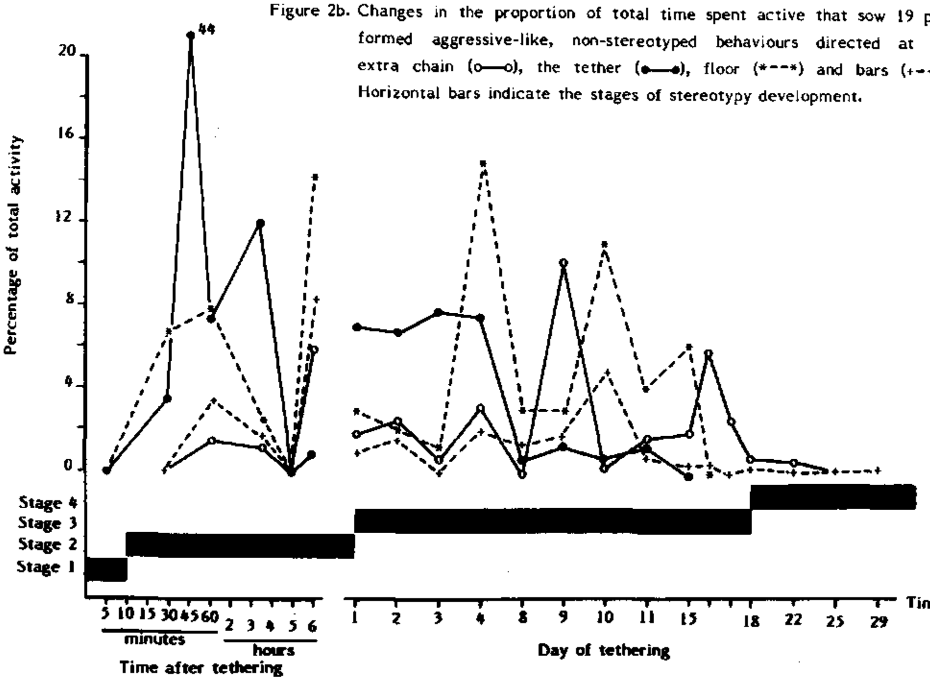

Figure 3a. Changes in the proportion of total time spent active that sow 63 performed various self-directed, sham chewing actions (open circles) and her ultimate tongue-flicking stereotypy (solid dots). Horizontal lines indicate the stages of stereotypy development.

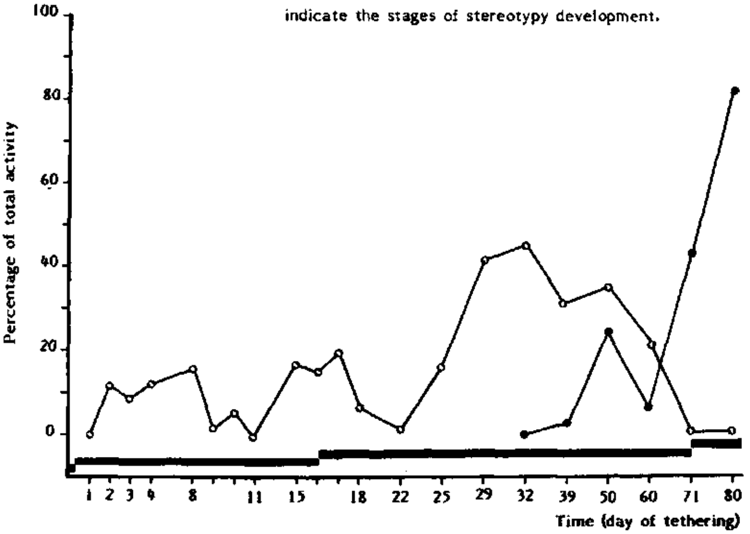

Figure 3b. Changes in the proportion of total time spent active that sow 63 performed aggressive-like acts against the tether (●—●), floor (*---*) and bars (+---+). Horizontal bars indicate the stages of stereotypy development.

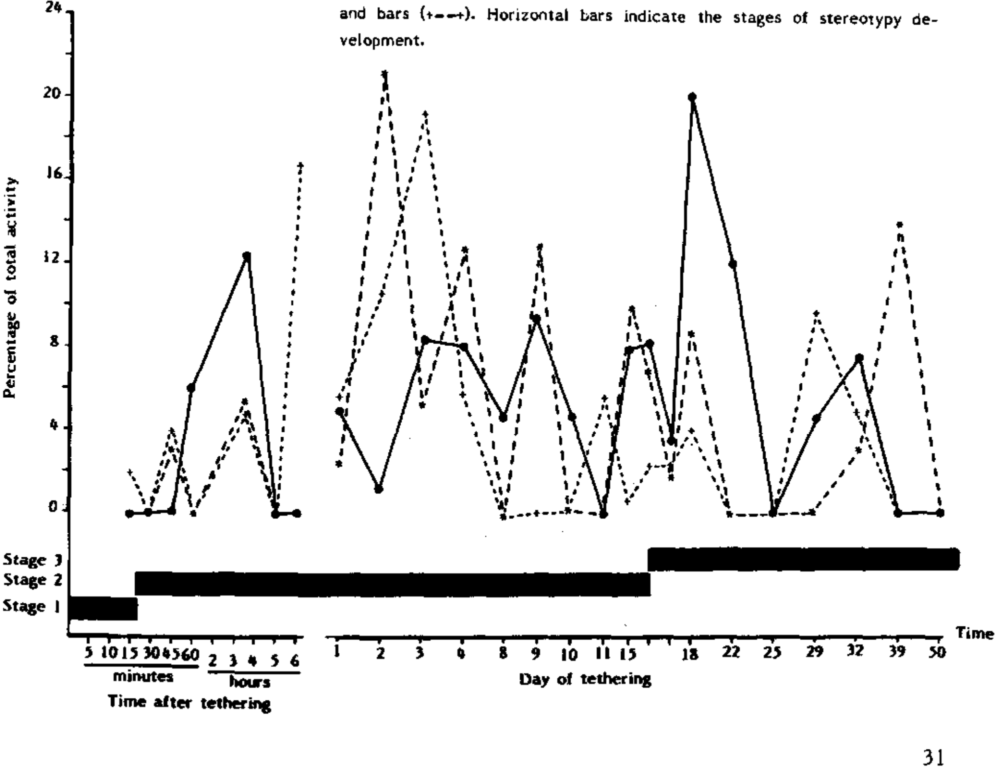

Table 3. Amount of time (approximate) that individual sows spent in stages 1-3, and the time to reach stage 4, following tethering on day 1.

|  | Stage 1 |  | Stage 2 |  | Stage 3 | Stage 4 |
|---|---|---|---|---|---|---|
|  | Duration of: |  | Duration of: |  | Duration | Time to reach stage |
| Sow number | a) 1st escape (min) | b) total stage (min) | a) immobility (min) | b) total stage (days) | (days) | (day) |
| 19 | 7 | 10 | 25 | 1 | 17 | 18 |
| 36 | 4.5 | 90 | 150 | 0.16 | 14.8 | 15 |
| 37 | 3 | 90 | 120 | 3 | 40 | 43 |
| 54 | 2 | 180 | 120 | 0.21 | 15.7 | 16 |
| 63 | 12 | 20 | 160 | 16 | 55 | 71 |
| 64 | 9 | 45 | 90 | 0.10 | 14.9 | 15 |
| 77 | 5.5 | 40 | 30 | 16 | 20 | 36 |
| 78 | 11 | 50 | 120 | 0.12 | 7.8 | 8 |
| 79 | 13.5 | 15 | 35 | 1 | 15 | 16 |
| Median | 7 | 45 | 120 | 1 | 15.7 | 16 |

and a corresponding increase in the proportion of activity that was spent on particular acts (Fig. 2a). Although much activity was in the form of mild investigatory behaviours, aggressive-like acts were nevertheless common. Typical mild investigatory acts included sniff, lick, touch, nibble and paw, whereas aggressive acts were bite, nose and root. All of these actions were initially random and performed in short bouts on almost every accessible aspect of the environment. Figure 2b suggests a trend towards a reduction in the level of aggressive-like acts during the latter part of stage 3 and the beginning of stage 4 for one sow.

When a behaviour sequence previously identified as conforming with the definition of a stereotypy became the most commonly performed action (see Figures 2a, 3a and 4), stage 3 was considered to have ended. This also corresponded with a reduction in aggressive-like acts (Fig. 2b) and an increase in the bout length of the stereotyped act (Fig. 4). Figures 3a and b illustrate the changes in the level of performance of repetitive sham actions and aggressive-like acts, respectively, in sow 63 over time. This sow expressed a number of surges in the performances of different sham stereotypies (variations of self-directed oral actions) during stages 2 and 3 (see Fig. 3a). On days 25-29 for example, such a situation occurred. Noticeably there was no aggressive-like behaviour recorded on day 25. On and after day 29 however, sow 63 again performed aggressive acts and the performance of that particular repetitive action gradually diminished. The level of aggressive-like acts remained at a low level past day 50, and by day 71 a new and "successful" stereotypy was established.

The median duration of stage 3 was 15.7 days (range = 7.8 - 55.0 days), and there was a significant relationship between the durations of stages 2 (inactivity) and 3 ($r_s = 0.89$, $P < 0.01$, $n = 9$).

Three types of stereotyped behaviour were developed in response to tether housing and were performed by the sows in stage 4. These different categories of behaviour had either developed in stage 3 or were modified in that stage from existing behaviour patterns.

### 1) Actions associated with major events

Prior to, and during, the performances of major events the sows performed specific stereotyped sequences. Because the events in question - defaecation, urination, posture change, feed and drink - had important functions for the sows, it was assumed that the associated relevant behaviours were similarly functional. Furthermore, since the behaviours had short bout durations, they could not by definition be classed as stereotypies. Thus the behaviours were not studied in great detail during the present experiment.

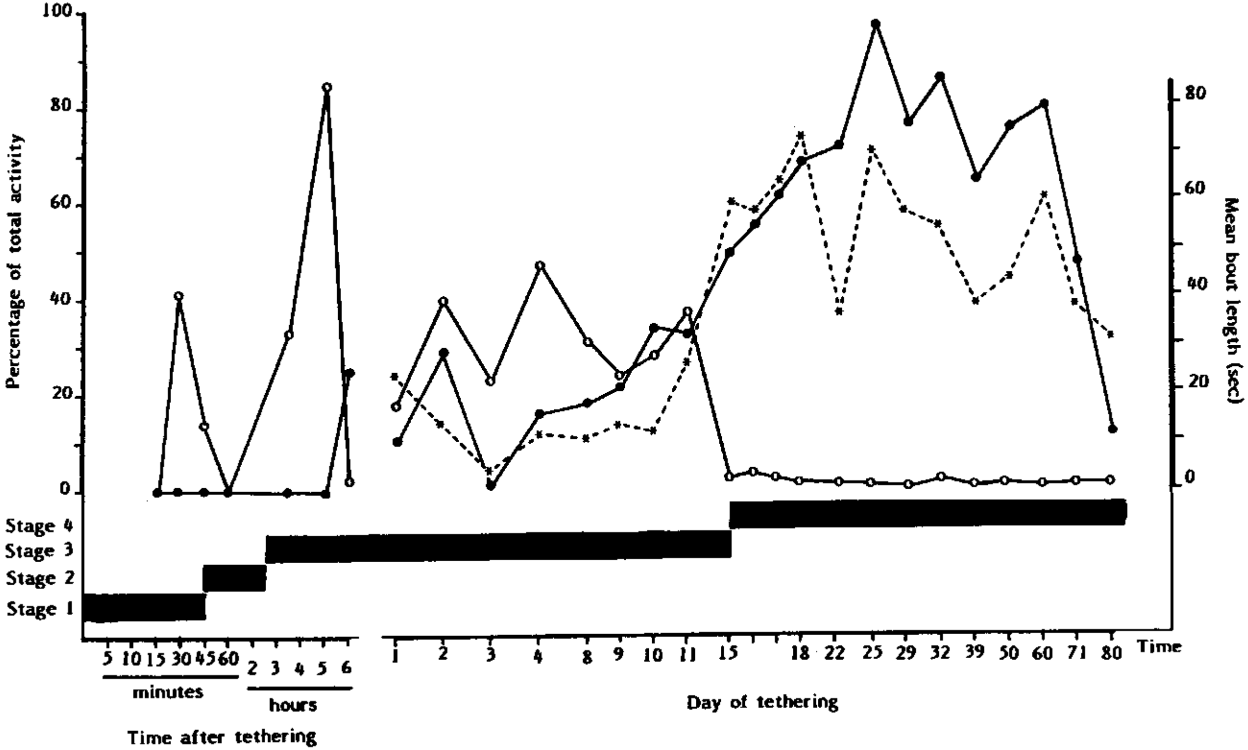

Figure 4. Changes in the proportion of total time spent active that sow 64 performed tether-chain chewing (solid dots) and tether chain-directed aggressive acts (open circles) after tethering. The former action became the stereotypy of this sow. Mean bout length of tether chain chewing is indicated by *---*. Horizontal bars indicate the stages of stereotypy development.

### 1a. Defaecation/urination

Prior to the occurrence of these functions, all 9 sows performed similar, aggressive-like preliminary sequences. The sequences were noted to develop from early attempts to leave the tether stall prior to defaecation/urination. Instead, the sows became agitated and would bite and root (particularly) the front bars of the stall. The sows seemed to learn that defaecation/urination would succeed only after the performance of these aggressive-like acts. Thus in order to urinate, for example, a tethered sow bites/roots the bars in a stereotyped way, then thrusts her snout between the bars while her rear legs "mark time on the spot" (rear leg stepping - see Table 1). Shortly, the back becomes arched over and the sow stands still in this position and attempts to urinate. If not successful, the sow returns to a normal standing posture, and commences the sequence of preliminary actions over again.

### 1b. Posture changing

A number of the sows developed abnormal methods of changing directly from a standing to a sitting posture. Sows should normally do this via a series of postural changes and according to the sequence: standing - kneeling - belly lying - sitting. Preceding the abnormal sequence, sows performed aggressive-like preliminary acts, mostly rooting of the side bars.

A second form of stereotyped behaviour preceded normal posture changing. Prior to changing from standing to lying (tucking in, see Van Putten, 1977), but particularly before bedding down for the night, sows directed aggressive-like sequences at the tether chain (nose/root) and floor (root/paw).

### 1c. Pre-feeding behaviour

Within 3 days of being tethered, the sows learnt the association between the prefeeding warning bell and the presentation of feed in their troughs. Although the 10 sec. interval between the occurrence of these 2 events could not be influenced by the behaviour of the sows, sows nevertheless developed, and consistently performed, rapid stereotyped head movements during this time.

### 1d. Eating and drinking

These actions had obvious functional characteristics but would occur in the same form and circumstances each day. In response to the limited trough space, and the location of the drinker in an area confined by bars, the sows adapted their actions to suit their confinement limits. It should be noted here that both

Table 4. Changes to the mean duration (plus std. devn.) of components and ratio of occurrence in stereotyped sequences of 3 sows, with indications of earlier sequences from which the stereotypies were derived. Unless indicated, the stereotypies were performed whilst standing. (EC = extra chain, TC = tether chain, F = floor, SC = sham chew; asterisk alongside day number = start of stage 4).

| Sow | Day | Behaviour sequences | Mean(s.d.) component durations : n = 30 | Ratio of occurrence |
|---|---|---|---|---|
| 54 | 1 | Lie SC/sham suck | 6.3(4.3) : 13.1(9.9) | 1:1 |
| | 3 | Lie SC/sham suck; | 8.9(4.8) : 7.4(7.1) | 1:1 |
| | | Lie SC/pause | 8.1(7.4) : 3.0(1.3) | 1:1 |
| | 9 | Lie SC/sham suck; | 4.2(2.3) : 7.5(5.6) | 1:1 |
| | | SC/sham suck | 3.6(1.6) : 5.6(3.1) | 1:1 |
| | 11 | Lie SC/sham suck; | 3.7(1.6) : 5.1(2.1) | 1:1 |
| | | SC/sham suck | 3.9(1.6) : 11.6(12.4) | 1:1 |
| | 16* | SC/sham suck | 3.2(2.4) : 8.5(5.7) | 1:1 |
| | 32 | " | 2.1(1.2) : 5.0(2.5) | 1:1 |
| | 46 | " | 2.2(2.2) : 6.0(3.1) | 1:1 |
| | 60 | " | 2.6(1.1) : 3.9 (1.8) | 1:1 |
| | 80 | " | 3.4(1.7) : 4.5(3.1) | 1:1 |
| 19 | 2 | nibble EC/bite EC/SC | | |
| | 9 | nose EC/nibble EC/chew EC; | | |
| | | nibble EC/chew EC | | |
| | 15 | nibble EC/chew EC/hold EC | mean values are not | |
| | 16 | nibble EC/chew EC/SC; | presented as bout | |
| | | chew EC/nibble EC; | lengths were too short | |
| | | chew EC/SC | | |
| | 18* | chew EC/SC | 4.8(2.6) : 1.2(0.5) | 1:1 |
| | 29 | " | 5.1(1.5) : 1.7(0.6) | 1:1 |
| | 39 | " | 5.6(2.6) : 2.3(1.1) | 1:1 |
| | 57 | " ; | 6.2(2.3) : 1.9(1.0) | 1:1 |
| | | chew EC/SC/lick T | 6.5(3.8) : 1.3(0.5) : 4.3(3.0) | 8:9:1 |
| | 71 | chew EC/SC ; | 7.5(4.2) : 1.8(0.7) | 1:1 |
| | | chew EC/SC/lick T | 6.4(3.7) : 1.5(0.6) : 3.3(2.2) | 10:11:1 |
| 64 | 1 | nose TC/bite TC | | |
| | 2 | nose TC/nibble TC/chew TC; | | |
| | | nose TC/bite TC | | |
| | 3 | nibble TC/nose TC ; | | |
| | | nibble TC/chew TC/nose TC | | |
| | 4 | nibble TC/chew TC; | | |
| | | nose TC/chew TC; | mean values are not | |
| | | paw TC/chew TC; | presented as bout | |
| | | nibble TC/bite TC/nose TC | lengths were too short | |
| | 8 | nose TC/bite TC/chew TC; | | |
| | | nose TC/chew TC; | | |
| | | nibble TC/chew TC | | |
| | 9 | root F/chew TC; | | |
| | | nose TC/chew TC; | | |
| | | root F/nose TC/chew TC | | |
| | 15* | continuous chew TC | - longer than trial length | |
| | 18 | chew TC/SC; | 57.4(45.6) : 1.9(0.9) | 1:1 |
| | | continuous chew TC | (also on subsequent days) | |
| | 29 | chew TC/SC | 38.9(36.2) : 1.9(0.7) | 1:1 |
| | 32 | " ; | 18.3(25.3) : 2.2(1.1) | 1:1 |
| | | chew TC/SC/lick T | 23.9(9.6) : 1.9(0.9) : 9.4(6.1) | 1:2:1 |
| | 43 | chew TC/pause; | 11.4(8.7) : 2.4(2.0) | 1:1 |
| | | chew TC/SC/lick T | 25.0(15.6) : 2.2(1.1) : 3.2(0.7) | 1:2:1 |
| | 53 | chew TC/pause | 16.5(14.7) : 2.3(0.8) | 1:1 |

the drinker and the trough became the objects of stereotypy direction in some sows.

2) Modified "old" stereotypies

Behaviours of this category were true stereotypies since they appeared to be quite functionless. The 3 sows in the present experiment that performed stereotypies prior to tethering (sows 19, 36 and 54) performed self-directed, sham oral actions whilst belly lying. None of these behaviours survived unchanged to stage 4. Early in stage 3, the particular sows performed their "old" stereotypies for as much as 40% of the observation time per day that they were active (see Fig. 2a). The "new" stereotypies which developed were obviously derived in part from the old actions (e.g. sham chew, sham suck, mouth stretch, etc.), however with large modifications. Typically, a standing posture replaced lying, head movements were directed towards specific locations in the tether stall, and new, sometimes aggressive-like, actions were added.

To illustrate this process, the change in the action of sow 54's stereotypy is qualitatively described here and quantitatively in Table 4. Sow 54's "old" stereotypy was composed of 2 alternating oral actions: sham chew/sham suck, performed whilst belly lying. Prior to tethering, the duration of each component was about 3-4 sec. and bout length was frequently greater than 20 min. After tethering (on day 1) sow 54 rapidly reached stage 3 (see Table 3) and was recorded to perform her "old" stereotypy during 44% of the 14.00 h, and 27% of the afternoon post-feeding, observation sessions. On day 2 these percentages increased to 100 and 70%, respectively, and resulted in an average stereotypy performance time of 51%, when considered over all observation time. On day 3 the sow spent equal time (29%) standing and lying whilst stereotyping. Over the next 2 observation days, the proportion of time spent in the standing posture declined. From day 9 however, this trend reversed, and after day 15, stereotyped behaviour was almost exclusively performed whilst standing. Up to day 15 much aggressive-like behaviour was recorded. On day 9 while stereotyping, the sow was noted to press her snout between the front bars at one location. By day 15, the action was seldom performed at a fixed point but rather through an area of space between 2 bars. The sow moved her snout horizontally back and forth through the space while stereotyping. At the end of the action the sow "kissed" or sucked on the lower bar. The rhythm of the head action seemed to influence the entire body, as the sow swayed with the action. The sow also looked "blank" while stereotyping. As a second example of a sow that modified an "old" stereotypy, data of sow 19's "old" and "new" stereotypies are illustrated in Figure 2a, and her "new" stereotypies in Table 4.

3) New stereotypies

Especially in the latter part of stage 3, all sows "assembled" and "tried out" a number of repetitive, seemingly non-functional behaviours. These behaviours were generally directed at some aspect of the sows' external environment, and occurred with greatest frequency in the post-feeding and 14.00 h sessions. Many different behaviours were combined into sequences which were repeatedly performed during periods of a few minutes, only to be "abandoned". Most sequences contained aggressive-like components (see Table 4, sow 64), but towards the end of stage 3, the aggressiveness was toned down (e.g. biting became chewing or mouthing) or largely disappeared (see Fig. 2b and 4).

A typical pattern of development of chain play involved the sequence nose-nibble-bite. Gradually this altered to nose-nibble-chew, then nose-chew (with the nose component being reduced to a single action) or nibble-chew, with chew becoming quite repetitive. Pauses occurring between bouts were usually interrupted by the nose component, as if this was necessary for locating/positioning the chain before chewing it. Later, pauses were often filled with sham chewing actions, which became stereotyped in duration and movement and thus linked bouts of stereotyped actions.

In the development of the drinker-use stereotypies of sows 36 and 77, the first component in the sequence (press with rooting disk) probably also functioned to locate the drinker. Following this, the sows performed other aggressive-like actions (especially rooting the drinker nipple) before alternating drinking with sham oral actions (see Table 2).

Thus, stage 4 commenced amid a drastic reduction in the frequency and duration of aggressive-like acts, which eventually were confined to pre-feeding sessions, or prior to specific events like dunging.

## Building on a basic stereotypy

Once established, a basic stereotyped action was gradually enlarged through the addition of extra components (see Tables 2 and 4). Most sows never lost the ability to revert to performing the original components during the period of the experiment. Indeed, bouts of stereotypy performance commonly commenced with just the basic components. After a few minutes the other components were added in turn, until by about 10 min. the full stereotypy was recognizable. As described in Figures 2a, 3a and 4, more than 70% of a sow's activity during the observation time per day could be spent in the performance of stereotypies.

Addition of a new component to a stereotypy did not always appear to be an easy process. Sometimes the new element was functional, as in the case of sow 79. The basic stereotypy of this sow was continuous chewing of the extra chain (Table 2). During her normally prolonged bouts of chain chewing, sow 79 found it difficult to break off the behaviour in order to drink from the nipple drinker. Many attempts were made to retain the chain in the mouth while still chewing, and at the same time move the head towards the drinker. As the chain was not long enough to reach the drinker, and the sow could not wrench the chain in that direction, the only options were to drop the chain or not to drink at all while stereotyping. Sow 79 solved this problem by day 53, with the incorporation of an existing drinker-use sequence into her chain-directed stereotypy. To achieve this alteration, some frustration was apparent,as aggressive behaviours were also performed at that time against the extra chain (bite and root at the attachment point) and the drinker (bite and root). By day 60, a smooth performance of chain chewing was interspersed at about 5 min. intervals by mouth stretching with drinker in mouth, alternating with drinking, during about 30 sec.

Other sows however, were sometimes unsuccessful in adding new components. Sow 36 for example, was performing her usual stereotypy (see Table 2, sow 36 sequence iii) on day 36. This sequence began each day after the morning feeding from the basic sequence - press drinker/drink/mouth stretch. During the 11.00 h observation session, the sow began to insert the component - root drinker nipple - into her full stereotypy sequence. It appeared that the stereotypy became too imbalanced or too large for the sow to control, and the entire action was terminated. Subsequently, the aggressive actions - nose, root and bite tether chain, and root floor - were performed during 2 min. before the sow resumed her stereotypy at the basic level, but did not attempt to reintroduce this new component.

Over the following weeks the sow succeeded in modifying and enlarging her stereotypy with other components (see Table 2). However, she was also drinking much water; she urinated at regular 25 min. intervals throughout the day. On day 80, sow 36 added a new component - spray water from mouth - which may have helped her to reduce her water intake.

### Time of day and stereotypy performance

As mentioned earlier, sows initially engaged in stereotypy performance in the post-feeding and 14.00 h sessions. At first, the sows were alert or simply idle in the other sessions, but within a week of reaching stage 4, most sows utilized time in all sessions for stereotypy performance. In general, however, sows did not stereotype during the 15 min. or so before feeding. At these times, the sows were mostly quiet and alert, but with occasional outbursts of bar biting.

The encroachment of stereotyping into the 11.00 h session in particular, was partly due to the difficulty that the sows had in stopping the performance of their stereotypies. In addition, they appeared to stereotype whilst in a daze, and some sows would "sway about" during the performance. Sow 54 was recorded on 6 occasions between day 60 and 80 to collapse to the floor while stereotyping, after which she stood and recommenced stereotyping.

Although some sows began stereotyping for the day shortly after the lights came on (at 06.30 h), towards the end of the experiment most sows would not begin stereotyping until immediately after the morning feed. While sows often had difficulty in creating an opportunity to drink, urinate, defaecate, and so on during the day, some sows on occasions had difficulty in stopping the performance of their stereotypy in the evening before "lights out". Stereotypies were not recorded to occur however after 19.00 h. Time-lapse video recording was assisted during the dark period by illumination from a red light or 40-watt white light source.

Most of the stereotyping sows increased the level of stereotypy performance during stage 4, but towards the end of pregnancy the proportion of active time spent stereotyping decreased (see Figs. 2a and 4). Time-lapse video registrations during 24 h periods indicated that some sows (e.g. 19 and 54) performed their stereotypies at times for about 10 hours per day.

### Unsuccessful stereotypies?

Although it was earlier stated that all sows developed stereotypies in response to tethering, some indications exist that not all were "successful" in the long term. Apart from sows experiencing "false starts" in stereotypy development (e.g. sow 63, see Fig. 3a), two sows also changed their behaviour during the experiment in other ways.

Sow 77 developed drinker- and floor-directed stereotypes (see Table 2), the performance of which were restricted to the post-feeding sessions. From day 39, 3 days after reaching stage 4, the sow began to displace long bouts of lying idle with idle sitting while the head was drooped, a posture previously described by Fraser (1975) and Sambraus (1981). The sow had a glazed expression at these times, but rapidly responded to straw in her trough, which she thoroughly investigated (ate) before lying down.

Another sow, sow 78, had developed an extra-chain directed stereotypy. During a weekend (between day 39 and 43) she escaped from her tether and was free in the sow room. Upon retethering she reverted to the second part of stage 1, i.e. she performed much aggressive behaviour but without escape attempts, before entering a period of inactivity (stage 2). Surprisingly she almost completely ignored the extra chain for the remainder of that pregnancy. After passing through stage 3 again, she developed self-directed oral activities such as sham chewing and tongue flicking. When retethered in her next pregnancy, she returned to an extra-chain directed stereotypy.

## Discussion

The 9 sows in the present experiment readily developed stereotyped sequences of behaviour. Predominant amongst these sequences were seemingly non-functional stereotypies, performed in a repetitive manner sometimes during many hours per day. These abnormal behaviours are considered to develop in response to chronic stress.

That pigs are stressed by tethering has been physiologically demonstrated by Becker et al. (1983) from measurements of blood cortisol levels. That pigs express behaviours indicative of conflict and frustration at being tethered was apparent from the present experiment. Displacement activities, redirected aggressive acts and other inappropriate behaviours were noted to occur when escape from the tether stall was blocked. At least 3 potential sources of chronic stress faced the sows at and after tethering: 1) physical restraint, 2) social restriction and 3) habituation to a barren environment, which together resulted in a general loss of controllability over the environment.

The results of the present experiment indicate that stereotypies develop in tethered sows in a consistent manner. Four distinct stages were identified - escape attempt, inactivity, outward-directed activity and basic stereotypy. The behaviours performed by the sows in these stages were consistent with the responses of animals to conflict/ frustration due to the existence of a permanently insoluble problem (Davenport et al, 1966, with chimpanzees; Bowlby, 1969, with children expressing hospital syndrome).

Two very interesting behaviours were recorded for the sows shortly after tethering: 1) pressing the snout between the bars and 2) immobility. The former behaviour was previously described by Fraser (1975). Since it occurred here and later on at times of conflict (when escape was blocked before defaecation/urination), this behaviour may be a reliable indicator of a state of conflict (or distress) in pigs in intensive housing systems. The second behaviour, immobility, was observed at the end of the escape attempt stage. Similar cataleptic-like states of immobility have been described by other authors as a fear-dependent reflex. In rabbits, Millan and Duka (1981) showed that opiates prolonged the duration of this state. There is a growing awareness in recent times that endogenous opiates (endorphins) are activated by, and are involved in adaptation to, stress in mammals (Amir et al., 1980). There is some possibility therefore that high endorphin levels induced by the severe stress of tethering per se resulted in inactivity of the sows in stage 2.

However, while we may attribute the immediate (and short-term) responses to tethering per se, we are nevertheless presented with 9 different responses from 9 individual sows. Different degrees of stressor application and different levels of perception by the animals are likely to produce variable responses to "stress" between individuals. In addition, during long-term adaptation to tethering, there are presumably fluctuations in the levels of perceived conflict and frustration. These are encountered firstly, when sows discover that certain essential and specific behaviour programs and sequences (Stolba, 1983) are blocked due to restraint, meaning that controllability is lost. Secondly, as the sows habituate to their barren, unchanging environment, lack of information may further reduce controllability. Thus taken together, the level of contingency held over the environment is lowered (Mason, 1978). The fact that sows restricted the performance of stereotypies to certain times of the day suggests that they perceive deficits in their environment at these times. On the other hand, since sows did not stereotype at night, is it then correct to interpret this as meaning that sows' well-being is better at night?

On many occasions in the present experiment, sows performed aggressive acts in response to frustration, for example at finding escape blocked. Dantzer et al. (1980) have demonstrated that in response to frustration, pigs develop aggressive behaviour accompanied by increases of plasma corticosteroid levels. The results of the present experiment suggest that the ability to develop and perform a stereotypy reduced the level of aggressive-like acts. In specific circumstances this clearly occurred: e.g. when sow 36 failed to add a new component to her stereotypy, and so on.

Redirected aggressive acts commonly occurred also when behaviour programs, necessary to the performance of certain functions such as dunging, were blocked. Inevitably these redirected sequences became stereotyped rituals for the sows in the present experiment. This is not unexpected since dunging did eventually occur. Due to the initial conflict prior to dunging however, sows superstitiously linked their behaviour with the reward (dunging). That this should occur is in agreement with the general principle that behavioural changes followed by rewards tend to be repeated (Feldman, 1978). But with no apparent reward available, why were such senseless behaviours like stereotypies performed? It is not unlikely that stereotypies also develop under the influence of some reward. Many authors attribute "the reward" to be a reduction in anxiety levels (conflict/frustration) e.g. Maier (1949), Duncan and Wood-Gush (1974), Dantzer and Mormède (1983), amongst others. Indeed, Kravitz et al. (1960) in their studies of children performing head-banging stereotypies, reported ... "the absence of crying associated with head-banging and the apparent absence of pain....".

More recently, Cronin et al. (1985) have presented evidence that endorphins (endogenous opioids) may be the underlying factor behind the performance of stereotypies. Activation of a labile endorphin system by chronic stress could conceivably produce overactivity in this modulating system (Rossier, 1977; Amir et al., 1981; Berger et al., 1982). Furthermore, Barnett et al. (1981) and Becker et al. (1983) have shown that stress in pigs disturbs the pituitary-adrenal axis for up to 4 days. Since endorphins are derived from the same precursor molecule as ACTH (Guillemin et al., 1977) which in turn activates the pituitary-adrenal axis, we have circumstantial evidence to suggest that endorphin levels may remain high in chronically-stressed sows for some time following tethering. This period would be long enough to have affected most sows in the present experiment, well into stage 3 of the development process.

On the assumption that the performance of a behaviour (e.g. aggressive acts in response to frustration) produce a release of endorphins, we may speculate therefore that stereotypies develop in tethered sows in the following manner. During stage 2 (a period of inactivity) the occasional bouts of activity invariably contained aggressive-like acts. Here, the sows begin to learn to associate two phenomena: 1) outbursts of aggression with 2) the feeling of well-being produced by a (fresh) release of endorphins. Once the association is established, the sows become more active (stage 3) in an attempt to reproduce the feeling of well-being provided by endorphins. The slower that sows were to recognize this association, the slower they were to develop a basic stereotypy, that is to reach stage 4. The behaviours which occurred were initially performed in a random manner. It is not unlikely that animals possess the ability to introduce order into their actions, and thus commonly used actions are likely to become stereotyped (Fentress,1976). In addition, because of the existence of an "unseen" reinforcer (endorphins), superstitious selection of particular acts should result. As recorded in the present experimental situation, the number of different behaviours performed by sows decreased with time. By the sow concentrating on one simple behaviour, indicates that she has probably learnt the association between the behaviour and the gaining of well-being. As stage 4 began, the incidence of random, aggressive-like acts markedly declined.

If stereotypies in fact develop in this manner, then we can take some steps towards answering the question of what stereotypies are in reality. Stereotypies may be a means by which tethered sows react to, and potentially cope with, chronic stress. For the present experiment we tethered sows in the second pregnancy, since sows at this stage of their productive life reliably develop stereotypies. Had we tethered gilts as Barnett et al. (1985) did, the pigs may not have responded by developing stereotypies. The tethered gilts of the latter authors instead experienced long-term (chronic) elevations of blood cortisol during the first pregnancy, compared with gilts in less restrictive housing situations. Thus, one should not forget that there are alternative responses to long-term stressors in pigs. The selection of coping strategies may well follow the model proposed by McBride (1980) with the ultimate (hopefully successful) strategy being influenced by factors such as breed, physiological state (pregnant or not pregnant), age and prior experience.

Apart from stereotypy development and chronic elevations of blood cortisol, tethered pigs have also been reported to perform excessive drinking (Barnett et al., 1984), idle sitting (Sambraus, 1981) and idle belly lying (Vestergaard, 1984). Some of these behaviour responses were evident amongst the sows in the present experiment. That some of our tethered sows experienced a "false start" in the development of a stereotypy, or the failure of an established stereotypy, suggests that the development of a stereotypy may be a difficult process, and a reflection indeed of the continued perception of the "stressor" over a long period of time. Certainly not all sows were "successful stereotypers" in the long-term.

Those behaviours which fitted the definition of a stereotypy were unique to the particular individual as reported for individual animals in other experimental and survey data. Furthermore, there are apparent species-specific morphological characteristics of stereotypies amongst animals. Not unexpectedly, the stereotypies observed for the sows in the present experiment were largely related to oral actions typical of pigs, as previously described by Schmidt (1982). The choice of substrate(s),on the other hand, may be due to other factors.

As noted in the results, 3 sows had developed stereotypies prior to the present experiment. While we did not observe the development of these "old" stereotypies, it is likely that they developed largely as a result of habituation to a relatively barren environment. Significantly, the stereotypies were self-directed, sham oral actions performed whilst the sows occupied a lying posture. After tethering, stereotypies which successfully developed at first were exclusively environment-directed, and largely derived from redirected aggressive actions. It would seem that the already established, self-directed stereotypies did not "solve the problems" faced by the newly-tethered sows. Keiper (1969) suggested that 2 basic categories of non-pharmacologically induced stereotypies exist. First, those related to physical restriction, and second, those resulting from some sort of sensory or motor deprivation. The results of the present experiment, and those of Stolba et al. (1983) with individually-housed and tethered sows, would seem to support this conclusion. Furthermore, as also suggested by the latter authors, stereotypies derived from the first category are likely to be environment-directed actions, whereas those of the second category should be self-directed actions.

Hutton (1983) reported that lack of stimulation was an important factor influencing the development of stereotypies in piglets. After habituation to the barren environments of incubators and flat-deck cages, piglets spent long periods in a low state of arousal due to a general lack of stimulation. Thus while it seems that stereotypies can develop in animals subjected to 2 opposed situations: i.e. where there is either 1) too little (Kiley-Worthington, 1977; Hutton, 1983) or 2) too much stimulation (Duncan and Wood-Gush, 1974), the underlying factor is still the same: loss of controllability. Thus stereotypies function to buffer the individual against an adverse environment. Whether a stereotypy developed under the latter conditions can later be used to generate stimuli in an habituated individual is unknown. Above all, the performance of chronic levels of these abnormal behaviours certainly indicates the existence of a problem.

As a class of behaviour, stereotypies are easily recognized especially when the performer is another human, an ape or monkey. Experimental studies have clearly indicated that deprivation of social contact in social animals reliably induces the development of these "neurotic" behaviours (Kravitz et al., 1960; Berkson, 1968; Davenport, 1979). In most studies of stereotypy development the subjects were infants or young animals reared in isolation from their mothers and/or other conspecifics. Needless to say, such rearing conditions for a social animal like the pig will also result in deficiencies of normal social and sexual behaviours (Hemsworth et al., 1977, 1978, 1982; Hutton, 1983).

Surprisingly, stereotypies are common amongst normal human infants. Thelen (1979) proposed that such stereotypies were manifestations of normal maturation processes. Infants may use these behaviours whilst learning a new behaviour or solving a problem, e.g. how to crawl. Thus, stereotypies observed in older, normal individuals may also be attempts at learning a new behaviour. However, should the stereotypies persist then one must consider that the problem was insoluble, or that the performer has become neurotic!

The results of the present experiment do not indicate whether the tethered sows adapted to their housing situation during the 12 weeks of observation. Some sows were noted to stereotype for up to 10 hours per day (at times). Davenport (1979) reported that restricted-reared chimpanzees engaged in stereotypy performance in about three-quarters of their waking day. Thus there may be little difference between the severity of effects which produced the stereotypies of apes and monkeys reared in isolation, and the sows tethered in the present experiment.

That tethered sows in general performed less stereotyping towards the end of pregnancy is consistent with the findings of Cronin and Wiepkema (1984), but may not be related to states of improved well-being. Long-term studies of tethered sows parallel to that of Stolba et al. (1983) may confirm whether sows ever really adapt to tether restraint _per se_, and what this implies for the welfare of animals so housed. Simultaneously, we must consider at what point does lack of stimulation have a stronger influence than restraint in "driving" the performances of established stereotypies.

In conclusion, stereotypies appear to develop from severe conflict/frustration at the loss of controllability over the environment. Whilst the stereotypies of tethered sows were rapidly initiated in response to physical restraint, they may continue to be performed in the longer-term due to lack of stimulation. The development of these disturbed behaviours in normal individuals could be avoided, by providing housing conditions that are not closely restrictive, that allow social interaction and which present variation in the quantity and quality of environmental stimulation.

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## References

Amir, S., Brown, Z.W. and Amit, Z., 1980. The role of endorphins in stress: Evidence and speculations. Neurosci. Biobehav.Rev., 4: 77-86.

Amir, S., Amit, Z. and Brown, Z.W. 1981. Stress, endorphins and psychosis. A hypothesis. In: H.M. Emrich (Editor), The Role of Endorphins in Neuropsychiatry. S. Karger, Basel, pp. 192-201.

Barnett, J.L., Cronin, G.M. and Winfield, C.G., 1981. The effects of individual and group penning of pigs on plasma total and free corticosteroid concentrations and the maximum corticosteroid binding capacity. Gen. Comp. Endocr., 44: 219-225.

Barnett, J.L., Cronin, G.M., Winfield, C.G. and Dewar, A.M., 1984. The welfare of adult pigs: the effects of five housing treatments on behaviour, plasma corticosteroids and injuries. Appl. Anim. Beh. Sci., 12: 209-232.

Barnett, J.L., Winfield, C.G., Cronin, G.M., Hemsworth, P.H. and Dewar, A.M., 1985. The effect of individual and group housing on behavioural and physiological responses related to the welfare of pregnant pigs. Appl. Anim. Beh. Sci. (In press).

Becker, B.A., Ford J.J., De Shazer, J.A. and Hahn, G.L., 1983. The effects of tether stalls on the circadian rhythm of cortisol, behavioural activities and estrous response in ovariectomized gilts. In: W.F. Hall (Editor), The Behaviour and Welfare of Farm Animals. Proc. Conf. on Human-Animal Bond, 13-14 June 1983, at Minneapolis, Minnesota.

Berger, P.A., Akil, H., Watson, S.J. and Barchas, J.D., 1982. Behavioural pharmacology of the endorphins. Ann.Rev. Med., 33: 397-415.

Berkson, G., 1968. Development of abnormal stereotyped behaviours. Developmental Psychobiology, 1: 118-132.

Berkson, G. and Davenport, R.K., 1962. Stereotyped movements of mental defectives. I. Initial survey. Amer. J. ment. Def., 66: 849-852.

Bowlby, J., 1969. Attachment and loss. I. Attachment. The Int. Psychoanal. Library 79, London, Hogarth Press.

Cronin, G.M., Wiepkema, P.R. and van Ree, J.M., 1985. Evidence for a relationship between endorphins and the performance of abnormal stereotyped behaviours in tethered sows. Submitted for publication in Appl. Amin. Beh. Sci.

Daelemans, J., 1984. Confinement of sows related to their productivity. Ann. Rech. Vét., 15: 149-158.

Dantzer, R., Arnone, M. and Mormède, P., 1980. Effects of frustration on behaviour and plasma corticosteroid levels in pigs. Physiol. and Beh., 24: 1-4.

Dantzer, R. and Mormède, P., 1983. De-arousal properties of stereotyped behaviour: evidence from pituitary-adrenal correlates in pigs. Appl. Anim. Ethol. 10: 233-244.

Davenport, R.K., 1979. Some behavioral disturbances of great apes in captivity. In: D.A. Hamburg and E.R. McCown (Editors), The Great Apes. The Benjamin/ Cummings Publishing Co., Menlo Park, California, pp. 341-357.

Davenport, R.K., Menzel, E.W. and Rogers, C.M., 1966. Effects of severe isolation on "normal" juvenile chimpanzees. Health, weight gain and stereotyped behaviors. Arch. Gen. Psychiat., 14: 134-138.

Duncan, I.H.J. and Wood-Gush, D.G.M., 1972. Thwarting of feeding behaviour in the domestic fowl. Anim. Behav., 20: 444-451.

Duncan, I.J.H. and Wood-Gush, D.G.M., 1974. The effect of a rauwolfia tranquillizer on stereotyped movements in frustrated domestic fowl. Appl. Anim. Ethol., 1: 67-76.

Ekesbo, I., 1977. Ethics, ethology and animal health in modern Swedish livestock production. In: D.W. Fölsch (Editor), The Ethology and Ethics of Farm Animal Production, Birkhäuser Verlag, Basel and Stuttgart, pp. 46-50.

Feldman, R.S., 1978. Environmental and physiological determinants of fixated behaviour in mammals. 1st World Congress on Ethology Applied to Zootechnics, Editorial Garsi, Madrid, pp. 487-493.

Fentress, J.C., 1976. Dynamic boundaries of patterned behaviour: interaction and selforganization. In: P.P.G. Bateson and R.A. Hinde (Editors), Growing Points in Ethology. Cambridge University Press, Cambridge, pp. 135-169.

Fraser, D., 1975. The effect of straw on the behaviour of sows in tether stalls. Anim. Prod., 21: 59-68.

Guillemin, R., Vargo, T., Rossier, J., Minick, S., Ling, N., Rivier, C., Vale, W. and Bloom, F., 1977. β-Endorphin and andrenocorticotrophin are secreted concomitantly by the pituitary gland. Science, 197: 1367-1369.

Hediger, H., 1950. Wild animals in captivity. Butterworths, London, 207 pp.

Hemsworth, P.H., Beilharz, R.G. and Galloway, D.B., 1977. The influence of social conditions during rearing on the sexual behaviour of the domestic boar. Anim. Prod., 24: 245-251.

Hemsworth, P.H., Cronin, G.M. and Hansen, C., 1982. The influence of social restriction during rearing on the oestrous behaviour of the gilt. Anim. Prod., 35: 35-40.

Hemsworth, P.H., Findlay, J.K. and Beilharz, R.G., 1978. The importance of physical contact with other pigs during rearing on the sexual behaviour of the male domestic pig. Anim. Prod., 27: 201-207.

Holzapfel, M., 1938. Ueber Bewegungsstereotypien bei gehaltenen Säugern. I. Mitt. Bewegungsstereotypien bei Caniden und Hyaena. II. Mitt. Das "Weben" der Pferde. Z. Tierpsychol., 2: 46-72.

Hutton, R., 1983. The development of social behaviour in piglets. Ph.D.Thesis, University of Edinburgh.

Keiper, R.R., 1969. Causal factors of stereotypies in caged birds. Anim. Behav., 17: 114-119.

Kiley-Worthington, M., 1977. Stereotypies. In: Behavioural Problems of Farm Animals. Oriel Press, Stocksfield, pp. 74-79.

Kravitz, H., Rosenthal, V., Teplitz, Z., Murphy, J.B. and Lesser, R.E., 1960. A study of head-banging in infants and children. Diseases of the nerv. sys., 21: 203-208.

Maier, N.R.F., 1949. Frustration. The Study of Behaviour Without a Goal. McGraw-Hill, New York, N.Y. 264 pp.

Mason, W.A., 1978. Social experience and primate cognitive development. In: G.M. Burghardt and M. Bekoff (Editors), The Development of Behaviour: Comparative and Evolutionary Aspects. Garland Press, N.Y., pp. 233-251.

McBride, G., 1980. Adaptation and welfare at the man-animal interface. In: M. Wodzicka-Tomaszewska, T.N. Edey and J.J. Lynch (Editors), Behaviour in Relation to Reproduction, Management and Welfare of Farm Animals. Reviews in Rural Science No. IV, The University of New England, pp. 195-198.

Millan, M.J. and Duka, Th., 1981. Anxiolytic properties of opiates and endogenous opioid peptides and their relationship to the actions of benzodiazepines. In: H.M. Emrich (Editor), The Role of Endorphins in Neuropsychiatry. S. Karger, Basel, pp. 123-141.

Morris, D., 1964. The response of animals to a restricted environment. Symp. Zool. Soc. Lond., 13: 99-118.

Ödberg, F.O., 1978. Abnormal behaviours (stereotypies). 1st World Congress on Ethology. Applied to Zootechnics, Editorial Garsi, Madrid, pp. 475-480.

Ödberg, F.O., 1981. Environmental and pharmacological determinants of pathological stereotypies in voles (<u>Clethrionomys</u> <u>glareolus</u> <u>britannicus</u>). Ph.D. thesis, State University of Gent.

Putten, G.van, 1977. Comfort behaviour in pigs: informative for their well-being. In: D.W. Fölsch (Editor), The Ethology and Ethics of Farm Animal Production, Birkhäuser Verlag, Basel and Stuttgart, pp. 70-76.

Rossier J., French, E.D., Rivier, C., Ling, N., Guillemin, R. and Bloom, F.E., 1977. Footshock induced stress increases $\beta$-endorphin levels in blood but not brain. Nature, 270: 618-620.

Sambraus, H.H., 1981. Abnormal behaviour as an indication of immaterial suffering. Int. J. Study Anim. Prob., 2: 245-248.

Schmidt, M., 1982. Abnormal oral behaviour of pigs. In: W. Bessei (Editor), Disturbed Behaviour of Farm Animals, Verlag Eugen Ulmer, Stuttgart, pp. 115-121.

Steen, H.A.M. van der, 1983. Maternal and genetic influences on production and reproduction traits in pigs. Ph.D.Thesis, Agricultural University of Wageningen.

Stolba, A., 1983. The pig park family system: housing designed according to the consistent patterns of pig behaviour and social structure. In: W.F. Hall (Editor), The Behaviour and Welfare of Farm Animals. Proc.Conf. on the Human-Animal Bond, 13-14 June 1983, at Minneapolis, Minnesota.

Stolba, A., Baker, N. and Wood-Gush, D.G.M. 1983. The characterization of stereotyped behaviour in stalled sows by information redundancy. Behaviour, 87: 157-182.

Thelen, E., 1979. Rhythmical stereotypies in normal human infants. Animal Behaviour, 27: 699-715.

Vestergaard, K., 1984. An evaluation of ethological criteria and methods in the assessment of wellbeing in sows. Ann.Rech.Vét., 15: 227-235.

Wiepkema, P.R., Broom, D.M., Duncan, I.J.H. and Putten, G. van, 1983. Abnormal behaviours in farm animals. A report of the Commission of the European Communities, Autumn, 1983

Wood-Gush, D.G.M., Duncan, I.J.H. and Fraser, D., 1975. Social stress and welfare problems in agricultural animals. In: E.S.E. Hafez (Editor). The Behaviour of Domestic Animals, Baillière Tindall, London, pp. 182-200.

## CHAPTER 4

# THE DEVELOPMENT AND SIGNIFICANCE OF ABNORMAL STEREOTYPED BEHAVIOURS IN TETHERED SOWS

## EVIDENCE FOR A RELATIONSHIP BETWEEN ENDORPHINS AND THE PERFORMANCE OF ABNORMAL STEREOTYPED BEHAVIOURS IN TETHERED SOWS

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## Abstract

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Evidence for a relationship between endorphins and the performance of abnormal stereotyped behaviours in tethered sows. Applied Animal Behaviour Science.

In order to test the hypothesis that endorphins (endogenous morphines) are associated with the performance of stereotypies in sows, 8 tethered and 3 loose Yorkshire x Dutch landrace (DL) or pure-bred DL sows were treated with saline and the specific opiate antagonist naloxone on consecutive days. The tethered sows were treated when performing stereotypies. While saline did not effect the behaviours of the sows, naloxone caused severe disruption to the stereotypies of all sows. Naloxone had no effect on the performance of normal behaviours in that exploratory behaviours of loose sows were not affected.

Within 30 minutes of naloxone treatment, all 8 tethered sows had performed altered forms of their normal stereotypies or new repetitive behaviours not previously recorded for the sows. By the end of the first 2 hours after naloxone treatment (day N) less time was spent in the performance of stereotypies than during the same period on the previous (saline) day (day N-1): median values for days N-1 and N, 86 and 33% of observation time. After naloxone treatment sows performed more idling behaviour, as well as behaviours such as escape attempts, aggressive acts, vocal distress signals and a behaviour in which the snout is pressed between the bars: behaviours, which were rarely recorded since the time of the sows' initial tethering 23 to 56 weeks prior to treatment, and which are indicative of frustration/conflict in sows. Seven of the 8 tethered sows ceased the performance of their stereotypies in the short term after naloxone. The latency to cease performance was positively related to the "age" of the particular stereotypy, known from detailed historical behaviour records kept on each sow, and to the time since initially tethered. Naloxone treatment also produced long-term effects on the tethered sows' behaviour: particularly disruption of sleep/rest and nocturnal stereotypy performance.

Since naloxone interfered with stereotypies and not normal behaviours of sows, the results suggest that endorphins may play a specific role in stereotypy performance. The potential role of brain endorphins in the development of stereotypies is discussed and the interpretation of this in relation to animal well-being is mentioned. It is proposed that tethered sows display stereotypies in order to cope with the physical and, or mental suffering associated with tethering and that endorphins are implicated in this coping strategy.

## Introduction

Amongst the earliest scientific records pertaining to abnormal stereotyped behaviours (stereotypies) in animals are from Holzapfel (1938), Hediger (1950) and Morris (1964). While the early accounts concern pet shop, circus and zoo animals, it was not until recently that such behaviours were noticed in domestic farm animals (Wood-Gush et al., 1975). This "sudden" appearance of stereotypies among certain farm animal species is clearly associated with the modern trends in animal housing to which the particular species have been subjected: a greater degree of individual restraint, long-term indoor confinement and an unstimulating, and possibly socially-imbalanced, environment. Ödberg (1981) showed that the degree of environmental enrichment influenced the proportion of captive voles which developed stereotypies: as the quality of the environment decreased so the proportion of stereotyping voles increased. Applied ethologists concerned with the welfare of farm animals in intensive husbandry systems strongly emphasize that the incidence of abnormal or disturbed behaviours is a major criterion for assessing welfare (Wiepkema et al., 1983). Stolba et al. (1983) and Cronin and Wiepkema (1984) have reported that a large proportion of the behaviour performed by individually-housed and tethered sows, respectively, was abnormal stereotyped behaviour (stereotypies).

Stereotypies are defined by Ödberg (1978) as morphologically identical movements which are regularly repeated and seemingly purposeless. Unlike functional stereotyped behaviours (e.g. feeding behaviour), the performance of stereotypies is related to former or current serious conflict(s) experienced by the animal, and from which there appears to be no "normal" solution. From a morphological point of view, stereotypies can be dissected to their basic structures or behaviour elements (Cronin and Wiepkema, 1984). An ordered sequence of distinguishable elements which is performed in a repetitive manner is termed a cycle of stereotyped behaviour. The individual elements are performed for repeatable durations in the successive cycles. A bout of stereotyped behaviour consists of a series of such cycles. In the classic studies, stereotypies are performed on an automatic level, in that the animal appears to have lost sight of the original reason for performing the behaviour. Despite a number of studies which investigated stereotypies in various species (e.g. Berkson, 1968, in monkeys, Duncan and Wood-Gush, 1974, in hens, Ödberg, 1981, in voles; amongst others), it remains unclear as to how and why animals should develop such behaviours. Tethered sows may perform stereotypies for up to 8 hours per day (observations reported in this paper), during which time it would appear that the sows' brain processes remain fully occupied. How the behaviour starts for the first time, how the animal maintains the behaviour for such a long time and why the performance of such a behaviour should stop are still unknown. Since other organisms including man may develop stereotypies, these remain very important questions. In normal individuals a repetitive approach to problem solving facilitates learning, as suggested by Wolff (1968) and Thelen (1979) in children. Furthermore, Fentress (1976) argues that commonly used behaviour programs will become stereotyped leaving the user free to perform them without being fully aware of one's actions. The user may then be able to run other programs simultaneously. Indeed, Stolba et al. (1983) reported that functional behaviours of free pigs in their pig park became more stereotyped (less variable) with increase in age of the animals. Stereotypies (abnormal stereotyped behaviours) however are generally considered to be "coping behaviours" (Kiley-Worthington, 1977) possessing de-arousal properties (Dantzer and Mormède, 1983), although little else is known about their function.

In the case of the tethered breeding sow, we propose that the stereotypies are performed to cope with the continued physical (De Koning, 1984) and, or mental suffering associated with tethering and that endorphins are implicated in this coping strategy.

Endorphins are endogenous opioids with pharmacological activity similar to that of morphine and other opiates (see the reviews by Berger et al., 1982; Van Ree and De Wied, 1983). A much researched role of endorphins (particularly β-endorphin) is that of increasing the threshold for pain, but other studies suggest a much wider role, with involvement in many physiological functions and behaviour, and even in drug addiction (Van Ree and De Wied, 1983). β-Endorphin, derived from the same precursor molecule (pro-opiomelanocortin) as ACTH, is released from the pituitary and in the brain (Berger et al., 1982). Guillemin et al. (1977) have demonstrated that stress releases β-endorphin along with ACTH in rats. The rate of β-endorphin production from these sites in response to stress is possibly related to the degree and, or duration of the stressful treatment (Rossier, 1977). Prolonged stress in rats not only altered the rate of peptide release, but also increased the biosynthesis of pro-opiomelanocortin in the hypothalamus (Schachter et al., unpublished, cited by Berger et al., 1982). Thus, sows suffering continued stress at and after tethering may also possess and develop this capacity to produce supernormal quantities of β-endorphin. The fact that animals possess the ability to self-stimulate "pleasure areas" of their brain (electrically - Olds and Milner, 1954; and with β-endorphin - Van Ree et al., 1979) and to aquire an addiction to the procedure involved, contributed to our hypothesis that tethered sows under stress could learn to self-stimulate the release of β-endorphin. This in turn would provide a potential reward system upon which the sows could base an association between behaviour performed and reward gained. This endorphin system may then eventually be taken over by another system involving for e.g. dopamine, so that the stereotypy becomes a "normal" behaviour.

We tested our hypothesis concerning the relation between stereotypies and endorphins with the use of the specific opioid antagonist naloxone (N-allynornoxymorphone). These experiments will help us to gain further insight into the possible manner of development of these behaviours and their significance for sow well-being. In addition, in order to ensure that normal behaviour of sows was not interrupted by treatment with naloxone, it was necessary to test the influence of naloxone on another class of behaviour. We have chosen exploratory behaviour, since it may be considered that stereotypies displace this behaviour in animals housed in very restricted and unstimulating environments.

## Materials and methods

A total of eleven physically-sound, female pigs (9 sows and 2 gilts) were used in this experiment. The pigs were either pure-bred Dutch Landrace (DL) or DL-Yorkshire crosses. All 9 sows had been tethered for various lengths of time in individual tether stalls. The sows were part of a small experimental herd under regular observation in an ethological study recording the development of stereotypies in tethered sows. For the majority of their first tethering period, behavioural records were made on 2 to 4 days per week and at 4 times per day. In subsequent tethering periods, behaviour observations were recorded at 3-week intervals and at 3 times per day. Frequent observations were also made when the sows were housed in farrowing accommodation. A hard copy of the records of these observations were available and provided a detailed historical record of the development of stereotypies in all the treatment sows. The two gilts were part of a group of 5 gilts and had not experienced tethering.

The pigs were husbanded in a manner not too dissimilar from that practiced on commercial, intensive pig breeding farms in Holland. Briefly, prior to and during the first pregnancy, gilts were loose housed in small groups on straw bedding. On day 112 after insemination, pregnant gilts/sows entered farrowing crates and farrowed with or without straw, according to a predetermined plan as part of another aspect of the study involving these sows. Lactation proceeded for about 28 days, during which time all sows and their litters received straw bedding. At weaning, sows were placed singly in a spacious straw pen adjacent to a mature boar. Two days later, the sows were moved into individual stalls with straw bedding

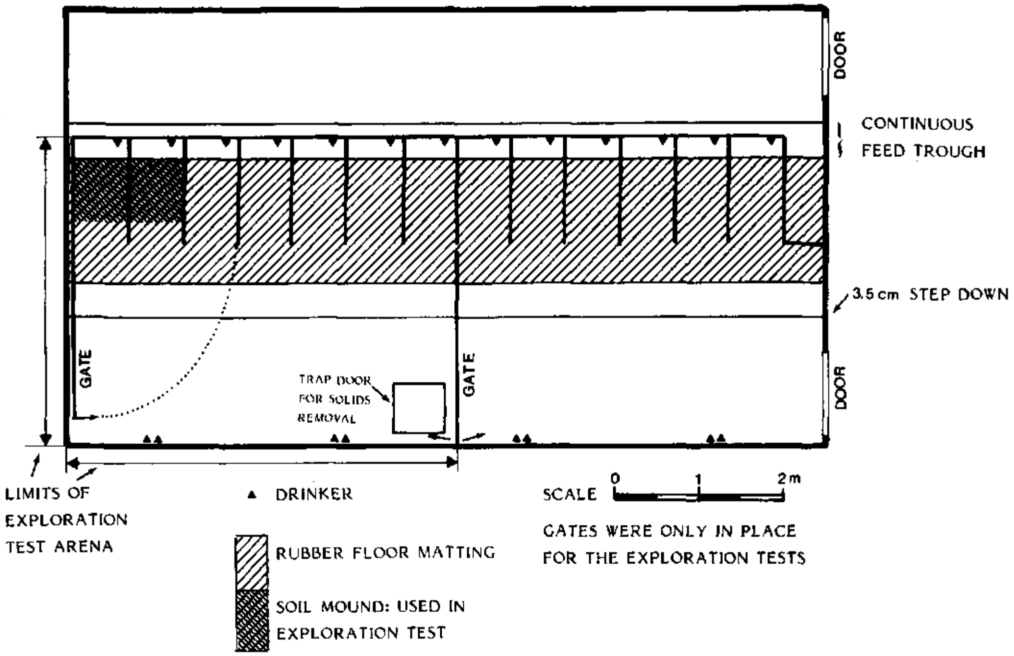


Figure 1. Floor plan of the dry-sow room.

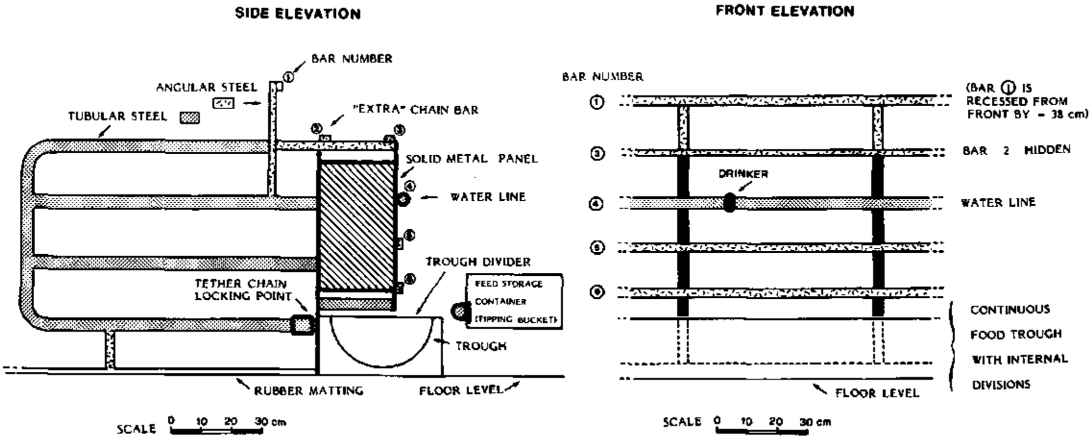


Figure 2. Constructional details of the dry-sow stalls, showing front and side elevations.

near to the boar pens. Sows failing to exhibit oestrus within 14 days after weaning received an intramuscular injection of a combination of pregnant mare serum gonadotrophin (PMSG) and human chorionic gonadotrophin (HCG) (400 I.U. FSH and 200 I.U. LH, "PG600", Intervet) to stimulate the onset of oestrus. For facilitation of the regular behaviour observations which were performed on these sows when tethered in the dry sow room (DSR), mostly 3 sows were tethered (or retethered) at the same time. It was possible therefore, that at some times not all of the sows tethered in the DSR were pregnant. To ensure that oestrus would not be missed in these sows, nor returns to oestrus amongst the other sows, a vasectomized boar was brought each day into the DSR. Sows detected in oestrus were artificially inseminated and sows persistently anoestrus were further treated with "PG600".

The tethered sows in the DSR were fed simultaneously from a semiautomatic feeding system. Feed was presented only after a warning bell had sounded so that the sows would not associate the presence of an observer with feeding. Feeding occurred twice daily at 08.45 and 15.30 h, while water was continuously available via nipple drinkers. Gilts in the loose housing accomodation were hand fed at similar times to the tethered sows, but were housed in another room.

Straw was not available to the sows in the DSR. Instead, the concrete floor was covered by grooved rubber mats in the area where the tethered sows stood (see Fig. 1) in order to reduce the possibility of leg and foot injuries as observed in other studies involving tethered sows (e.g. Barnett et al., 1984). Two small windows (total dimensions 30 x 312 cm) at one end of the DSR permitted the entry of natural light into the room, although this was supplemented with artificial fluorescent lighting from 06.30 to 18.30 h.

The sows were attached to their tether stalls by means of conventional neck tethers (Model 2013, Brouwers, Holland). When the sow did not pull backwards, the tether would hang loosely around her neck. However, should she attempt to back out of her stall, escape would be prevented by the plastic-coated, metal side straps of the tether being drawn together at their bottom ends by means of a loop of chain. This loop was in turn connected to a 50 cm length of heavy gauge chain, which was fixed to the tether attachment point on the side bars. Constructional details of the tether stalls in the DSR are shown in Fig. 2. Whilst tethered, most of the test sows had continuous access to a 40 cm length of medium gauge chain. This "extra" chain was suspended in the front of the tether stalls, above the trough from bar 2 (see Fig. 2) 15 cm from the left side. Sow 80, which was used in an exploration test in the present experiment was tethered after her first litter had been weaned. This sow remained anoestrus, but for the purposes

Table I. Data relevant to the pigs used in the present experiment

Pigs treated with naloxone (N) and saline (S)

| Part of experiment | | Pig number | Treatment regime | Sow age at N (days) | Sow wt. (kg)** | No. of tethering periods | Days since last insemination (to day N) |
|---|---|---|---|---|---|---|---|
| 1a | | 23 | SNS | 618 | 160 | 2 | 12 |
| | | 60 | | 626 | 169 | 2 | 35 |
| | | 63 | | 816 | 225 | 2 | 111 |
| | | 68 | | 748 | 172 | 3 | NI |
| | 1b | 76 | SSN | 665 | 176 | 2 | 60 |
| | | 54 x 1 | | 843 | 197 | 3 | NI |
| | 1b | 79 | | 667 | 151 | 2 | 4 |
| 1a | | 81 | | 511 | 210 | 2 | NI |
| | | 54 x 2 | SN | 899 | 208 | 3 | NI |
| 2 | | 80 | SNS | 425 | 180 | 2 | NI |
| | | 1* | | 331 | 174 | 0 | NI |
| 2 | | 2* | SSN | 334 | 160 | 0 | NI |

NI : not inseminated in current tethering period.

* : never tethered.

** : Sows were weighed approximately 7 days before naloxone treatment.

of this experiment, she was released from her tether after 46 days and kept loose on straw for approximately one month. Shortly before her participation in the exploration test, she was retethered in the DSR.

The present experiment was performed in 2 parts (see Table I). In part 1, a) the short- and b) the long-term behavioural responses of tethered sows to treatment with saline or naloxone were investigated, with particular interest in the quantity and quality of stereotypies performed. In part 2, the influence of naloxone on the ability of unrestrained pigs to perform exploratory behaviour was investigated.

When administered, naloxone was dissolved in 5 ml. of 0.9% NaCl solution. Naloxone solutions and saline blanks were administered subcutaneously at one site on the pigs' necks. The pigs used in parts 1a and 1b of this experiment were tethered during the whole period of observation, whereas the pigs in part 2 were loose during observations. The experiment was performed between October, 1983, and March, 1984. Continuous behaviour observations were recorded for all sows; in parts 1a and 2 either directly by an observer seated in the DSR, indirectly via a video monitor away from the DSR, or at a later time from a video tape record. In part 1b time-lapse video recording enabled longer-term, continuous observations. The behaviour observations were quantified in an OS-3 event recorder (Observational Systems Inc., Seattle, Washington) by means of digital code schemes designed to suite the individual ethograms of the sows. For the observations recorded in part 1a, the code scheme described for individual sows at all times their posture, action and the substrate upon which the action was directed. Thus the duration, frequency and sequence of individual behaviour elements could be measured. For the other parts of the experiment, behaviours were recorded after being interpreted and categorized by the observer (see Results section). Data collected in the OS-3 event recorder were dumped to a host computer for further processing.

### Part 1a. Measurements of the short-term effects of naloxone administration on stereotypy performance

Naloxone was administered to 8 tethered sows at the rates listed in Table II. Sow 54 was treated on 2 occasions, the second time at a dose rate approximately twice that of the first. Thus, sow 54 is referred to as sow 54 x 1 and 54 x 2, respectively, for the single and double dose treatments. Treatment with either saline or naloxone solution occurred on consecutive days at 09.30 h. Four sows received the treatment regime - saline, naloxone, saline (S1, N, S2), while the others received - S1, S2, N (see Table I). Continuous behaviour observations were recorded from 09.30 to at least 11.45 h on treatment days, but on most days

Table II. The latency to cease the performance of class 1 behaviours by the sows followin
treatment with naloxone and the relationship with other parameters

| Sow | Parameters[1](units) | | | | | |
|---|---|---|---|---|---|---|
| no. | 1 (min) | 2 (weeks) | 3 (mg/kg) | 4 (weeks) | 5 (weeks) | 6 (days) |
| 23 | 10 | 4 | 0.96 | 20 | 25 | 31 |
| 81 | 20 | 3 | 0.64 | 17 | 23 | 28 |
| 76 | 25 | 8 | 0.91 | 19 | 26 | 51 |
| 68 | 40 | 26 | 0.78 | 39 | 49 | 27 |
| 63 | 45 | 30 | 0.76 | 44 | 51 | 226 |
| 79 | 85 | 32 | 1.00 | 27 | 36 | 53 |
| 60 | 135 | 20 | 1.00 | 21 | 28 | 38 |
| 54 x 1 | 180[2] | 53 | 0.81 | 43 | 56 | 52 |
| Spearman rank correlation | $r_s$ | 0.83 | 0.30 | 0.64 | 0.76 | 0.52 |
| two-tailed significance level | | $P < 0.02$ | ns | $P < 0.10$ | $P < 0.05$ | ns |

[1] Parameters included in the table:

1: Latency to cease the performance of class 1 behaviour following treatment with naloxone (min.).

2: time since the particular class 1 behaviour was first recorded for the sow (weeks).

3: dose of naloxone (mg/kg sow liveweight).

4: total time that the sow had been tethered (weeks).

5: time since the sow was initially tethered (weeks).

6: time spent tethered in the current tethering period (days).

[2] Sow 54 x 1 did not cease the performance of her class 1 behaviour following naloxone treatment, but for inclusion in the analyses a latency of 180 min. was assumed.

video records were made from 09.20 to 13.00 h.

During the treatment of sows 23, 68 and 81, once the saline or naloxone had been administered the observers left the DSR. On the treatment days of sows 63 and 60, and 76, 54 x 1 and 79, the observer(s) remained quietly in the DSR for 135 and 30 min., respectively, after injection. At designated times following injection, the observer performed the 3 tests described below - feed, straw and slap tests - in order to assess the attentiveness of these 5 sows. The "feed" test and the "straw" test were performed in an identical manner, but differed in that 6 feed pellets or a small handful of chopped straw, respectively, were placed in the sows' feed troughs. For these tests, the observer slowly positioned his hand containing the feed or straw about 30 cm above the trough, and then allowed the feed or straw to drop into the trough. The time interval between the feed or straw landing in the trough and its investigation by the sow was recorded. All 5 sows were subjected to a "feed" test at 10.00 h on each treatment day. Sows 63 and 60 also experienced a second feed test on each day at 11.00 h, as well as "straw" tests at 10.30 and 11.30 h. After 15 min. of each test being performed on sows 63 and 60, any uneaten feed or straw was cleared from the trough by the observer. If at these times, either sow 63 or 60 were lying idly, the observer applied the "slap" test. By firmly slapping the top of the sow's neck, the observer recorded the number of slaps needed before the sow rose to the standing posture. Slaps were applied at a rate of 1 per 5 sec.

### Part 1b. Measurement of the long-term effects of naloxone administration on stereotypy performance

The behaviour of 3 of the sows used in part 1a (sows 76, 54 x 1 and 79) was continuously recorded by time-lapse video from 3 days before to 3 days after the day of naloxone administration. The 3 sows occupied adjacent tether stalls in the DSR. A video camera was positioned above and to the fore of the sows such that a clear picture of all 3 sows was possible on the video monitor. Night-time video recording was assisted with illumination from a red light suspended 1.5 m above the sow stalls. The treatment of saline or naloxone was staggered by one day between the sows. As mentioned previously, sow 54 was treated a second time with naloxone. Long-term video recordings were also made on this sow over 7 days, 3 days before and 3 days after naloxone.

### Part 2. Measurement of the influence of naloxone administration on exploratory behaviour

The behaviour of 3 individual pigs (see Table I, part 2) was recorded over 3 consecutive days (sessions) during the presence or absence of selected sets of stimuli following administration of saline or naloxone. For the 3 sessions of testing with sow 80 and gilt 1, a treatment regime of S1, N, S2 was used. The other pig, gilt 2, experienced S1, S2, N. The doses of naloxone administered to sow 80, gilt 1 and gilt 2, respectively, were 1.00, 0.89 and 0.97 mg/kg liveweight. The test arena was situated within the DSR, and is described in Fig. 1.

At 10.30 h, the test pig was introduced into the test arena for a 10 min. familiarization period, after which the pig was quietly manoevered into one of the stalls within the arena and injected with saline or naloxone. Five minutes later, the first stimulus was presented. The 3 sets of stimuli chosen for this test were always presented in the same order: 1-straw, 2-novel objects and 3-soil. Each set of stimuli remained available to the pig for 10 min. before its removal (straw and novel objects) or before access was denied (gate closure in the case of the soil mound). A period of 5 min. separated the removal/denial of one set of stimuli and the presentation of the next. Each set of stimuli were presented twice per session. The straw, which weighed 1.4 kg at the start of each test session, was reused in the second presentation. Between presentations it was swept out of the test arena. The novel objects consisted of one-half of a vehicle tyre (0.8 diameter and split longitudinally), a tree branch (7 cm diameter and 1.2 m long) and 2 standard paving bricks. The mound of soil contained approximately 0.25 $m^3$ of sandy loam. In order to allow for the possibility that rooting in the soil might reap delectable titbits, such as worms or roots, for the first pig tested or for any of the pigs in their earlier exposures to the soil, a small quantity of feed pellets was sprinkled over the soil before each exposure. Further, before the start of each test day, the soil was loosened with a shovel and lightly sprinkled with water in an attempt to provide soil of similar consistency between days.

Two observers were present in the room at the time of the tests, one to continuously record the pig's behaviour in an OS-3 event recorder, and the other to affect presentation and removal of the different sets of stimuli. The observers swapped roles half way through the test procedure each day.

## Results

### Part 1. The behavioural response of tethered sows to naloxone treatment

The record of the continuous behaviour observations for each of the 8 tethered sows treated with naloxone was individually studied and the various behaviours were classified into the following categories:

Class 1 behaviours: the normally occurring stereotypy(ies). See Table III, part a for the description of each sow's main stereotypy. Quantitative descriptions of the class 1 behaviours of 3 sows are presented in Table III parts b and c, and Fig. 3.

Class 2 behaviours: behaviours recognized as basically similar to a class 1 behaviour of the sow, but which varied in one of the following 2 aspects - the location of the head of the sow was unusual (e.g. away from cf. along the bars) or the action was unusual (e.g. chain wrenching cf. chain chewing).

Class 3 behaviours: behaviours which were repetitive and appeared to be non-functional, and which had not been previously recorded for that sow.

Class 4 behaviours: drinker-directed behaviours. Although this class involved mostly drinking water by the sow, some water could also be imbibed from the trough, where "drinking" would have been classed as a trough-directed behaviour.

Class 5 behaviour: idling behaviour - instances when no activity was performed (e.g. standing idle or lying idle); this class could also include instances when the sows were alert but inactive.

Class 6 behaviours: non-stereotyped behaviours directed at environmental objects (trough, floor, bars, tether or extra chain and neighbouring sows) e.g. sniffing, licking, rooting, pawing, nibbling.

Class 7 behaviours: aggressive acts against the environment including another sow (nosing, biting), escape attempts or vocal distress signals. In addition, a behaviour as previously described by Fraser (1975), in which the sow remains for some time with her snout pressed between the bars or into a corner (e.g. in the trough) was also included; and

Class 8 behaviours: other behaviours such as eliminative behaviours.

Part 1a. The short term behavioural response to tethered sows following treatment with saline or naloxone

To aid the description of the short-term behavioural response of the sows to naloxone, saline or no injection treatment (for e.g. sow 54 x 1 on day N+1), three examples are shown (Figs. 4a, b and c). The 3 sows represented, sows 23, 63 and 54 x 1, respectively, are animals that varied widely in their behavioural response to naloxone. Histograms show the proportion of each successive 5 min. period after 09.30 h that the individual sows performed classes 1, 2, 3 and 4 behaviour. Asterisks at the top of individual figures indicate, that for more than 50% of the 5 min. observation period, the sow was idle (class 5 behaviour).

Table III. Descriptions of the class I behaviours (normal stereotypies) of the sows treated with naloxone

IIIa: General descriptions of the stereotypies

| Sow | Posture | Main substrate(s) | Action | Elements |
|---|---|---|---|---|
| 23 | stand | extra chain | chew, flick | 5 |
| 54 | " | self | chew, suck, head tilt | 4 |
| 60 | " | extra chain | chew | 3 |
| 63 | " | self/front bar/trough | tongue flick inside mouth, chew/suck/lick | 4 |
| 68 | " | extra chain | chew, root | 6 |
| 76 | " | extra chain | chew | 3 |
| 79 | stand/sit | extra chain/drinker | chew/drink | 3 |
| 81 | stand | extra chain | chew | 4 |

IIIb: Detailed descriptions of the main stereotypies of 3 sows by elements. E1 = element 1, etc. See also Fig. 3.

Sow 23: E1 - sow picks up extra chain in left hand side of mouth and chews up the chain to the top; E2 - turns head to left bringing chain to right hand side (RHS) of mouth; E3 - snout is withdrawn from chain attachment bar and chain is flickec over the snout as head turns from left to right; E4 - chain is chewed while snout remains behind chain attachment point; E5 - head is lowered and chain is allowed to drop from mouth although chewing action continues.

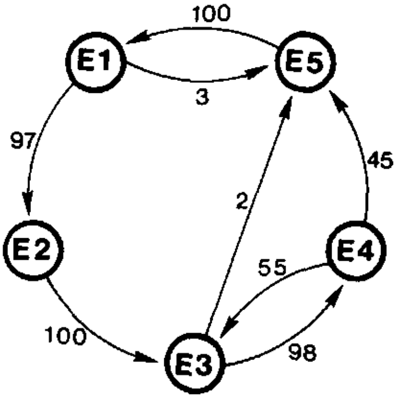
Sow 60: E1 - sow picks up chain in RHS of mouth and chews up the chain to the top; E2 - the chain is then allowed to drop from the mouth and sow runs chain over rooting disk; E3 - sham chewing while attempting to pick up chain in mouth.

Sow 63: E1 - sow sucks ("kisses") the lowest front bar at about the mid point of the bar; E2 - head is withdrawn from bar and tongue is rapidly flicked about inside mouth while a chewing action is performed but without mouth being opened much; E3 - sham chewing away from the front bars; E4 - head is lowered into trough, sow licks trough.

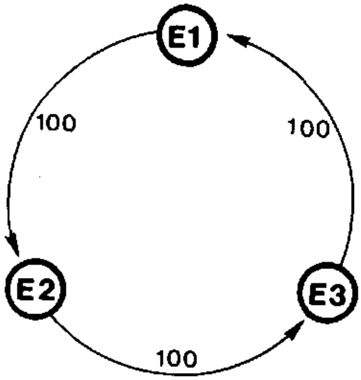
IIIc: Quantification of the stereotyped elements by duration of performance time (sec.)

| Sow number | 23 | | | | | 60 | | | 63 | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Element no. | 1 | 2 | 3 | 4 | 5 | 1 | 2 | 3 | 1 | 2 | 3 | 4 |
| Parameter | | | | | | | | | | | | |
| Mean | 1.08 | 1.27 | 1.08 | 1.98 | 0.86 | 3.07 | 0.68 | 0.75 | 1.04 | 1.54 | 1.45 | 21.10 |
| Mode | 0.90 | 1.30 | 1.00 | 1.40 | 0.70 | 2.90 | 0.70 | 0.70 | 0.80 | 0.80 | 1.30 | 12.10 |
| Median | 1.00 | 1.26 | 1.02 | 1.89 | 0.77 | 2.94 | 0.66 | 0.71 | 0.88 | 0.99 | 1.32 | 25.30 |
| Kurtosis | 10.25 | -0.50 | 19.50 | 0.15 | 9.65 | 17.21 | 30.81 | 4.77 | 21.17 | 2.65 | 3.92 | -- |
| Skewedness | 2.70 | 0.47 | 3.75 | 0.80 | 3.13 | 2.93 | 4.89 | 1.59 | 4.15 | 1.87 | 1.87 | -1.72 |
| Minimum | 0.7 | 0.8 | 0.7 | 1.0 | 0.7 | 0.6 | 0.5 | 0.4 | 0.6 | 0.5 | 0.6 | 12.1 |
| Maximum | 2.4 | 2.0 | 3.0 | 3.8 | 2.0 | 9.1 | 2.0 | 1.6 | 4.4 | 5.6 | 4.0 | 25.9 |
| Variance | 0.96 | 1.12 | 1.03 | 4.54 | 1.02 | 11.67 | 0.42 | 0.39 | 3.30 | 15.15 | 6.06 | 608.40 |
| Std. Error | 0.05 | 0.06 | 0.04 | 0.83 | 0.06 | 0.14 | 0.03 | 0.02 | 0.07 | 0.16 | 0.11 | 4.50 |
| n | 32 | 31 | 66 | 65 | 31 | 57 | 56 | 56 | 59 | 60 | 45 | 3 |

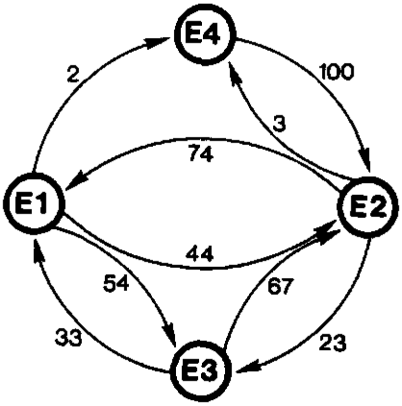
Sow 23



Sow 60



Sow 63



Sow 23 MAJOR "LOOP" E3 ↔ E4:

| NO. OF EXTRA LOOPS | % FREQUENCY |
|---|---|
| 0 | 20 |
| 1 | 57 |
| 2 | 13 |
| 3 | 7 |
| 4 | 3 |
| | 100 % |

Figure 3. Quantitative descriptions of the stereotypies of sows 23, 60 and 63 by flow diagrams. Numbers along arrows indicate the percentage of occasions that individual elements succeeded other elements. E1: element 1, etc. The percentage frequency of extra "loops" between E3 and E4 for sow 23 is also shown.

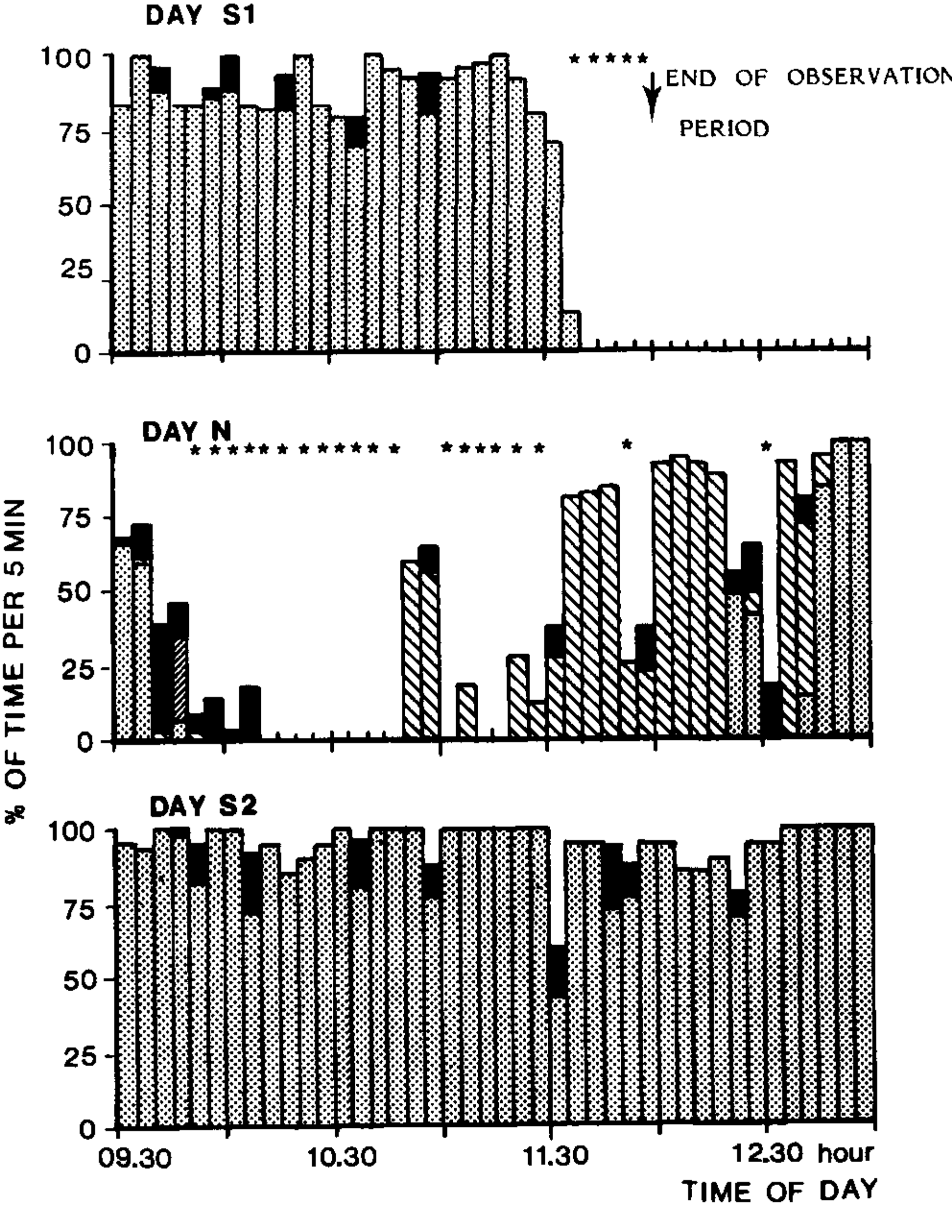


Figure 4a. Changes in the behaviour pattern of sow 23 after treatment with saline (days S1 and S2) or naloxone (day N) at 09.30 h. Stippled bars = class 1 behaviour; narrow stripes = class 2; wide stripes = class 3; solid bars = class 4; asterisk indicates that class 5 behaviour occurred during more than 50% of the 5 min. period.

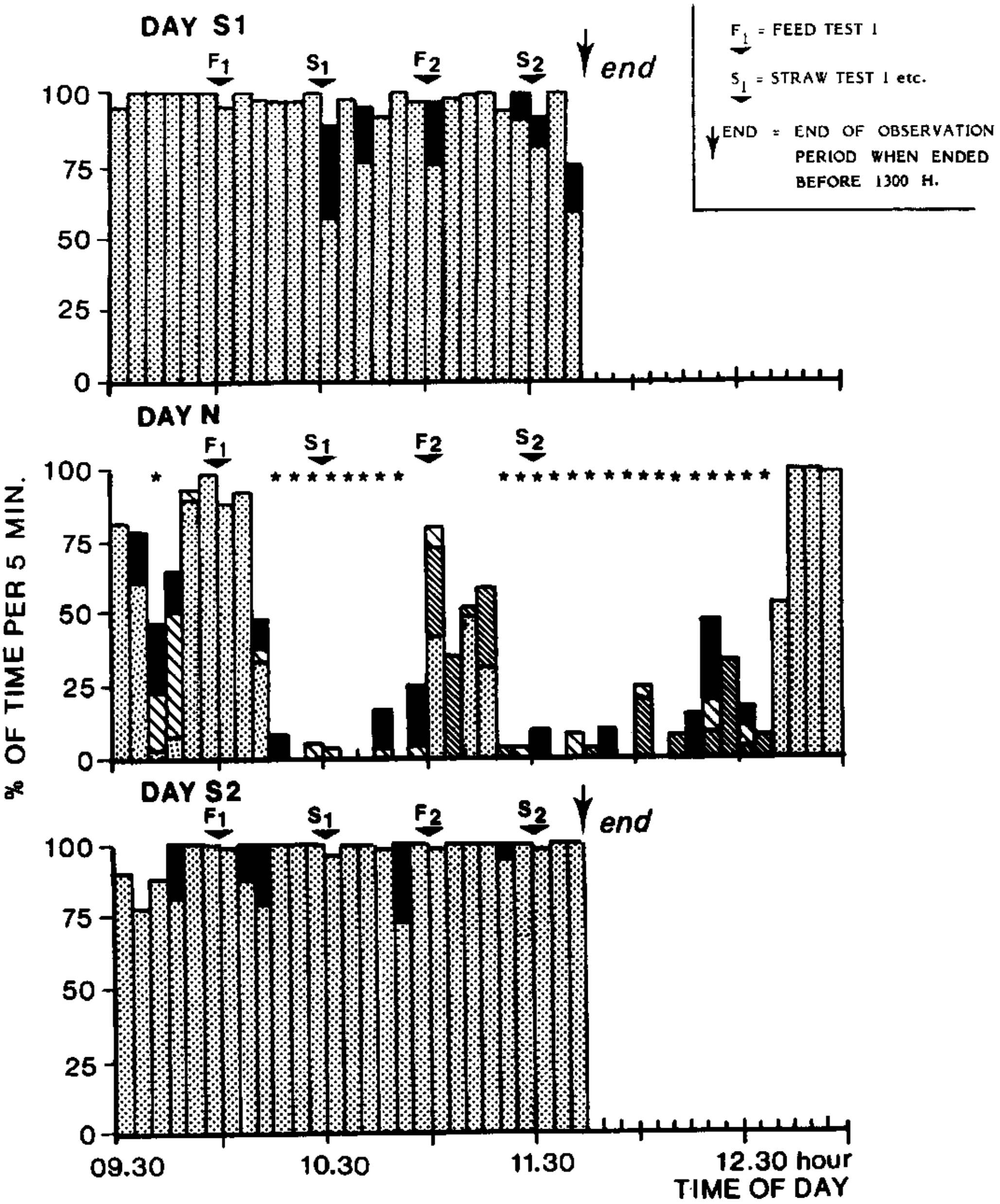


Figure 4b. Changes in the behaviour pattern of sow 63 after treatment with saline (days S1 and S2) or naloxone (day N) at 09.30 h. Stippled bars = class 1 behaviour; narrow stripes = class 2; wide stripes = class 3; solid bars = class 4; asterisk indicates that class 5 behaviour occurred during more than 50% of the 5 min. period.

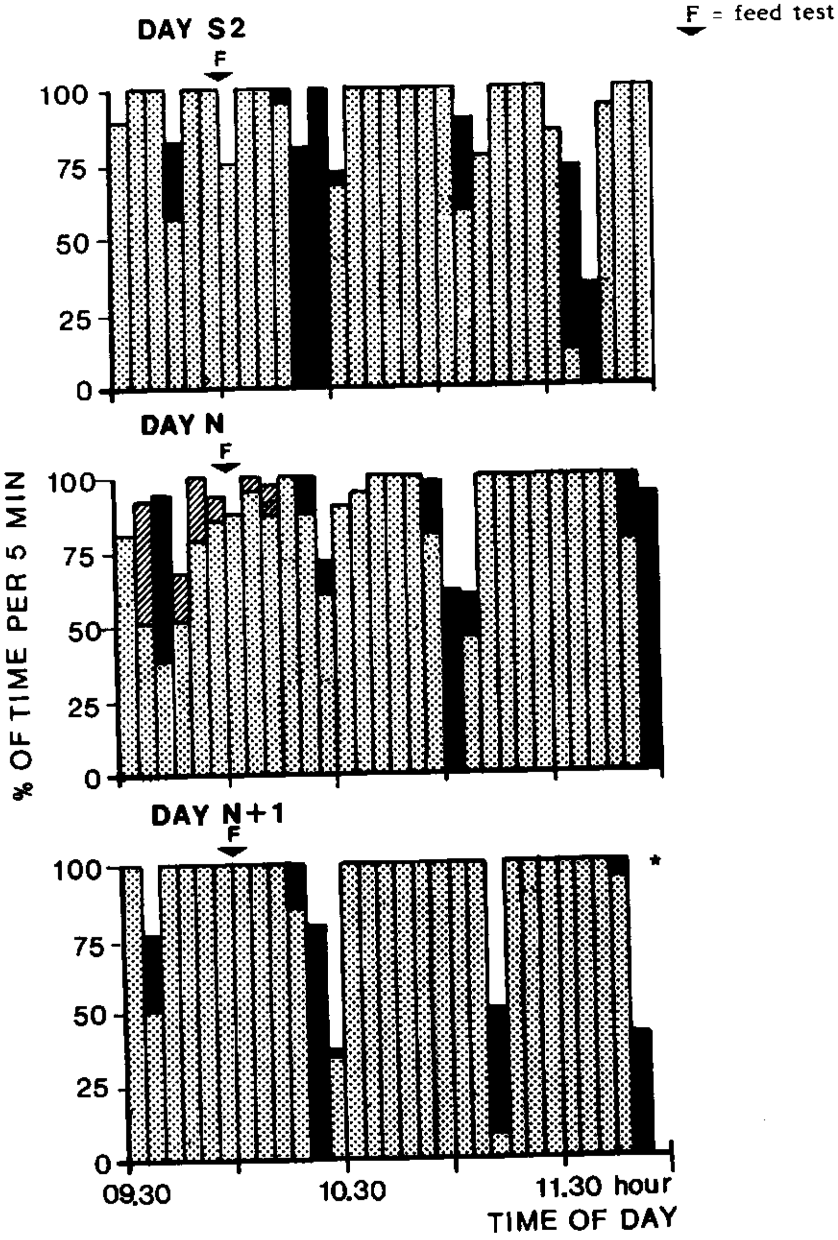


Figure 4c. Changes in the behaviour pattern of sow 54 x 1 after treatment with saline (days S2), naloxone (day N) or no treatment (day N+1) at 09.30 h. Stippled bars = class 1 behaviour; narrow stripes = class 2 behaviour; solid bars = class 4 behaviour; asterisk indicates that class 5 behaviour occurred during more than 50% of the 5 min. period. Class 3 behaviour was not recorded.

In general, the short-term behavioural response of stereotyping sows to naloxone treatment can be described as follows. Within 10 min. of treatment with naloxone, the sows appeared to notice that something had happened to them. Their class 1 behaviour then altered slightly (to class 2) and, or radically (to class 3). By 30 min. after naloxone injection, most sows had performed more, although not significantly more, drinking behaviour: medians with ranges for days N-1 and N, respectively, 4.0% (0-8.5) and 8.7% (1.3-12.5) of the first 30 min.; Wilcoxon matched-pairs signed-ranks test, nsd; data of sow 79 was not included since drinking was part of her class 1 behaviour. In addition sows directed their behaviour, often forcefully, against the environment including nosing or biting on the tether chain and its attachment point on the side bars. Most sows attempted to attack neighbouring sows through the side bars and tried to escape from the tether. If a sow did not perform her class 1 behaviour during an interval lasting longer than 5 min., she was considered to have ceased stereotyping in the short-term. By the end of the first 30 min. period all sows had "experimented with" or modified their stereotypies at least temporarily, with the result that all 8 sows performed less class 1 behaviour in the 30 min. following naloxone treatment compared with saline (medians with ranges: 88.4% (57.5-99.1) and 54.8% (22.1-70.1) of the time, respectively, for saline and naloxone; Wilcoxon test, 2 tailed; $P < 0.01$). By the end of the first hour, 5 of the 8 sows had ceased stereotypy performance for considerable periods of time, and by the end of the next half hour the sixth sow had stopped. The seventh sow ceased her performance after 135 min. The eighth sow, sow 54 x 1, did not cease stereotyping in the 3 hours after naloxone. The latencies to cease the performance of class 1 behaviours by the sows are shown in Table II along with other treatment parameters. As expected, there were significant relationships between the time since initial tethering and the total time spent tethered ($r_s = 0.95$, $P < 0.01$, $n = 8$) and "age" of the class 1 behaviour ($r_s = 0.93$, $P < 0.01$, $n = 8$). The "age" of the stereotypy refers to the time since the particular class 1 behaviour was first recorded for the sow.

Latency times were subjected to Spearman's rank correlation analyses with the parameters: - "age" of the class 1 behaviour, the dose of naloxone administered, the total time that the sow had been tethered, the time since the sow was initially tethered, and the time spent tethered in the current tethering period (see Table II). There were significant relationships between the latency time and the "age" of the stereotypy ($P < 0.02$), the time since the sow had been initially tethered ($P < 0.05$) and the total time that the sow had spent neck tethered during her life time ($P < 0.10$). Since not all of these parameters were independent of each other,

Table IV. The proportion of time that individual sows performed their normal stereotypies (class 1) and modified stereotypies (class 2) or new repetitive behaviours (class 3) between 09.30 and 11.30 h on treatment days. The values shown are percentages (N = naloxone, S = saline).

| | Behavioural classes[1] | | | | | |
|---|---|---|---|---|---|---|
| | Class 1 | | | | Class 2 | Class 3 |
| Day | N-2 | N-1 | N | N+1 | N | N |
| Treatment | - | S | N | S | N | N |
| Sow 23 | | 88 | 5 | 96 | 0 | 9 |
| 63 | | 94 | 28 | 94 | 4 | 4 |
| 60 | | 89 | 63 | 93 | 14 | 3 |
| 68 | | 74 | 38 | 45 | 16 | 1 |
| Treatment | S | S | N | - | N | N |
| Sow 76 | 80 | 67 | 11 | 66 | 2 | 11 |
| 54 x 1 | 89 | 84 | 80 | 89 | 4 | 0 |
| 79 | 92 | 96 | 65 | 26 | 3 | 2 |
| 81 | 20 | 18 | 13 | 48 | 6 | 0 |
| Median | | $86^{***}$ | 33 | 77.5 | $4^{**}$ | $2.5^{*}$ |

[1] No sow performed either class 2 or 3 behaviours on days N-1 or N+1 except sow 79 which performed class 3 behaviour for 48% of the observation time (09.30 to 11.30 h) on day N+1.

* Within behaviour classes, median value for day N differs significantly from day N-1 (* $P < 0.05$, ** $P < 0.02$, *** $P < 0.01$; Wilcoxon test, 2 tailed).

Table V. The proportion of time that individual sows performed the different classes of behaviour (classes 4 to 8) between 09.30 and 11.30 h on days N-1 and N. The values shown are percentages (N = naloxone). Class 4 = drinking, class 5 = idle, class = non-stereotyped actions, class 7 = aggressive acts, etc. and class 8 = other.

| Sow | Day | Behaviour class | | | | |
|---|---|---|---|---|---|---|
| | | 4 | 5 | 6 | 7 | 8 |
| 23 | N-1 | 2 | 0 | 7 | 0 | 3 |
| | N | 4 | 71 | 8 | + | 3 |
| 63 | N-1 | 3 | + | 3 | 0 | 0 |
| | N | 4 | 54 | 5 | 1 | 0 |
| 60 | N-1 | 5 | + | 5 | 0 | + |
| | N | 7 | 3 | 9 | 1 | 1 |
| 68 | N-1 | 6 | 5 | 15 | 0 | + |
| | N | 5 | 21 | 17 | 2 | 0 |
| 76 | N-1 | 4 | 0 | 28 | 0 | 1 |
| | N | 3 | 40 | 16 | 13 | 4 |
| 54 x 1 | N-1 | 6 | 0 | 10 | 0 | 0 |
| | N | 7 | 1 | 7 | 1 | 0 |
| 79[1] | N-1 | 0 (14) | 0 | 4 | 0 | 0 |
| | N | 0 (10) | 18 | 9 | 3 | 0 |
| 81 | N-1 | 2 | 69 | 11 | 0 | 0 |
| | N | 3 | 54 | 26 | 2 | 0 |
| Median | N-1 | 3.5 | 0 | 8.5 | 0 | 0 |
| | N | 4.0 | $30^{*}$ | 9 | $1.5^{**}$ | 0 |

[1] Sow 79: drinking (class 4) is presented as 0% since drinking was part of the stereotypy of this sow. The values presented in brackets are the actual percentages, but these have not be included in the analysis.

\+ : Values $0 < \% < 0.5$

* : Within behaviour classes, median for day N differs significantly from day N-1 (* $P < 0.05$, ** $P < 0.01$; Wilcoxon test, 2 tailed).

and since we wished to stress the individual differences between sows, we have selected "age" of the stereotypy was the best predictor of naloxone response.

Once the stereotypies ceased to be performed the sows laid down, or if they remained standing for some time, they pressed their snout between the bars or into a corner. Occasionally the sows would recommence a repetitive behaviour or assault their environment before again becoming inactive. Although the sows were generally inactive some time after naloxone, they became very alert, frequently having their ears drawn back and the edges of their rooting disks flared, typical of the alert pose of pigs. Two sows, sows 60 and 79, appeared to be quite fearful of the human observer and were alert to every movement he made. It is a point of interest that in the 5 min. period prior to the first "feed" test (10.00 h), the behaviour of sow 60 altered radically and perhaps she would have shortly ceased stereotyping had the scheduled feed and straw tests not been performed. Nevertheless, this sow continued performing her stereotypy while the observer remained in the DSR, but over the last 30 min. that the observer was seated in front of her, she was groaning and performed continually less chain-related activity with each 5 min. period. The video record revealed that as soon as the observers had left the room (11.45 h), the sow ceased stereotyping. This was not the case for this sow on days when saline was administered. Sow 79 also appeared to be fearful of the presence of the human observer. For this sow, however, direct observation ended 30 min. after naloxone treatment.

The proportion of time that individual sows performed the 8 classes of behaviour in the period 09.30 to 11.30 h on treatment days is shown in Tables IV and V. In addition, the data pertaining to the day following naloxone are shown for sows 76, 54 x 1, 79 and 81, even though saline was not administered on that day. While it was our original intention to compare the quality and quantity of stereotypies on all days, we later discovered drastic long term after-effects of naloxone (see part 1b), which meant that the post-naloxone day could not be used as a control day. Similarly, since sow 54 was treated twice with naloxone it was decided that the data pertaining to sow 54 x 2 should not be included in any analyses. Instead, the data relevant to the short-term behavioural response to naloxone by this sow is reported separately, later in the results section.

In the 2 h period following treatment with naloxone, all sows performed less class 1 behaviour compared with the same period on the previous day (median values for days N-1 and N, respectively, 86 and 33%, $P < 0.01$, Wilcoxon test, 2 tailed). Seven of the 8 sows responded to naloxone by performing some class 2 behaviour and 6 sows performed class 3 behaviour (Table IV). Neither of these behaviour classes were found to occur on day N-1. Sow 79 performed class 3 behaviours (tether chain chewing, sham chewing and extended bouts of drinker play) on the day following naloxone treatment, thus the proportion of time spent in the performance of her class 1 behaviour was lower on day N+1 than day N-1. No other sow performed class 2 or 3 behaviours on day N+1. Thus in Table IV, the proportions of time spent in the performance of class 2 and 3 behaviours are only shown for day N.

Amongst the remaining 5 classes of behaviour, the sows performed significantly more class 7: aggressive-like, (median 1.5 and 0%; $P < 0.01$) and class 5: idling, behaviours (median 30 and 0%; $P < 0.05$, Wilcoxon test, 2 tailed) on day N than day N-1, respectively, in the 2 hours following treatment. Class 7 followed by class 5 behaviours are typical of the short-term behavioural response of sows at the initial tethering. There were no significant treatment effects on classes 4, 6 and 8 behaviour.

The 7 sows which ceased stereotypy performance after naloxone treatment resumed the behaviours during the afternoon of the same day. Following the 15.30 h feeding time, all 8 sows were observed to commence and perform their class 1 behaviours in the manner typical for each sow at that time of day.

In the feed- and straw-tests performed on 5 sows while under direct observations, the sows were all slowest to react on the first occasion that feed pellets were presented in their troughs (always a saline day) compared with subsequent tests performed on the same or following days with either feed pellets or straw. The slap-test was only performed on sow 63 and on the naloxone treatment day, since on saline days the sow did not lie down while under direct observation. Sow 60 remained standing at all times while being observed directly. On the 2 occasions that sow 63 was slapped, 1 and 2 slaps, respectively, were applied before the sow stood.

Sow 54 x 2 had experienced a further 8 weeks of tethering when she was treated with naloxone for the second time. Her class 1 behaviour had not altered during that period, thus the stereotypy had an "age" of 61 weeks. The short term behavioural response of this sow to a "double dose" of naloxone was in general similar to that recorded on the first treatment occasion. Interestingly, in the 2 hour period following naloxone treatment, the sow performed more class 1 behaviour than on day N-1 (72 and 85% of the time, respectively, for days N-1 and N). During the 3 days prior to naloxone treatment, sow 54 x 2 had performed her class 1 behaviour for an average of 92.6% of each 5 min. period between 09.30 and 11.00 h. From about 11.00 to 11.30 h the sow spent most of the time standing idle, before lying down at around 11.30 h. The treatment with naloxone not only displaced this period of idle behaviour (class 5) but also resulted in class 2 behaviour being performed during 8% of the 2 hour observation period. This was twice the level recorded after the first (single) dose of naloxone (see Table IV). As with her first naloxone treatment, sow 54 x 2 did not perform a class 3 behaviour.

### Part 1b. The behaviour response to naloxone in the longer term

The proportion of each one-hour period that sows performed each of the 8 classes of behaviour was recorded over 7 consecutive days from continuous time-lapse video records, beginning 3 days prior to treatment with naloxone. Over these 3 days, the pattern of performance of class 1 behaviour by each individual sow was fairly consistent between days. Only sow 54 x 2 was seen to perform class 1 behaviour at night, but bout lengths were short (less than 5 min. in duration). Furthermore, the sow was in a lying posture. During virtually the entire night-time period the sows rested or slept. Diurnal activity was generally confined to 2 periods: following the morning feeding (08.45 h) to until about 15.00 h, and after the afternoon feeding (15.30 h) to just before "lights out" (18.30 h). On the days prior to treatment with naloxone, sow 76, 54 x 1, 79 and 54 x 2 performed stereotypies for approximately 6, 7, 8 and 7 hours per 24-hour period, respectively.

The administration of naloxone, however, drastically altered the daily pattern of class 1 behaviour performance. Examples of the results for 2 sows, sows 79 and 54 x 1, are shown in Fig. 5. The figure shows the proportion of each hour period that the sows performed classes 1, 2 or 3 behaviour over 5 consecutive days, from one day before to 3 days after naloxone. The majority of the remaining time was spent in resting behaviour (class 5) although it is not indicated on the figure. Typically all sows experienced nocturnal bouts of stereotyped behaviour, and disruption to their diurnal behaviour rhythm in the 3 days following naloxone treatment. As previously mentioned sow 54 did not perform any class 3 behaviour after either of her naloxone treatments. On days N+1 and N+2, sow 79 performed significant amounts of class 3 behaviour: specifically tether chain chewing, sham chewing and drinker play.

### Part 2. Measurement of the influence of naloxone administration on the performance of exploratory behaviours

The following actions when performed by the test pig were interpreted to be exploratory behaviour: sniffing, licking, rooting, nibbling, walking and listening

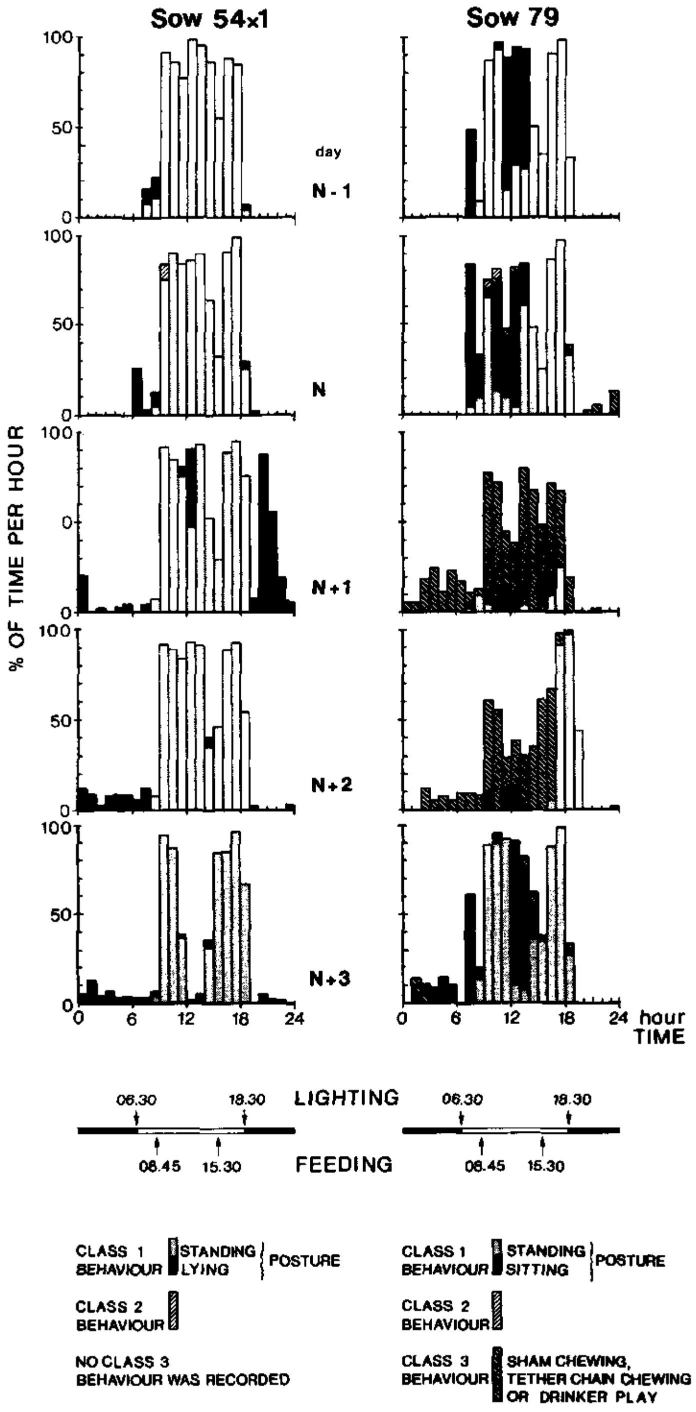


Figure 5. Changes in the behaviour patterns of sows 54 x 1 and 79 from 1 day before to 3 days after naloxone treatment. Naloxone was administered at 09.30 h on day N while saline was administered at 09.30 h on day N-2 and N-1.

actions. Naloxone did not appear to alter the proportion of total test time (105 min.) that exploratory behaviour was performed by the test animals, compared with the same period on the first day of saline treatment, day S1 (Table VI). All 3 test animals performed less exploratory behaviour on day S2 than day S1. It is interesting to note, however, that naloxone treatment appears to have reversed the trend to perform less exploratory behaviour with repeated introductions in the same test situation over consecutive days. A contributing factor to this reversal may be that pigs expressed an alert pose for a higher proportion of total test time after naloxone than after saline (Table VI). In the alert pose, pigs draw their ears backwards, remain immobile and quiet while they sniff the air.

During the six, 10-min exposures to the sets of specific stimuli on each test day, the pigs on average utilized the soil stimulus for a significantly greater proportion of the test period than the other stimuli (soil: 90.3%, novel objects: 26.2% and straw: 21.4% of the available time respectively; one-way ANOVA, $P < 0.001$). Of the other stimuli, both gilts utilized the novel objects more than the straw, while the sow "preferred" the straw to the novel objects (Table VI). There were no consistent differences in the use of the individual stimuli in relation to treatment with naloxone or saline, nor between the 2 exposures to the same stimulus on the same day.

Table VI. Total exploratory behaviour and alert behaviour expressed by test pigs as a proportion of the total observation time, and the proportion of each specific stimulation period that the pigs utilized the accessible stimuli, on days when treated with either naloxone (N) or saline (day S1 or day S2). The values shown in the table are percentages.

| Pig number | Day and Treatment | | Total exploratory behaviour | Alert behaviour | Straw use | | Novel objects use | | Soil use | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | 1 | 2 | 1 | 2 | 1 | 2 |
| Sow 80 | 1 | S1 | 85 | 2.5 | 60 | 72 | 12 | 12 | 83 | 97 |
| | 2 | N | 89 | 3.8 | 35 | 61 | 14 | 20 | 92 | 97 |
| | 3 | S2 | 73 | 3.5 | 24 | 3 | 36 | 33 | 78 | 91 |
| | mean % | | | | 42.5 | | 21.1 | | 89.7 | |
| Gilt 1 | 1 | S1 | 93 | 1.2 | 11 | 6 | 53 | 25 | 96 | 96 |
| | 2 | N | 91 | 10.6 | 4 | 4 | 40 | 9 | 92 | 81 |
| | 3 | S2 | 82 | 3.5 | 59 | 12 | 18 | 14 | 86 | 86 |
| | mean % | | | | 16.0 | | 26.5 | | 89.5 | |
| Gilt 2 | 1 | S1 | 91 | 5.2 | 3 | 3 | 48 | 19 | 94 | 94 |
| | 2 | S2 | 87 | 4.5 | 7 | 0 | 63 | 21 | 91 | 80 |
| | 3 | N | 91 | 9.7 | 12 | 20 | 29 | 6 | 96 | 96 |
| | mean % | | | | 5.8 | | 31.0 | | 91.8 | |
| Over all means | | | | | 21.4b | | 26.2b | | 90.3a | |

Across columns a, b denote significant differences $P < 0.001$

## Discussion

The results of the present experiment show that endorphins are probably associated with the performance of stereotypies but not of exploratory behaviours in sows. This observation is an important step towards explaining the manner in which stereotypies develop and function in animals. Furthermore, since tethering imposes severe stress on pigs (Becker et al., 1983), and since it has been shown by Dantzer and Mormède (1983) that stereotypies possess dearousal properties, our results support the conclusion of Amir et al. (1980) that endorphins play a significant role in the adaptation to stress. The sows in the present experiment might have done this by developing an association between seemingly purposeless, repetitive behaviours - stereotypies - and a release of endorphins. By blocking this apparent association, the sows reverted to behaviours typically observed at initial tethering. At first, newly tethered sows perform escape attempts and aggressive acts against the environment, including neighbouring sows. These behaviours precede periods in which the sows press their snouts between the bars or into a corner. Shortly afterwards, the sows become idle and virtually immobile for long periods of time (Cronin, Wiepkema and Hofstede, to be published).

Our use of the term stereotypy does not imply that used in the literature, but rather, it refers to an homogenetic group of behavioural events. There appear to be different classes of stereotypies; the classes may be recognized from differences in their causation, the underlying biochemical mechanisms and the morphology of the expressed behaviours. Because of these differences, it would be unwise to simply categorize all forms of stereotypies together in a single class of (disturbed) behaviour. For example, apparent differences exist between the stereotypies reported for tethered sows in the present experiment and pharmacologically- and schedule-induced stereotypies. While the two latter forms may be only temporary motoric outputs dependent on acute interference with neurotransmission processes and an external operant, respectively, the former type more closely resemble stereotypies seen in the practical situation, that is, in zoo animals and man. The sows in the present study performed stereotypies which were derived out of conflict situations and which were developed largely as strategies to overcome loss of control over the environment. The development of our sows' stereotypies, as observed and recorded in the historical data of each sow, reflects a process similar to normal learning processes. Taken together, the observations that stereotypies and endorphins might be coupled, and that the development process resembles learning processes, we can suggest that endorphins are the counterpart of these disturbed behaviours. However it may be of little benefit to compare the results of this experiment with the mass of studies on stereotypies reported in the pharmacological literature. Instead it may be more beneficial to compare studies in which endorphins are seen to be related to naturally-occurring behaviours. For example, Panksepp et al. (1980) have reviewed many experiments investigating the role of endogenous brain opioids in the development and performance of social behaviour in young animals. These authors suggest that opioids facilitate social learning processes.

Endorphins have many attributes that could be useful and which would seem to be essential in the development and continued performance of stereotypies. For example, endorphins are released in response to stress (Guillemin et al., 1977) both internal and external to the brain (Berger et al., 1982). Continued high levels of stress enhanced the production of the precursor molecule (Schachter et al., unpublished, cited by Berger et al., 1982) and large doses of corticotrophin-releasing factor in rats resulted in a prolonged duration of plasma β-endorphin rise (Nussbaum et al., 1983). Furthermore, animals might learn to self-stimulate the release of endorphins in the brain and become addicted to the behaviour associated with this release, since endorphins have dependence-creating properties (Van Ree et al., 1979). Finally, their potential gating function may be used to block out undesirable circumstances and thus reduce emotional distress (Lewis et al., 1981) and pain (Berger et al., 1982). Endorphins therefore are a likely candidate for the underlying biochemical mechanism in stereotypy performance. Thus, while Dantzer and Mormède (1983) have demonstrated a relationship between the performance of stereotyped behaviour and stress reduction, via corticosteroid measurement in pigs, the present results strongly suggest that this stress reduction might be via endorphin release calming the frustrated animal.

From the results of the present experiment, the question arises as to why "older" stereotypies were less sensitive to naloxone than "newer" stereotypies? According to Fentress (1976), frequently used behaviours will become automated or even emancipated over time from their original causation. Thus, as the stereotypies of tethered sows age, the animals may gradually accept the behaviour as normal and, or increase tolerance to endorphins with the result that the reliance upon an endorphin-related mechanism is reduced. Future research may identify if other control systems involving for e.g. dopamine, take over from endorphins in time. Alternatively, if sows do eventually accept tethering with all its associated problems such as loss of environmental contingency and the gaining (hopefully) of contingency over a new but much reduced environment, then with time there may be a gradual reduction in the proportion of opiate receptor sites in the brain which sows need to keep occupied in order to experience an acceptable level of well-being. In either situation, there is reduced reliance on endorphins over time. The fact that the short-term behavioural response of stereotyping, tethered sows to naloxone treatment diminished as age of the stereotypy and time spent tethered increased appears to support this conclusion. Whether it is correct to conclude that as tethered sows become less affected by, or feel less need to produce large quantities of, endorphins, they are accepting tethering is unknown. In the present experiment, we selected individual sows which "chose" stereotypies as their coping strategy. In these sows, the endorphin reward may have assisted with changing the sows' perception of control in order to cope with the new environment. Absence of control is demonstrably stressful and excessive exposure to uncontrollable events or inordinate loss of control is a clear danger to the individual's health (Overmier et al., 1980). Thus, while tethered sows suffering from loss of control may develop stereotypies to gain new contingency, other behavioural strategies, such as polydipsia and motionless sitting (Sambraus, 1981) have been identified. While the former solution may be also effective via an association with endorphins (Baldwin and Parrott, 1984), the mechanism of the latter, if it is a successful coping strategy, is unknown. Similarly, whether all sows are successful in adapting a strategy to cope with tethering is not known.

Repeated stressful experiences may facilitate the release of endorphins and this interfered with the effectiveness of opioid antagonists (Cabib et al., 1984). The observation from the exploration tests in the present experiment also support this: gilt 2, which was a socially subordinate and presumably therefore more stressed pig, expressed discomfort vocalizations except when the soil stimulus (with some food pellets) was available, whereas gilt 1, a socially dominant pig did not, after naloxone treatment. It would seem to be critical therefore, to know in detail the historical background of each animal under treatment. In the present experiment such historical records on the behaviour of the individual sows enabled us to draw conclusions about the effect of naloxone in relation to the "age" of the stereotypy. Many pharmacological experiments studying the effects of naloxone on drug-induced stereotypies produced inconclusive results, possibly due to the experimentors basing their data on average responses in animals, and perhaps also because the pharmacologically-induced stereotypies are emotionally neutral.

While it seems clear from the short-term effects of naloxone that endorphins and stereotypies are associated in stressed individuals, there were long-term effects of naloxone treatment which endured well beyond the expected duration of the effectiveness of naloxone. The interruption to sleep/rest during the nights following naloxone and the consequent nocturnal bouts of stereotypy performance were a most striking feature. One possible explanation for the disturbed activity and rest patterns may be that naloxone affects the pituitary-adrenal axis, in particular the circadian rhythm of cortisol release (Barnett et al., 1981a; Becker et al., 1983). The peaks in circulating plasma cortisol levels appear to relate to periods of motor activity in pigs (Barnett et al., 1981b) as well as other species. Data from further investigations in which the stereotypies of sows were interrupted, but without the use of naloxone, detected no such behavioural disruptions in the days following treatment (to be published). Thus, the observed long-term disruption to the behaviour patterns of the sows appears to be due to treatment with naloxone.

The specific approach taken in this experiment, in which a large amount of detailed knowledge was amassed on the behavioural history of each sow, has emphasized the fact that each individual animal performs a unique coping response to stress. In future research great emphasis should be placed on comparisons of physiology and behaviour at the level of the individual. Certainly animal welfare problems, which are individual problems, need this approach.

Throughout this discussion, the role of endorphins in reducing both physical pain and negative emotions (mental pain) has not been mentioned in detail. A sow suffering "pain" is likely to make use of whatever pain-reducing mechanisms are available in order to improve the sensation of well-being. It is tempting to speculate that a major role of endorphins from the pituitary and the brain, respectively, concerns reduction of physical and mental pain. It is feasible therefore that after being tethered for some time, physical pain may dissipate and be reflected in "normal" levels of plasma endorphins and corticosteroids. However, the need for tethered sows to continue performing stereotypies for many hours per day and for much of their adult life time probably indicates that mental pain does not dissipate so readily. Further research on this point is urgently needed.

In conclusion, the results of the present experiment are a first indicator of the potential role of endorphins in the development and performance of stereotypies. Although there appears to be a plausible relationship between brain endorphins and stereotypies there is a clear need to impose other techniques, for example to measure brain endorphin levels, or to investigate the relationship between endorphins and pain perception in tethered sows, to further explore the postulated link between endorphins and stereotypies.

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## References

Amir, S., Brown, Z.W. and Amit, Z., 1980. The role of endorphins in stress: Evidence and speculations. Neurosci. Biobehav. Rev., 4: 77-86.

Baldwin, B.A. and Parrott, R.F., 1984. Effects of naloxone on feeding and drinking in pigs. In: Proc. of the International Congress on Applied Ethology in Farm Animals, 1-4 August 1984, at Kiel, FRG, pp. 382-385.

Barnett, J.L., Cronin, G.M. and Winfield, C.G., 1981a. The effects of individual and group penning of pigs on plasma total and free corticosteroid concentrations and the maximum corticosteroid binding capacity. Gen. Comp. Endocr., 44: 219-225.

Barnett, J.L., Winfield, C.G., Cronin, G.M. and Makin, A.W., 1981b. Effects of photoperiod and feeding on plasma corticosteroid binding capacity in pigs. Aust. J. Biol. Sci., 34: 577-585.

Barnett, J.L., Cronin, G.M., Winfield, C.G. and Dewar, A.M., 1984. The welfare of adult pigs: the effects of five housing treatments on behaviour, plasma corticosteroids and injuries. Applied Animal Behaviour Science, 12: 209-232.

Becker, B.A., Ford, J.J., De Shazer, J.A. and Hahn, G.L., 1983. The effects of tether stalls on the circadian rhythm of cortisol, behavioural activities and estrous response in ovariectomized gilts. In: The Behaviour and Welfare of Farm Animals. Proc. Conference on human-animal bond, 13-14 June 1983, at Minneapolis, Minnesota.

Berger, P.A., Akil, H., Watson, S.J. and Barchas, J.D., 1982. Behavioural pharmacology of the endorphins. Ann. Rev. Med., 33: 397-415.

Berkson, G., 1968. Development of abnormal stereotyped behaviours. Developmental Psychobiology, 1: 118-132.

Cabib, S., Puglisi-Allegra, S. and Oliverio, A., 1984. Chronic stress enhances apomorphine-induced stereotyped behaviour in mice: involvement of endogenous opioids. Brain Research, 298: 138-140.

Cronin, G.M. and Wiepkema, P.R., 1984. An analysis of stereotyped behaviour in tethered sows. Annales de Recherches Vétérinaires, 15: 263-270.

De Koning, R. 1984. Injuries in confined sows. Incidence and relation with behaviour. Ann. Rech. Vét., 15: 205-214.

Dantzer, R. and Mormède, P., 1983. De-arousal properties of stereotyped behaviour: evidence from pituitary-adrenal correlates in pigs. Applied Animal Ethology, 10: 233-244.

Duncan, I.J.H. and Wood-Gush, D.G.M., 1974. The effect of a rauwolfia tranquillizer on stereotyped movements in frustrated domestic fowl. Applied Animal Ethology, 1: 67-76.

Fentress, J.C., 1976. Dynamic boundaries of patterned behaviour: interaction and self-organization. In: P.P.G. Bateson and R.A. Hinde (Editors), Growing Points in Ethology. Cambridge University Press, Cambridge, pp. 135-169.

Fraser, D., 1975. The effect of straw on the behaviour of sows in tether stalls. Anim. Prod., 21: 59-68.

Guillemin, R., Vargo, T., Rossier, J., Minick, S., Ling, N., Rivier, C., Vale, W. and Bloom, F., 1977. β-Endorphin and adrenocorticotrophin are secreted concomitantly by the pituitary gland. Science, 197: 1367-1369.

Hediger, H., 1950. Wild animals in captivity. Butterworths, London, 207 pp.

Holzapfel, M., 1938. Ueber Bewegungsstereotypien bei gehaltenen Säugern. I. Mitt. Bewegungsstereotypien bei Caniden und Hyaena. II. Mitt. Das "Weben" der Pferde. Z. Tierpsychol., 2: 46-72.

Kiley-Worthington, M., 1977. Stereotypies. In: Behavioural Problems of Farm Animals. Oriel Press, Stocksfield, pp. 74-79.

Lewis, M.E., Mishkin, M., Bragin, E., Brown, R.M., Pert, C.B. and Pert, A., 1981. Opiate receptor gradients in monkey cerebral cortex: correspondence with sensory processing hierarchies. Science, 211: 1166-1169.

Morris, D., 1964. The response of animals to a restricted environment. Symp. Zool. Soc. Lond., 13: 99-118.

Nussbaum, S.R., Carr, D.B., Bergland, R.M., Kliman, B., Fisher, J., Reiner, B., Kleshinski, S. and Rosenblaat, M., 1983. Dynamics of cortisol and endorphin responses to graded doses of synthetic ovine CRF in sheep. Endocrinology, 112: 1877-1879.

Ödberg, F.O., 1978. Abnormal behaviours (stereotypies). 1st World Congress on Ethology. Applied to Zootechnics, Editorial Garsi, Madrid, pp. 475-480.

Ödberg, F.O., 1981. Environmental and pharmacological determinants of pathological stereotypies in voles (Clethrionomys glareolus britannicus). Ph.D. thesis, State University of Gent.

Olds, J. and Milner, P., 1984. Positive reinforcement produced by electrical stimulation of septal area and other regions of the rat brain. J. Comp. Physiol. Psychol., 47: 419-427.

Overmier, J.B., Patterson, J. and Wielkiewicz, R.M., 1980. Environmental contingencies as sources of stress in animals. In: S. Levine and H. Ursin (Editors), Coping and Health. Plenum Press, New York and London, pp. 1-38.

Panksepp, J., Herman, B.H., Vilberg, T., Bishop, P. and De Eskinazi, F.G., 1980. Endogenous opioids and social behaviour. Neuroscience and Biobehavioural Rev., 4: 473-487.

Rossier, J., French, E.D., Rivier, C., Ling, N., Guillemin, R. and Bloom, F.E., 1977. Foot-shock induced stress increases β-endorphin levels in blood but not brain. Nature, 270: 618-620.

Sambraus, H.H., 1981. Abnormal behaviour as an indication of immaterial suffering. Int. J. Study Anim. Prob., 2: 245-248.

Stolba, A., Baker, N. and Wood-Gush, D.G.M., 1983. The chracterization of stereotyped behaviour in stalled sows by information redundancy. Behaviour, 87: 157-182.

Thelen, E., 1979. Rhythmical stereotypies in normal human infants. Animal Behaviour, 27: 699-715.

Van Ree, J.M., Smyth, D.G. and Colpaert, F.C., 1979. Dependence creating properties of lipotrophin C-fragment (β-endorphin): evidence for its internal control of behavior. Life Sci., 24: 495-502.

Van Ree, J.M. and De Wied, D., 1983. Behavioral effects of endorphins - modulation of opiate reward by neuropeptides related to pro-opiocortin and neurohypophyseal hormones. In: Smith and Lane (Editors), The Neurobiology of opiate reward processes. Elsevier Biomedical Press, Amsterdam, pp. 109-145.

Wiepkema, P.R., Broom, D.M., Duncan, I.J.H. and Van Putten, G., 1983. Abnormal behaviours in farm animals. A report of the Commission of the European Communities, Autumn, 1983.

Wolff, P.H., 1968. Stereotypic behaviour and development. The Canadian Psychologist, 9: 474-484.

Wood-Gush, D.G.M., Duncan, I.J.H. and Fraser, D., 1975. Social stress and welfare problems in agricultural animals. In: E.S.E. Hafez (Editor). The Behaviour of Domestic Animals, Baillière Tindall, London, pp. 182-200.

## CHAPTER 5

# THE DEVELOPMENT AND SIGNIFICANCE OF ABNORMAL STEREOTYPED BEHAVIOURS IN TETHERED SOWS

## STEREOTYPY PERFORMANCE CHARACTERISTICS OF TETHERED SOWS IN A COMMERCIAL HERD AND THE RELATIONSHIP TO SOW WELFARE AND PRODUCTIVITY

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## Abstract

The behaviour of 117 non-lactating sows in 6 parities (1 to 6) was surveyed in a commercial herd. Some sows were observed on more than one observation day, i.e. in different parities or pregnancy stages of the same parity, making a total of 178 sow observations. Sows were 1) observed between 10.00 and 14.00 h to determine the quantitative and qualitative characteristics of stereotypies performed, and 2) tested for their response to novel stimulation.

Low parity number sows tended to perform environment-directed (ED) stereotypies whereas high parity number sows performed mostly self-directed (SD) stereotypies. It was suggested that ED stereotypies developed as a result of tether restraint, but as sows adapted they altered their stereotypies to SD in the face of habituation to a monotonous environment.

There was large between-sow variation in the performance of stereotypies, even within parity x pregnancy stage groups. Within groups, sows were classed as either HIGH or LOW stereotypers if they performed greater or less than the mean group performance level. At the farrowing before observation, sows classed as HIGH stereotypers produced larger litters in parities 2 and 3 but smaller litters in parities 5 and 6 than LOW sows. At the farrowing after observation, HIGH stereotypers tended to produce smaller litters in parities 5 and 6 than LOW stereotypers.

In response to novel stimulation, the HIGH sows tended to be more attentive and were faster to react than LOW stereotypers. The responsiveness of sows (level of interest and fearfulness shown) are discussed in conjunction with the survey results to interpret the effect of adaptation to tethering in relation to litter size and welfare of tethered sows.

The study concludes that sows may be subject to chronic stress for at least 3 parities before adapting to tether housing.

## Introduction

Pig housing has changed rapidly in recent years towards systems of high capital investment, low labour requirement and minimalization of floor area per animal. The current European situation for the housing of breeding sows during pregnancy has been outlined by Daelemans (1984). Briefly, pregnant sows are commonly housed in individual stalls, with no access to bedding material and limited possibility to perform exercise, and comfortive and social behaviours. Many sows, in addition, are physically restrained by neck- or girth-tethers in partial stalls. Feed is provided in highly concentrated form either once or twice per day, and access to water may be similarly restricted.

Breeding sows subjected to these conditions in the long-term commonly develop abnormal stereotyped behaviours (stereotypies). Stereotypies are defined by Ödberg (1978) as morphologically identical movements which are regularly repeated and seemingly purposeless. It is apparent that stereotypies develop out of adverse situations, for example, situations involving long-term loss of control and, or physical pain. Dogs, monkeys and chimpanzees (see review by Hutt and Hutt, 1970) and pigs (Hutton, 1983) reared in isolation for various periods of time after birth, commonly developed stereotypies. In the rat (Maier, 1949) and hen (Duncan and Wood-Gush, 1974), frustration in the face of insoluble problems led to the development of stereotypies, which for many animals persisted even after the problem became soluble. Antelman and Szechtman (1975) have demonstrated that stereotypies also develop in rats in response to intermittent pain (tail pinch), and Dantzer and Mormède (1981) reported the development of chain-pulling stereotypies in pigs subjected to feeding on a fixed-interval schedule.

It has been demonstrated in humans (e.g. Hutt and Hutt, 1970) and is suggested for animals (e.g. Kiley-Worthington, 1977; Davenport, 1979), that stereotypies are performed in two seemingly opposed situations: under- and over-stimulation. Frankenhaeuser (1976) reported that both under- and over-stimulation induced an increase in catecholamine secretion compared with a "medium" input level in an "ordinary" environment. This author placed strong emphasis on the importance of controllability as a determinant of stress. Controllability was in fact more important as a determinant of stress than the duration of stress. Thus it is not unexpected to find that the performance of stereotypies, which developed out of chronic stress situations, to be in some way effective in reducing stress.

Dantzer and Mormède (1983) present evidence that the performance of stereotypies in pigs reduces "stress", as measured via blood corticosteroid levels. More recently, Cronin, Wiepkema and Hofstede (1985a) and Cronin, Wiepkema and van Ree (1985b) have hypothesized that under chronic stress situations (tethering), sows experience a significant increase in the release of endorphins. Consequently, sows associate the subsequent feeling of improved well-being with the performance of redirected, aggressive-like acts. Because the chronic stress situation remains for tethered sows in the long-term, the sows learn to perform these acts in order to self-stimulate the release of endorphins, and thus stereotypies are formed. The point in time when tethered sows no longer perceive chronic stress is unknown. Neither is it known whether they ever reach such a point.

Stress indicates the state of an organism that 1) suddenly experiences a strong decrease in the level of predictability and, or controllability of environmental changes (acute stress) or 2) a long-lasting low predictability and, or controllability of environmental changes (chronic stress) (Wiepkema, 1985; Wiepkema and Cronin, 1985). Studies aimed at measuring stress responses in tethered pigs have produced consistent results, that is, that tethering is stressful (Becker, Ford, De Shazer and Hahn, 1984; Barnett, Cronin, Winfield and Dewar, 1984; Štuhec, Schlichting, Smidt and Unshelm, 1984; Barnett, Winfield, Cronin, Hemsworth and Dewar, 1985). However, the actual way in which animals cope seems to be influenced by factors such as physiological state (pregnant or not- pregnant), individual capabilities and age at tethering, amongst others. The approaches taken by the above-mentioned authors were in all cases multi-disciplinary, although primary significance was placed on physiological correlates of stress response vis. adrenal function. We must take into account that "chronic" behavioural responses to stress are also indicative of chronic stress. A multi-disciplinary approach to the study of adaptation to stress, as advocated for instance by Corson and Corson (1976), is self-evident.

That the occurrence of disturbed or abnormal behaviours in animals is indicative of some underlying pathological condition or welfare problem is widely accepted. In the sow, recent studies by Sambraus and Schunke (1982), Stolba, Baker and Wood-Gush (1983), Blackshaw and McVeigh (1984), Broom and Potter (1984), Cronin and Wiepkema (1984) and Rushen (1984) provide evidence that stereotypies occur in a high proportion of tethered and individually-housed sows. Furthermore, Cronin et al. (1985a) have described in detail the manner in which stereotypies develop in sows after tethering. These authors conclude that stereotypies develop out of chronic stress situations.

With the exception of the study by Stolba et al. (1983), other investigations of the behaviours performed by tethered sows have involved relatively small numbers of animals. While this is a common consequence when studying the behaviour of individual sows in fine detail, there are always doubts whether the situation under study is representative of that in commercial herds. Thus there is a clear need to survey the behaviour of a large number of tethered sows in a commercial situation. Furthermore, it is important to carry out this survey in a stratified manner, so that the characteristics of performance level and morphology of stereotypes recorded can be better interpreted in relation to stage of adaptation to tethering.

Compared with less-restrictive housing systems, tethering is reported to result in a higher proportion of sows showing neck lesions (De Koning, 1984), to have adverse effects on sow farrowing performance (Vestergaard, 1984) and to be associated with the development of new pathological conditions such as urogenital problems (Tillon and Madec, 1984). Cariolet and Dantzer (1984) postulate the link between tethering and the thin-sow syndrome. On the basis that tethering is stressful therefore, it should be possible to detect effects on the productivity of sows: between sows that are "coping" versus "non-coping".

The aims of the present experiment were to survey a large number of tethered sows in order to determine whether sows in a typical commercial situation perform stereotypies. Since it is likely that variation will exist, for example, in the levels of stereotypy performance, the second aim was to relate the possible variation to production parameters. Thirdly, since it is known that stereotypy performance is related to reduced attentiveness and, or fearfulness, we wanted to describe the relationship between stereotypy performance variation and attentiveness and fearfulness. In this way we may gain a better understanding of the relevance of disturbed behaviour to production and welfare in sows.

## Material and Methods

This study was performed at a semi-commercial research piggery in the Netherlands between November 1982 and February 1984. The pigs observed in the study were mainly Large White (LW) x Dutch Landrace (DR) crossbred sows. About one-half of the parity 1 and 10% of parity 2 sows included in the study were Duroc (D) x DL crossbreds, respectively. Nulliparous female pigs (gilts) were not observed.

The management of the sows was similar to that practised on Dutch commercial pig breeding farms. Gilts were selected at 6 months of age to enter the breeding herd. At this time they were allotted to receive either "normal" or "special" sow diet. Apart from lactation periods, when all sows were fed normal diet, sows received their specified diet at all other times. The normal diet consisted of commercial breeder sow diet. The special diet was based on the normal diet but with the addition of extra roughage in the form of lucerne. Since the roughage levels differed (normal = 6.5 and special = 8.9%), the special- diet sows were fed an extra 0.25 kg of diet per day. It had been determined that protein and energy levels fed to the sows in the 2 diet treatments were then equivalent.

From 8 months of age, oestrous gilts were artificially inseminated with semen from boars of the regional A.I. centre. Gilts not inseminated by nine months of age received up to 2 treatments (2 weeks apart) of a combination of pregnant mare serum gonadotrophin (PMSG) and human chorionic gonadotrophin (HCG) (400 i.u. FSH and 200 i.u. LH, "PG 600", Intervet) to stimulate the onset of oestrus. Gilts that were still not inseminated were culled. Similarly, animals that exhibited leg weakness at any time were also culled.

About 1 month prior to the first farrowing, pregnant gilts were taken from their group pens and placed in individual stalls. Although the gilts could not "escape" from these stalls, neck tethers were fitted to the gilts. In this way gilts could become accustomed to restraint and to wearing a collar. Shortly before farrowing, gilts (and sows) were tethered in farrowing crates (girth or neck tethers). Farrowings tended to occur in batches. Litter sizes were standardized by fostering piglets away from sows with larger litters and onto sows with smaller litters.

Litters were suckled for about 35 days. Weaning occurred on Wednesdays, when the sows were transferred to individual stalls near to a mature boar. Sows not detected in oestrus within 10 days of weaning were treated with PG 600. After 14 days from treatment a second dose was injected if necessary. Non-responding sows were culled.

Sows that expressed oestrus and were then artificially inseminated were moved to the dry sow room (DSR) and were neck tethered in partial stalls. The floor in the area that the sows stood was solid concrete, but was slatted behind the sows. Sow stalls were 85 cm wide, with horizontal side bars and a solid pressed-cement front panel above a continuous trough. The tether chain was attached to a locking device between the 2 lowest bars on one side of the tether stall. There was a total of 66 tether stalls positioned "back to back" in the DSR.

Feed-holding bins were attached to the outside of the solid front panel of each tether stall so that feed could be automatically dropped into many sows' troughs at the one time. A single herdsman thus fed all sows in rapid succession, then refilled the holding bins for the next day. Sows were fed pelleted diets at about 07.45 h daily. Water was available from nipple drinkers located at the base of the front panel and above the feed trough during 2, one-hour periods per day from 09.00 and 17.00 h. Sows in the diet classes "normal" and "special" received 2.75 and 3.0 kg of feed per day, respectively. No straw or other substrate was available to the sows. The DSR was heated in cold weather, and the mean maximum DSR temperature on observation days was 19.8°C (s.d. = 2.8). Natural light entered the DSR through a large window at one end of the room and through roof "sky lights".

### Behaviour observations

In contrast to Sambraus and Schunke (1982), the results of Broom and Potter (1984) and unpublished data from our own research piggery indicated that stereotypy performance of tethered sows was unaffected by the presence of a passive human observer. This was most likely since in the latter studies the sows did not associate the human with feeding. In the present experiment the observer entered the DSR about 20 min before the commencement of observations. At that time most sows were still busy drinking. For identification purposes, the appropriate sow stalls were marked by a numbered card. During the observations, the observer stood quietly in the aisle before the sow stalls but 2 to 3 m to one side of the relevant sow.

Four sows were observed on each of the 45 observations days of the experiment. The complete behaviour of individual sows was continuously recorded in turn during 5 out of every 20 min between 10.00 and 14.00 h. After 7 such "rotations", a 20-min pause was taken. In all, each sow was observed for a total of 11, five-min trials per observation day (for further details see Cronin and Wiepkema, 1984). An OS-3 event recorder (Observational Systems Inc., Seattle, Washington) was used to store the sequence and duration of coded behaviours entered by the observer. The postures, actions and substrates utilized by sows, that together were considered to comprise behaviours, have been listed elsewhere (see Cronin et al., 1985a).

The behavioural records of each sow were examined to identify the existence of stereotyped sequences of behaviour, including single behaviours performed continuously. All sequences that appeared functional (e.g. resting, dunging, etc.) were removed from the data. The proportion of observation time that stereotypies were performed, and the number and morphology of different stereotypes, were determined for each individual sow.

### Novel object response test

Following the completion of the behaviour observations each day, the 4 sows in turn were tested for their responses to a novel object (NO). The NO was as 36 x 36 cm piece of plywood with concentric green, yellow, red and blue rings painted on one surface. Prior to the test, the observer noted whether the sow was active and which posture it occupied. The NO was then slowly placed against the inside surface of the tether-stall's front panel and lightly tapped against the panel. If a sow showed little or no response the tapping was repeated every 30 sec. During the test the observer recorded the behaviour of the sow and her response to the test situation. The test was terminated when the sow touched the NO or 2 min had elapsed. The latency time to touch the NO was also recorded.

Sows were classed according to the level of apparent interest shown in the NO: sows that exhibited little or no interest were considered to be disinterested. Secondly, the sows that showed responses other than disinterest were classified according to the apparent level of fearfulness expressed. Classes of fearfulness were: very-, moderately-, slightly- and not-fearful. These categories were formed on the basis of behavioural disposition of the sows during the test. Very-fearful pigs were recognized by their vigorous and usually sustained withdrawl from the NO, which was accompanied by retraction of the ears and widening of the eyelids. Groans or screams were occasionally emitted. Not-fearful pigs readily approached the NO which they investigated along with the experimenter's hand if presented.

### Animals

The behaviour of tethered sows experiencing their second to seventh pregnancy was recorded while the sows were housed in the DSR. Each sow was classified by its parity and stage of pregnancy. On average sows spend about 105 days tethered in the DSR each pregnancy (after the first), and this time was divided into 5 periods of 20 days. Sows for observation within the 6 parities (1 to 6) were distributed as evenly as possible across the 5 time periods.

Under the batch-handling system operative at the study piggery, recently inseminated sows were brought into the DSR on Thursdays. Thus there is an expected relationship between time spent tethered in the current pregnancy and days since insemination for sows that did not return to oestrus. In order that this relationship was not disrupted, sows that had returned to oestrus in the current tethering period were not observed in that parity.

While it would have been more balanced to observe an equal number of sows in each of the 6 parity groups, the uneven proportions of sows per parity in the herd implied that markedly fewer older sows were available for observation. Thus, observations were concentrated on sows in parity 1 to 4. Furthermore, in order to investigate the changes within individual sows over time, about one-quarter of the sows in parities 1 to 4 were observed for a second time in the subsequent parity. Within parities, sows were chosen at random and in advance from available sows.

### Sow productivity

Parameters that contribute to sow productivity include the number of piglets born and weaned, and the number of litters per year. Production data of sows in the present study were examined from the litter immediately before, and the litter after, behaviour observation. The general details of production of the sows are shown in Table 1.

TABLE 1. Productivity data of the sows included in the present experiment in the litter immediately before, and after, observation. Values shown for litter sizes are means per sow (plus standard errors).

| Parameter | Litter number | | | | | | |
|---|---|---|---|---|---|---|---|
| | 1 | 2 | 3 | 4 | 5 | 6 | 7 |
| Number of sows | 36 | 60 | 60 | 56 | 40 | 31 | 12 |
| Piglet production: | | | | | | | |
| Litter size 1) birth - total piglets | 10.23(0.38) | 11.56(0.39) | 12.28(0.41) | 12.88(0.40) | 12.53(0.46) | 12.06(0.56) | 13.25(0.87) |
| - live piglets | 9.69(0.35) | 11.08(0.38) | 11.70(0.39) | 12.34(0.38) | 11.88(0.45) | 11.00(0.55) | 12.50(0.77) |
| 2) weaning - live piglets | 9.40(0.31) | 10.02(0.23) | 9.92(0.20) | 9.86(0.20) | 9.51(0.24) | 9.80(0.26) | 10.09(0.39) |
| Piglet losses: | | | | | | | |
| % of litters | | | | | | | |
| 1) containing still born piglets | 25.7 | 33.3 | 35.0 | 35.7 | 47.5 | 61.9 | 33.3 |
| 2) in which live piglets died preweaning | 48.6 | 65.0 | 73.3 | 83.9 | 76.9 | 83.3 | 90.9 |
| 3) in which deaths occurred due to crushing | 31.4 | 31.7 | 43.3 | 57.1 | 46.2 | 50.0 | 45.5 |
| % of live-born piglets that died preweaning | 10.11 | 11.22 | 12.48 | 16.99 | 17.11 | 15.27 | 16.40 |
| % of preweaning deaths due to crushing by sow | 35.6 | 75.0 | 43.0 | 47.8 | 48.0 | 39.6 | 52.4 |
| Delayed oestrus: | | | | | | | |
| PG 600 use (% of sows) | 5.7 | 33.9 | 10.0 | 1.8 | 5.0 | 3.2 | 0 |

Data of farrowing rates (i.e. the proportion of inseminated sows that farrowed) are not shown, since sows that returned to oestrus prior to observation were not included in the study. Of the 36 sows observed in pregnancy stage 1 (1 to 20 days after insemination) only 2 animals subsequently returned to oestrus. The proportion of animals treated with PG 600 "per litter number" refers to the frequency of usage of the hormone preparation prior to the insemination which resulted in piglets born for that particular litter number. These data are included as they provide some indication of delay in the onset of oestrus, i.e. gilts failing to reach puberty by 9 months of age and sows exhibiting a weaning to remating interval of greater than 10 days, amongst animals that were not culled.

In addition, it is important to realize that the sows were selected throughout their life time on the basis of production parameters, or rather were culled for low production (potential). The 2 main reasons for culling sows in this herd during 1983 were infertility (anoestrus) and leg weakness. About 27, 24 and 21% of sows were culled following the weaning of their 1st, 2nd and 3rd litters, respectively. Due to these high culling proportions, about 45% of all sows were replaced during 1983 and the distribution of sows by parity number in the herd was heavily biassed towards the low parities. Thus comparisons between young and old sows, for example, must be made with some caution.

### Statistical analysis.

As mentioned earlier, a number of sows were observed in more than one parity (see Table 2). In addition, due to the low number of sows in parities 5 and 6, some of these sows were observed in different pregnancy stages of the same parity. This was done to ensure that sows were represented in all parity x pregnancy stage groups. Thus, in recognizing these peculiarities of the data, statistical comparisons between parities were restricted to independent data of sows in parities 1 to 4, inclusive. To achieve this, data from sows observed in one of the successive parities were omitted at random. Data of sows observed in more than one parity, but where a complete pregnancy separated the observations (e.g. sows observed in parity 2 and 4) were assumed to be independent.

TABLE 2. The number of sows observed per parity, the proportion of sows observed in subsequent parities, and the proportion of these sows that changed their class of stereotypy performance level between the successive parities (i.e. HIGH ⇄ LOW).

| | Parity number | | | | | | |
|---|---|---|---|---|---|---|---|
| Parameter | 1 | 2 | 3 | 4 | 5 | 6 | All |
| Number of sows | 36 | 35 | 36 | 29 | 27 | 15 | 178 |
| Sows/parity also observed in the next parity (%) | 22.2 | 28.6 | 19.4 | 31.0 | 6.9 | - | 22.1 |
| Sows that changed class (%) | 62.5 | 50.0 | 14.3 | 44.4 | 0 | - | 44.7 |
| | x | | | y | | | |

Within rows, x, y denote suggestive difference P < 0.1.

Parity x pregnancy stage data were not analysed due to the large within- group variation. The data for stereotypy performance time and number of stereotypies per sow were analysed by ANOVA for parity (1 to 4) effects on untransformed or log-transformed data. Significant differences between means were determined by Student-Newman-Keuls test for least significant range (Sokal and Rohlf, 1969). The data for litter size within parity, and response time in the novel object test, were analysed by Student's t-tests for effects of stereotypy performance level. The relationship between litter sizes of sows in successive parities was tested by correlation analysis. Frequency data were analysed by chi-square tests.

## Results

A total of 117 different tethered sows were observed in this experiment. The behaviour of 67, 40, 7 and 3 sows were recorded on 1, 2, 3 and 4 observation days, respectively. With the exception of some parity 5 and 6 sows, individual sows were only observed once per parity. Data of two parity 4 sows were omitted as the sows were found to be lame following observation, and were being treated with analgesic drugs.

Behaviour observations

- Stereotypy performance characteristics

All sows recorded in the present experiment were found to perform repetitive, seemingly non-functional behaviours (stereotypies). The proportion of observation time that sows performed stereotypies was highly variable between sows: mean = 43.6% (s.d. = 31.5). The minimum and maximum recorded values were 0.5 and 99.6%, respectively. Figure 1 shows the frequency distribution of sows in relation to the proportion of observation time spent stereotyping.

Both parity number and pregnancy stage appeared to influence the mean proportion of observation time that sows stereotyped. Mean values for sows in the 6 parities (1 to 6) and 5 pregnancy stages (1 to 5) are shown in Figure2. It would be extremely useful to also have some idea of how much stereotypy behaviour these sows performed per 24 h. Thus the estimated performance time per 24 h is also indicated on the figure. The relationship between the proportions of time spent stereotyping, during 24 h (y-axis) and during the 4 h period between 10.00 to 14.00 h (x-axis) of the same day, was calculated from 24 h time-lapse video records of 20 tethered sows. These sows were housed in our research facility in Wageningen, and were husbanded in a similar manner to the sows described in the present experiment. The equation for the above-mentioned relationship is:

$$y = 2.54x^{0.62};\ R^2 = 0.88,\ n = 20,\ P < 0.01.$$

The mean proportion of observation time that sows in the 6 parity groups performed stereotypies is shown in Figure 3. Parity 1 sows stereotyped significantly less ($P < 0.01$) than parities 2 to 4 during observation times. Parity 2 sows, however, spent a significantly greater ($P < 0.01$) proportion of observation time stereotyping than parities 1, 3 and 4.

Most sows were recorded to perform more than one morphologically different stereotypy routine during the 11, five-min observation trials per sow. However, many of the routines were in fact subroutines of larger stereotypies as previously described by Cronin and Wiepkema (1984) for tethered sows in the same herd. On average, the 178 sows performed 1.62 (s.d. = 0.70; range = 1 to 3) stereotypies that were considered to be distinctly different on the bases of action(s) performed and substrate(s) utilized. Parity 1 sows performed significantly more ($P < 0.01$)

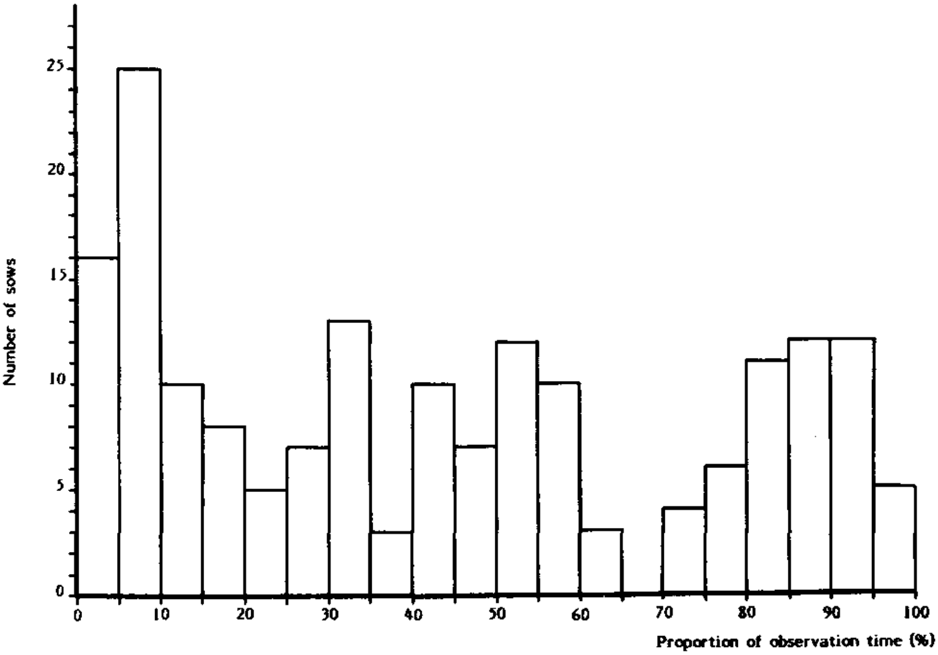

Fig. 1. Frequency distribution of sows performing stereotypies for different proportions of the observation time.

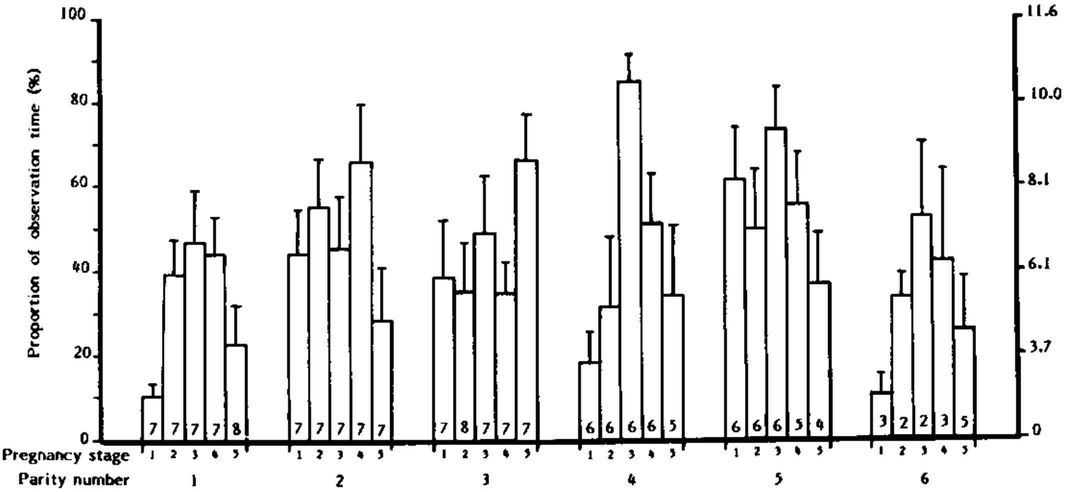

Fig. 2. The proportion of observation time, and the estimated time per 24 h, that sows in different parities and stages of pregnancy performed stereotypies. Values shown are mean percentages plus standard errors. The number of sows per parity-pregnancy stage group is indicated within the columns.

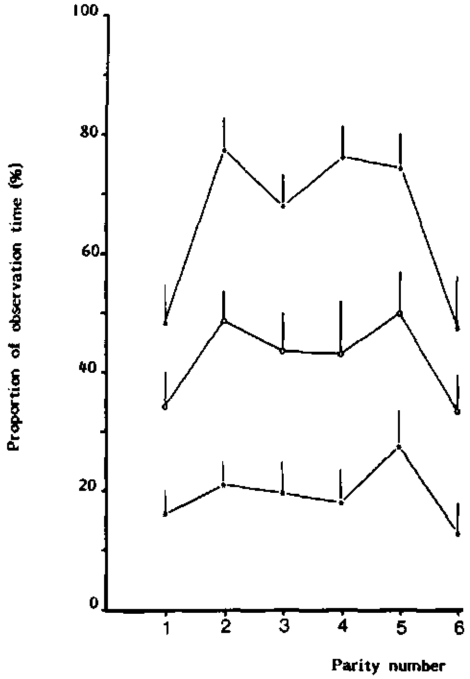

Fig. 3. The proportion of observation time that sows in the 6 parity groups performed stereotypies (open circles). The upper and lower lines (indicated by asterisks) refer to HIGH and LOW stereotypers, respectively. The values shown are mean percentages plus standard errors.

TABLE 3. Characteristics of the stereotypes of sows in the 6 parity groups.

| | Parity number | | | | | | |
|---|---|---|---|---|---|---|---|
| Parameter | 1 | 2 | 3 | 4 | 5 | 6 | All |
| Mean number of stereotypes/sow[1] | 1.97 | 1.60 | 1.53 | 1.55 | 1.48 | 1.47 | 1.62 |
| | a | | b | | | | |
| % of sows that performed stereotypes directed at | | | | | | | |
| 1) self (SD) | 36.1 | 57.1 | 61.1 | 41.4 | 48.1 | 66.7 | 50.6 |
| 2) environment (ED) | 8.3 | 11.4 | 8.3 | 13.8 | 14.8 | 0 | 10.1 |
| 3) both SD and ED | 55.6 | 31.4 | 30.6 | 44.8 | 37.0 | 33.3 | 39.3 |
| % of ED stereotypes primarily directed at | | | | | | | |
| 1) tether chain | 87.5 | 66.7 | 56.2 | 33.3 | 33.3 | 14.7 | 53.8 |
| 2) bars/trough front | 4.2 | 22.2 | 18.8 | 38.1 | 38.9 | 42.9 | 25.0 |
| 3) floor | 8.3 | 11.1 | 25.0 | 28.6 | 27.8 | 42.9 | 21.2 |
| Mean number of different postures recorded/sow whilst stereotyping | 1.3 | 1.5 | 1.2 | 1.3 | 1.4 | 1.8 | 1.4 |
| % of stereotypes performed by sows | | | | | | | |
| whilst 1) standing | 19.1 | 28.8 | 31.1 | 37.8 | 36.8 | 22.2 | 29.3 |
| 2) sitting | 10.6 | 5.8 | 11.1 | 13.5 | 21.1 | 22.2 | 13.0 |
| 3) belly lying | 59.6 | 46.2 | 51.2 | 35.1 | 39.5 | 33.3 | 45.5 |
| 4) other lying | 10.7 | 19.2 | 6.6 | 13.6 | 2.6 | 22.2 | 12.2 |

[1] Statistics performed on log-transformed data. Within rows, a, b denotes significant difference $P < 0.01$.

distinctly different stereotypies than sows in partities 2 to 4. The difference between the means of parity 2 and 4 sows was also significant ($P < 0.05$). The mean values (plus s.e.) for sows in all parities are shown in Table 3.

The morphology of the stereotypies of the sows varied widely. Sources of variation included differences in stereotypy components (the choice of actions performed on substrates), individual mannerisms of technique, rate of action and location of performance, and the sequence of components linked to form the stereotypy.

Of actions that were performed without contact with the sows' external physical environment (sham actions), 10 types of action were recorded. Most of these actions were described by Cronin and Wiepkema (1984). Only 3 sows in the present experiment did not perform sham chewing as a stereotypy component. On average, sows performed 2.17 different sham actions in stereotyped sequences.

Stereotypy components that involved actions in which the sow manipulated or contacted features of the external, physical environment were termed environment-directed (ED) components. On the basis of type of substrate(s) utilized by sows in the performance of their complete stereotypes, stereotypies were classified according to whether they were formed of purely sham components (i.e. self-directed = SD stereotypies), or contained ED components. About one- half (50.6%) of sows performed only SD stereotypies. Other sows (39.3%) performed both SD and ED stereotypies, and 10.1% of sows performed only ED stereotypies during observation times. The majority of ED stereotypies also contained some sham components. From parity 1 to 3 the proportion of sows that performed only SD stereotypies increased but in the subsequent parity decreased. The association between parity (1 to 4) and the proportion of sows that performed only SD stereotypies approached significance ( $\chi^2_3 = 7.83$, $P < 0.1$). Table 3 shows the fluctuation in the proportion of sows over the 6 parities that performed SD, ED and SD + ED stereotypies.

Of stereotypies that were ED, 3 main substrates were utilized by sows: tether chain, bars and floor. In Table 3 the proportions of ED stereotypies performed by sows of different parity number are shown in relation to the principle substrate. There was a significant association between the proportion of ED stereotypies directed at the tether, bars and floor and parity 1 to 4 sows ( $\chi^2_3 = 12.27$, $P < 0.01$). Amongst parity 1 sows that performed ED stereotypies, 87.5% of the behaviours were directed at the tether chain. As parity number increased, the proportion of tether-directed stereotypies decreased while the proportions of bar- and floor-directed stereotypies increased (see Table 3).

The types of actions performed on particular substrates were consistent across parity number. The most commonly-associated actions and substrates were: chewing and, or nosing the tether chain; nibbling, rooting or licking the bars; and rooting or licking the floor.

Sows performed the majority of stereotypies while occupying a lying posture. Of the 3 recorded variations of lying posture: belly-lying, side-lying and postures in between these, belly lying was most common (see Table 3). There was no significant association between the occurrence of stereotyping in sows of parity 1 to 4 and posture. About one-half of sows performed the same stereotypy in two postures, e.g. sitting and standing, or standing and belly lying.

Stereotypy performance classification.

As mentioned previously, there was a large between-sow variation in the level of stereotypy performance recorded for sows within parity x pregnancy stage groups. Within groups, sows were classified according to whether they stereotyped for more or less than the mean time. The sows are thus referred to as HIGH and LOW performers, respectively. Figure 3 shows the mean proportions of observation time (plus s.e.) that sows in the HIGH and LOW categories performed stereotypies in relation to parity number.

There were no associations between the breed of sows (LW x DL or D x DL), nor the diet provided for sows (normal or special roughage level), and the proportions of sows that were classed as HIGH or LOW stereotypers. There was however, an association between parity number and the proportion of sows observed in successive parities that changed their classification between observations. Sows observed in the successive parities 1-2 and 2-3 were suggestively less stable, in that 55.6% of the sows changed class,i.e. were recorded as HIGH in one parity and LOW in the next or vice versa, compared with 27.8% of sows in other parities ( $\chi^2_1$ = 2.86, $P < 0.1$). The proportions of sows that changed class between observation in one parity and the next are shown in Table 2.

- Measurement of interest level and fearfulness in the novel object test

Twenty-one percent of sows expressed little or no interest during the novel object (NO) test and did not touch the NO. While the occurrence of DISINTEREST was not associated with parity numbers 1 to 4 ( $\chi^2_3$ = 2.91, NS), there was a significant association with stereotypy performance level. The proportion of sows recorded to be DISINTERESTED during the NO test was lower amongst HIGH than LOW sows ( $\chi^2_1$ = 6.94, $P < 0.01$; 13.3 and 29.5%, respectively). Almost all DISINTERESTED sows were recorded to occupy a lying posture at the commencement of the test.

TABLE 4. Piglet production and losses by sows observed in parities 1 to 6 - classification of sows by level of stereotypy performance and the production of the sows at the previous litter.
(H = HIGH and L = LOW stereotypy performance level).

| Parity when sow was observed | 1 | | 2 | | 3 | | 4 | | 5 | | 6 | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Litter number | 1 | | 2 | | 3 | | 4 | | 5 | | 6 | |
| Stereotypy performance level | H | L | H | L | H | L | H | L | H | L | H | L |
| Number of sows | 16 | 20 | 17 | 18 | 19 | 17 | 14 | 15 | 12 | 9 | 6 | 6 |
| Piglets born/sow | 10.19 | 10.26 | 13.00 | 10.89 | 12.74 | 11.65 | 12.21 | 12.07 | 12.42 | 13.33 | 11.33 | 14.00 |
| t-value | -0.10 | | 2.11* | | 1.10 | | 0.11 | | -0.77 | | -1.64 | |
| Piglets weaned/sow | 9.31 | 9.47 | 10.00 | 9.89 | 10.53 | 9.76 | 10.14 | 9.78 | 9.83 | 9.67 | 10.50 | 9.50 |
| t-value | -0.26 | | 0.20 | | 1.78 | | 0.60 | | 0.26 | | 1.33 | |
| Preweaning deaths of live-born piglets (%) | 8.02 | 11.76 | 12.37 | 13.59 | 12.33 | 13.68 | 12.34 | 13.84 | 16.90 | 17.14 | 10.00 | 18.60 |
| $\chi^2_1$ value | 2.42 | | 0.13 | | 0.17 | | 0.16 | | 0.00 | | 2.10 | |

Asterisk indicates significant difference $P < 0.05$.

TABLE 5. Piglet production and losses by sows observed in parities 1 to 6 - the effect of level of stereotypy performance by sows on productivity at the subsequent litter. (H = HIGH and L = LOW stereotypy performance level).

| Parity when sow was observed | 1 | | 2 | | 3 | | 4 | | 5 | | 6 | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Litter number | 2 | | 3 | | 4 | | 5 | | 6 | | 7 | |
| Stereotypy performance level | H | L | H | L | H | L | H | L | H | L | H | L |
| Number of sows | 15 | 19 | 17 | 17 | 19 | 17 | 14 | 15 | 12 | 9 | 6 | 6 |
| Piglets born/sow | 10.40 | 11.61 | 12.29 | 12.23 | 13.10 | 13.43 | 11.79 | 12.93 | 11.84 | 12.00 | 11.67 | 14.83 |
| t-value | -1.12 | | 0.05 | | -0.40 | | -0.98 | | -0.12 | | -2.07* | |
| Piglets weaned/sow | 9.87 | 10.16 | 9.59 | 10.59 | 9.79 | 9.69 | 9.29 | 9.38 | 10.17 | 9.25 | 10.20 | 10.00 |
| t-value | -0.42 | | -1.76 | | 0.20 | | -0.19 | | 1.36 | | 0.24 | |
| Preweaning deaths of live-born piglets (%) | 10.08 | 12.90 | 12.83 | 12.20 | 18.78 | 20.10 | 18.24 | 18.12 | 12.23 | 19.57 | 21.67 | 11.76 |
| $\chi^2_1$ value | 0.36 | | 0.04 | | 0.12 | | 0.00 | | 2.32 | | 2.28 | |

Of the 140 sows that showed responses other than DISINTEREST, most touched the NO within the 2-min test time, while others sniffed at the NO from a distance or actively avoided contact. All these sows were classed as INTERESTED whether they touched the NO or not. There was no effect of posture nor activity performed immediately prior to the test on the subsequent type or latency of response by sows.

INTERESTED sows were further classified according to their apparent level of fearfulness expressed during the test: very- and moderately-fearful sows = FEARFUL and slightly- and not-fearful sows = NON FEARFUL, respectively. Parity 1 and 2 sows were more, but not significantly more, likely to be FEARFUL than parity 3 and 4 sows ($\chi^2_1 = 3.37$, $P < 0.1$; 34.5 and 18.9% of sows, respectively). FEARFUL sows were less likely to touch the NO than NON FEARFUL sows ($\chi^2_1 = 234.1$, $P < 0.001$; 10.5 and 68.6% of FEARFUL and NON FEARFUL sows, respectively, touched the NO). While there was no general association between apparent fearfulness and level of stereotypy performance by sows in parities 1 to 4, FEARFUL sows in parity 1 tended to be LOW stereotypers (7 of 10 sows) but in parity 2 tended to be HIGH stereotypers (6 of 9 sows).

Of the 105 sows that touched the NO during the 2-min. test period, a significantly higher proportion were HIGH than LOW sows ($\chi^2_1 = 6.79$, $P < 0.01$; 72.7 and 50.7%, respectively). This may have been due in part to the HIGH sows being more active or less fearful animals (in some parities). After removing data of FEARFUL sows, there was a significant difference in the time taken by HIGH and LOW sows in parities 1 to 4 to touch the NO ($t = -2.27$, $P < 0.05$, $n = 62$; 11.7 (s.d. = 16.4) and 22.6 (s.d. = 23.3) sec, respectively).

Most of the 35 FEARFUL sows failed to touch the NO. Eight main behavioural responses to the test situation were recorded, with about one-half of the sows performing more than one response. Most commonly, sows avoided eye-contact with the NO by inclining their heads downwards or turning sideways and, or pressing the snout between the bars. This occurred for 31.0% of responses. The remaining responses in order of decreasing frequency and with indication of the percent occurrence were: attempted escape (22.4%), apparently faster stereotypy performance (17.2%), distress vocalizations (10.3%), immobility (6.9%) and redirected aggression/displacement acts (6.9%). The few sows that touched the NO did so in a "hit and run" fashion (5.2% of responses).

Sow productivity and stereotypy performance level

- Production at the litter prior to observation

In Table 4 the mean litter sizes (plus s.e.) of HIGH and LOW sows are shown over litters 1 to 6. While there was no difference in the mean litter size of sows at the 1st and 4th litters, HIGH sows tended to produce larger 2nd and 3rd litters but smaller 5th and 6th litters than LOW sows. The difference at the 2nd litter was significant ($t = 2.11$, $P < 0.05$, $n = 35$; 13.00 and 10.89 piglets born (alive and dead) per sow). Although a greater proportion of HIGH than LOW sows gave birth to stillborn piglets in parities 1 to 4 ($\chi^2_1 = 2.93$, $P < 0.1$; 47.4 and 31.5% of sows, respectively), this was probably due to the larger litter sizes produced by HIGH sows at the 2nd and 3rd farrowings. There were no significant differences in the mean number of stillborn piglets per litter of HIGH and LOW sows in parities 1 to 4.

Litter sizes were standardized after farrowing; piglets were fostered away from larger litters and onto smaller litters. Despite this, HIGH sows weaned more piglets (NS) than LOW sows in all litters except the first (see Table 4). This was probably due to the fact that a lower proportion (NS) of live-born piglets died before weaning in litters of HIGH than LOW sows. While this finding can in part be attributed to the likelihood that smaller/weaker piglets (which are more susceptible to pre-weaning death) were fostered away from larger litters, this does not hold for sows at the 5th and 6th litters. In these litters HIGH sows tended to have smaller litters than LOW sows, yet weaned more piglets per litter (see Table 4). Interestingly, parity 2 sows classed as LOW stereotypers crushed a significantly greater proportion of live-born piglets than HIGH sows ($\chi^2_3 = 3.82$, $P < 0.05$; 3.61 and 8.25% of piglets were crushed by HIGH and LOW sows, respectively).

- Production at the litter after observation

Three sows did not farrow subsequent to observation in the present experiment due to abortion or being non-pregnant at term. There were no significant within-parity differences for mean number of piglets born (alive and dead) per litter for HIGH and LOW sows, although at most farrowings LOW sows had more piglets. At the seventh litter, the difference approached significance (11.67 and 14.83 piglets, respectively; $t = -2.071$, $P < 0.1$). The mean litter sizes (plus s.e.) of HIGH and LOW sows are shown over litters 2 to 7 in Table 5. There was no general effect of stereotypy performance level on the number of stillborn piglets and piglets weaned per litter, or the proportion of preweaning deaths amongst live-born piglets.

- Comparisons of litter sizes at the farrowing before and after observation

Since it was considered that litter size of a sow at one particular farrowing may influence the number of piglets born at the next, within-parity correlation analyses were performed for successive litter sizes. A significant relationship was detected for sows observed in parity 3 ($r = 0.50$, $P < 0.01$, $n = 36$). The relationship for parity 4 sows approached significance ($r = 0.346$, $P < 0.1$, $n = 29$). Due to the practice of fostering piglets between litters, consideration of other measures of the productive capability of individual sows is restricted. The results do however suggest that the observed differences in the litter sizes of younger sows may not be related to genetic factors alone.

## Discussion

By undertaking the present study in a commercial piggery, we have avoided many potential problems which may emerge when the results of experiments are interpreted for practical purposes. However, one unavoidable problem that exists in a commercial situation is that sows are culled for poor performance, viz. anoestrus, leg weakness, etc. Thus we have to be cautious in making comparisons, for example, between sows of low and high parity number. Furthermore, we have no idea whether differences observed between parity groups were due to parity as such or due to the constant removal of "substandard" animals from the population.

Two points however are clear. First, sows that recently experienced prolonged tethering for the first time, that is parity 1 and 2 sows, experienced more difficulties than gilts and older sows: compared with the latter, many parity 1 and 2 sows were treated with PG 600. Parity 1 sows were also noted for the high proportion of piglets which they crushed to death before weaning (see Table 1: production at litter 2). Second, the majority of breeding females in the herd were gilts and younger sows. According to recent reports (M.W.A. Verstegen, pers. comm., 1985) the most efficient reproductive phase of the sow is reached between the 4th and 7-8th parity, in terms of both biology and economics. In spite of this, heavy culling of young sows is common in commercial piggeries, meaning that only a minority of sows ever reach their maximum productive potential. The causes of these inefficiencies may well be related to intensive housing. For the present discussion, however, we restrict ourselves to the consequences of abnormal behaviour of tethered sows for welfare and piglet production.

The results of the present experiment clearly indicate that tethered sows in a commercial situation perform abnormal stereotyped behaviours similar to those described for sows in experimental herds. As emphasized by Stolba et al. (1983), younger sows directed their stereotypies towards the tether-stall, and especially the tether chain, whereas older sows tended to perform self-directed stereotypies. It has been suggested by these authors and by Cronin et al. (1985a) that ED and SD stereotypies, respectively, develop in response to physical restraint per se and habituation to a barren environment. While both situations lower the level of a sow's controllability over her environment, the latter condition occurs when the sow registers a continuous lack of appropriate information from the environment. In experimental studies on caged birds, Keiper (1969) has also shown that different types of stereotypy developed in response to physical restraint compared to sensory or motor deprivation. The higher proportion of ED than SD stereotypies amongst younger sows suggests that the majority of low parity sows developed and performed their stereotypies in response to restraint. However, it is known that tethered sows can alter the morphology of their stereotypies in the long-term (Cronin et al., loc.cit.). Furthermore, it is expected that the majority of sows in a herd would eventually adapt to the physical restraint aspect of tether housing. For example, once familiar with restraint, sows rarely perform escape attempts (see Cronin et al., loc.cit.) and do not appear to be suffering physical (somatic) pain. Thus we may suggest that older sows had changed the direction of their stereotypies as a result of habituation to the monotonous environment of the DSR.

In contrast to the survey data of Stolba et al. (1983), our results indicate that most sows developed stereotypies early on in their tethered life. Differences between the treatment of the sows in the 2 surveys were undoubtedly responsible. For example, in contrast to our animals the sows of Stolba et al. received straw each day, and so on. Differences may also arise due to the method of feed presentation.

There is considerable awareness that the level of predictability of feeding influences the behaviour of pigs. In many experimental studies of stereotyped behaviour, sows were hand-fed (e.g. Blackshaw and McVeigh, 1984; Rushen, 1984). This may result in a lengthy and, or variable interval between the first signal indicating feeding and the arrival of feed. Furthermore, the consequent association between the presence of a human and feed may influence the behaviour of sows at other times of the day (see Sambraus and Schunke, 1982). Dantzer and Mormède (1981) and Rushen (loc.cit.) investigated the behaviour of pigs around feeding and have identified classes of stereotyped behaviours consistent with the definitions of terminal and interim responses as proposed by Staddon and Simmelhag (1971).

In the commercial situation of the present experiment, sows had a high level of predictability over the presentation of feed, since sows were fed as the first job of the herdsman's day, and all sows were fed simultaneously. Thus there was a short, predictable interval between hearing the reliable cues that signalled feeding and the arrival of feed.

The stereotypies recorded for sows in the present experiment were certainly not terminal responses, since feeding and drinking were over by the time observations began. Furthermore, the present stereotypies did not lead to an observable goal situation and therefore seemed to be without function. Thus the behaviours were real stereotypies (Ödberg, 1978).

It is worthwhile to comment here on an additional point. Schmidt (1982) has reported that most abnormal behaviours of pigs are oral actions. In the present study it was interesting that almost every sow performed one specific sham action in their stereotypies, i.e. sham chewing, a behaviour sometimes referred to as "champing" (e.g. Barnett et al., 1984). The more than one-hour delay between feeding and water availability in the morning may be causally related to this occurrence. Saliva generated by champing may substitute for water the animals need after eating their day's ration of dry feed. Since sham chewing was a common stereotypy component following drinking time, it suggests that sometimes stereotypy behaviours may develop in functional circumstances.

Thus we may ask why should sows develop a stereotypy and what could be their function. It is known that animals develop stereotypies in chronic stress situations, e.g. unavoidable pain, conflict/frustration, etc.: situations in which the quality and quantity of information necessary for the animal to effectively control or predict the outcome of its own behaviour is inadequate. By developing and then performing a stereotypy, tethered sows may block out the undesirable aspects of the real environment, over which they had no control, and "rebuild" a new and possibly much reduced environment which they control through the performance of stereotypies. Thus stereotypies appear to be effective in many instances in calming animals, by offering new and possibly more reliable information in a greatly reduced environment. This latter effect may occur via the postulated link with endorphins (Cronin et al., 1985a and b). Endorphins have a potential gating function which may be used to block out undesirable circumstances and thus reduce emotional distress (Lewis, Mishkin, Bragin, Brown, Pert and Pert, 1981) and pain (Berger, Akil, Watson and Barchas, 1982). Therefore, the existence of stereotypies in the ethogram of an animal and the potential reliance on endorphins, indicate a serious problem for the animal in its past or present situation.

The observed variability in the level of stereotypy behaviour performed between sows within parity x pregnancy stage groups in the present experiment is therefore interesting. It strongly indicates that animals respond to stress in an individualistic manner. We may speculate that sows classed as high stereotypers were perhaps more stressed by tethering than low stereotypers and vice versa. Other studies on animals and humans that performed stereotypy behaviour, suggest that stereotypers were less attentive to their environment than "normal" subjects (Hutt and Hutt, 1970; Davenport, 1979).

It was therefore unexpected that many, although not all, of the low stereotypers in the present experiment should be less attentive and slower to react in the novel object test than the high stereotypers. Does this imply that these low performers were "less normal" than other sows? It is possible that unreactive sows were lethargic. Fraser (1984/85) describes a sort of depression that animals may suffer under the influence of severe stress, in which they may become inactive. We may speculate then, that many of the low stereotypers at the time of observation were not able to cope with the conflict of being tethered via the performance of a stereotypy. However, we do not know whether the observed level of their stereotypy performance was on an increasing, decreasing or stable plane, which may better indicate whether sows were coping or not. As reported in the results for sows observed in successive parities, more than half of the parity 1 and 2 sows changed behaviour class (high to low, or vice versa) between parities. Variation to enable this change to take place may occur since sows receive some respite from the constant environment of the DSR when they are moved to farrowing accomodation and can interact with piglets, and more frequently than before, with humans.

Evidence of this variability is also available from the behaviour of low parity number sows. Although parity 2 sows stereotyped during more of the observation time than parity 1 sows, sows in both parity groups tended to be more fearful than older sows. Interestingly, parity 1 sows that were fearful were mostly low stereotypers. On the other hand, parity 2 sows that were fearful were mostly high stereotypers. It is not unlikely that some individuals possess better coping capabilities than others. In the young tethered sows of the present experiment, stereotypies may have developed faster in the sows that coped sooner. This suggestion supports the results of Barnett et al. (1985) with tethered and individually-stalled pregnant gilts. The tethered gilts were inactive and experienced chronic elevations of blood corticosteroids. The individually-stalled gilts, in comparison, developed and performed "inappropriate" behaviours but had normal corticosteroid levels compared to group-housed gilts, and thus coped better than the tethered gilts.

On the basis of the results of the present study, which indicate that a high frequency of younger sows needed to develop "coping" behaviours, we must seriously consider that the majority of sows had/were suffering chronic stress, especially during parities 1 and 2. The response of individuals to stress has important considerations for interpreting animal welfare. However, the form of coping response chosen by an animal will be highly individualistic and will involve an integrated response - e.g. combinations of behavioural, neurophysiological responses, and so on. Thus the interpretation of welfare by a single parameter or observation, and without knowledge of historical aspects, could be inadequate.

It is accepted that stress influences the reproductive failure of sows (see review by Wrathall, 1975). In the present experiment there was a relationship between the level of stereotypy performance and the mean total litter size produced at the previous litter. High stereotypers in parities 2 and 3 had produced larger litters than low stereotypers. Amongst the parity 5 and 6 sows this tendency was reversed, with a "crossover" point occurring at parity 4. The results of the present study suggest that stereotypy behaviour may develop more rapidly in tethered pigs that have better ability to adapt to stress. Once these individuals cope, we could expect the level of their stereotypy behaviour performance to decline, or to at least stabilize. On the other hand, animals that are slower to develop stereotypies may experience greater difficulties with coping in the long-term.These individuals may go on increasing the level of stereotypy performance over time, and perhaps are more likely to be culled since they tend to be less productive than sows that cope rapidly. In Figure 4 we present a schematic diagram of the level of stereotypy performance over time by sows classed as "copers" and "non-copers", respectively. On the basis of such a model, it might be fruitful therefore to consider the sow productivity data of younger and older sows separately.

Younger sows that were low stereotypers may have perceived more stress since they were slower to adapt to tethering than high stereotypers, and as a consequence produced smaller litters. Older sows, on the other hand, had had more opportunity to develop a coping strategy. Since older sows that performed lower levels of stereotypy behaviour produced larger litters, both at the litter before and after observation, we can suggest then that the performance of high stereotypy levels in old sows was suggestive that the sows were not coping. On the basis of the "crossover" occurring at parity 4, we can suggest that this may be the mean point of adaptation to tether stress, as depicted in Figure 4.

Amongst younger sows there was no consistent effect of stereotypy performance level on production at the litter after observation. While this may be due to animals changing their "coping status" over time, it also emphasized the need to know historic details of the individuals before concrete conclusions can be drawn. Further investigation is therefore necessary in order to clarify the latter situation.

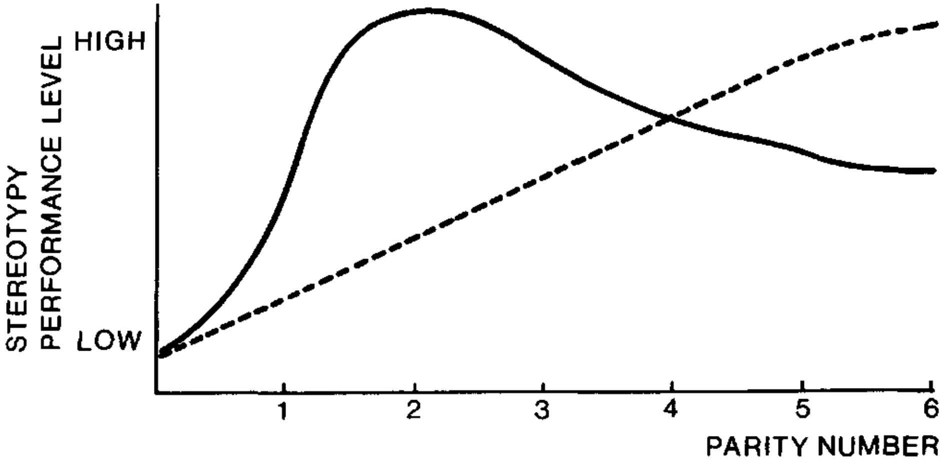

Fig. 4. Schematic diagram of the change in the level of stereotypy performance over time by "coping" (solid line) and "non-coping" (broken line) tethered sows, with the suggestion of a crossover point at parity 4.

In conclusion, this study indicates that stereotypies, which are responses to chronic stress, are performed by a high proportion of tethered sows, and at "chronic" levels by many individuals. Because a majority of breeding females in a herd are young sows, it is important for improved productivity of the whole enterprise, that production from young sows is maximized, and that culling rates are reduced. Younger sows exhibited stereotypies of a type that was largely developed in response to restraint, whereas older sows tended to perform stereotypies indicative of deprived sensory or motoric stimulation. The suggested relationship between improved welfare and productivity (especially amongst the younger sows as they form a majority), should encourage pig producers to seek improvements in welfare status of their animals in order to gain increased profitability per sow in the short- and long-term. The practice of tethering sows is undoubtedly perceived as a chronic stressor by pigs. Furthermore, sows may suffer chronic stress during as much as 2 or 3 parities until they adequately cope with their predicament.

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## References

Antelman, S.M. and Szechtman, H. 1975. Tail pinch induces eating in sated rats which appears to depend on nigrostriatal dopamine. Science **189**: 731-733.

Barnett, J.L., Cronin, G.M., Winfield, C.G. and Dewar, A.M. 1984. The welfare of adult pigs: the effects of five housing treatments on behaviour, plasma corticosteroids and injuries. Appl. Anim. Beh. Sci. **12**: 209-232.

Barnett, J.L., Winfield, C.G., Cronin, G.M., Hemsworth, P.H. and Dewar, A.M. 1985. The effect of individual and group housing on behavioural and physiological responses related to the welfare of pregnant pigs. Appl.Anim. Beh. Sci. (in press).

Becker, B. A.,Ford, J.J., De Shazer, J.A. and Hahn, G.L. 1983. The effects of tether stalls on the circadian rhythm of cortisol, behavioural activities and estrous response in ovariectomized gilts. In The Behavior and Welfare of Farm Animals (ed. W.F.Hall), Proc. Conf. on Human-Animal Bond, 13-14 June 1983, at Minneapolis, Minnesota.

Berger, P.A., Akil, H. Watson, S.J. and Barchas, J.D. 1982. The behavioral pharmacology of the endorphins. Ann. Rev. Med. **33**: 397-415.

Blackshaw, J.K. and McVeigh, J.F. 1984. The behaviour of sows and gilts, housed in stalls, tethers and groups. Animal Prod. in Australia **15**: 85-92.

Broom, D.M. and Potter, M.J. 1984. Factors affecting the occurrence of stereotypies in stall-housed dry sows. In Proc. Int. Cong. on Appl. Ethol. in Farm Animals (ed. J. Unshelm, G. van Putten and K. Zeeb). pp. 229-231, Kiel, F.R.G.

Cariolet, R. and Dantzer, R. 1984. Motor activity of tethered sows during pregnancy. Ann. Rech. Vét.**15** : 257-261.

Corson, S.A. and Corson, E.O. 1976. Constitutional differences in physiologic adaptation to stress and distress. In Psychopathology of Human Adaptation (ed. G. Serban), pp. 77-94, Plenum Press, New York.

Cronin, G.M. and Wiepkema, P.R. 1984. An analysis of stereotyped behaviour in tethered sows. Ann. Rech. Vét. **15**: 263-270.

Cronin, G.M., Wiepkema, P.R. and Hofstede, G.J. 1985a. The development of abnormal stereotyped behaviours in sows in response to neck tethering. Submitted for publication in Appl.Anim.Beh.Sci.

Cronin, G.M., Wiepkema, P.R. and van Ree, J.M. 1985b. Evidence for a relationship between endorphins and the performance of abnormal stereotyped behaviours in tethered sows. Submitted for publication in Appl. Anim. Beh. Sci.

Daelemans, J. 1984. Confinement of sows in relation to their productivity. Ann. Rech. Vét. **15**: 149-158.

Dantzer, R. and Mormède, P. 1981. Pituitary-adrenal consequences of adjunctive activities in pigs. Horm. Behav. **15**: 386-395.

Dantzer, R. and Mormède, P. 1983. De-arousal properties of stereotyped behaviour: evidence from pituitary-adrenal correlates in pigs. Appl. Anim. Ethol. **10**: 233-244.

Davenport, R.K. 1979. Some behavioural disturbances of great apes in captivity. In The Great Apes (ed. D.A. Hamburg and E.R. McCown), pp. 341-357, The Benjamin/Cummings Publishing Co., Menlo Park, California.

Duncan, I.J.H. and Wood-Gush, D.G.M. 1974. The effect of rauwolfia tranquillizer on stereotyped movements in frustrated domestic fowl. Appl. Anim. Ethol. **1**: 67-76.

De Koning, R. 1984. Injuries in confined sows. Incidence and relation with behaviour. Ann. Rech. Vét. **15**: 205-216.

Frankenhaeuser, M. 1976. The role of peripheral catecholamines in adaptation to understimulation and overstimulation. In Psychopathology of Human Adaptation (ed. G. Serban), pp. 173-191, Plenum Press, New York.

Fraser, A.F. 1984/85. The behaviour of suffering in animals. Appl. Anim. Beh. Sci. **13**: 1-6.

Hutt, C. and Hutt, S.J. 1970. Stereotypies and their relation to arousal: a study of autistic children. In Behaviour Studies in Psychiatry (ed. S.J. Hutt and C. Hutt), pp. 175-204, Pergamon Press, Oxford.

Hutton, R. 1983. The development of social behaviour in piglets. Ph. D. Thesis, University of Edinburgh.

Kiley-Worthington, M. 1977. Stereotypies. In Behavioural Problems of Farm Animals, pp. 74-79, Oriel Press, Stocksfield.

Lewis, M.E., Mishkin, M., Bragin, E. Brown, R.M., Pert, C.B. and Pert, A. 1981. Opiate receptor gradients in monkey cerebral cortex: correspondence with sensory processing hierarchies. Science **211**: 1166-1169.

Maier, N.R.F. 1949. Frustration. The Study of Behaviour Without a Goal. McGraw-Hill, New York.

Ödberg, F.O. 1978. Abnormal behaviours (stereotypies). 1st World Cong. on Ethology Appl. to Zootech., Editorial Garsi, pp. 475-480, Madrid.

Rushen, J. 1984. Stereotyped behaviour, adjunctive drinking and the feeding periods of tethered sows. Anim. Behav. **32:** 1059-1067.

Sambraus, H.H. and Schunke, B. 1982. [Behavioural disturbances in breeding sows kept in boxes]. Wien. tierarzl. Mschr. **69. Jahrgang heft 6/7**: 200-208.

Schmidt, M. 1982. Abnormal oral behaviour of pigs. In Disturbed Behaviour of Farm Animals (ed. W. Bessei), pp. 115-121, Verlag Eugen Ulmer, Stuttgart.

Sokal, R.R. and Rohlf, F.J. 1969. Biometry. The Principles and Practice of Statistics in Biological Research. Freeman, San Francisco.

Staddon, J.E.R. and Simmelhag, V.L. 1971. The "superstition" experiment: a re-examination of its implications for the principles of adaptive behaviour. Psychol. Rev. **78:** 3-43.

Stolba, A., Baker, N. and Wood-Gush, D.G.M. 1983. The characterization of stereotyped behaviour in stalled sows by information redundancy. Behaviour **87:** 157-182.

Štuhec, I., Schlichting, M.C., Smidt, D. and Unshelm, J. 1984. The effect of different housing systems on behaviour and plasma cortisol concentrations in gilts. In Proc. Int. Cong. on Appl. Ethol. in Farm Animals (ed. J. Unshelm, G. van Putten and K. Zeeb), pp. 139-143, Kiel, F.R.G.

Tillon, J.P. and Madec, F. 1984. Diseases affecting confined sows. Data from epidemological observations. Ann. Rech. Vét. **15:** 195-199.

Verstegen, M.W.A. 1985. Personal communication: Report of the Discussion Day on Sow Research, Inst. for Livestock Feeding and Nutrition. Lelystad, 10 August, 1984. (Mimeograph).

Vestergaard, K. 1984. An evaluation of ethological criteria and methods in the assessment of wellbeing in sows. Ann. Rech. Vét. **15:** 227-235.

Wiepkema, P.R. 1985. Physiological aspects of fear. Proc. 2nd World's Poultry Sci. Assoc., Celle, F.R.G. (in press).

Wiepkema, P.R. and Cronin, G.M. 1985. [Behavioural responses to stress]. Vakblad voor Biologen (in press).

Wrathall, A.E. 1975. Reproductive disorders in pigs. Comm. Bur. Anim. Health Rev., Slough, Ser. 11, pp. 58-82.

## CHAPTER 6

# THE DEVELOPMENT AND SIGNIFICANCE OF ABNORMAL STEREOTYPED BEHAVIOURS IN TETHERED SOWS

# THE INFLUENCE OF DEGREE OF ADAPTATION TO TETHER-HOUSING BY SOWS IN RELATION TO BEHAVIOUR AND ENERGY METABOLISM

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## Abstract

In response to tethering, many sows develop seemingly non-functional repetitive behaviours (stereotypies), which may be performed for hours per day.

The quality and quantity of activity performed by sows with different degrees of adaptation to tethering was studied in relation to energy expenditure. There were 5 sows per treatment: experienced (HIGH) and inexperienced (T/LOW). As a control comparison, the latter sows were regrouped (G/LOW) for the second half of the experiment.

HIGH sows were about 3 times more active than T/LOW sows (34.5 and 12.8% of 24 h.). Most of the former sows' activity was in the form of stereotypies. The activity level of the G/LOW sows was between that of the 2 tether treatments (16.6% of 24 h.). Both tethered treatments spent about 5% of 24 h. in drinker use compared with less than 2% of the time for the G/LOW sows.

HIGH sows produced 35.7% more heat than T/LOW sows during the 12 h. light period per day. During this period, 40.2 and 20.1% of heat production from HIGH and T/LOW sows was associated with activity. The diurnal activity of the G/LOW sows was associated with 23.5% of heat production.

Stereotypies and excessive drinker use accounted for 86, 52 and 24% of the activity of HIGH, T/LOW and G/LOW sows. The proportion of metabolizable energy intake required for these activities were 23, 7 and 4% for the 3 treatments. The study concludes that tethering is stressful because of the necessity for sows to develop, and then perform large quantities of, coping behaviours, and the association with increased metabolic rate.

## Introduction

Under intensive husbandry conditions, savings in construction and labour costs can be achieved by tethering sows. Daelemans (1984) indicated that in Europe, breeding sows are commonly tethered in double rows (tail to tail) without dunging alley or bedding material and with just 3.6 m between the opposing feed troughs. Feed costs represent about 70% of the total costs associated with husbanding pregnant sows on Dutch farms (W. Baltussen, pers. comm., 1984) but attempts to promote savings in feed conversion efficiency through reduction in activity levels of sows by increased physical restraint, have not succeeded. For example, Svendsen and Bengtsson (1983), Barnett, Cronin, Winfield and Dewar (1984) and Geuyen, Verhagen and Verstegen (1984) have reported that tethered sows are as active as group-housed sows. Some of the activities performed by individually housed sows may be related to their inability to huddle at temperatures below thermoneutrality (Geuyen et al., 1984), or to perform other behaviours such as walking (exercise), comfortive and social behaviours to their satisfaction. The motivation to perform these and many other "obligatory" behaviour sequences or programs (Stolba, 1983) still exists for individually-housed and tethered sows. With time, however, the behavioural repertoire of such sows becomes increasingly limited and stereotyped, but also redirected into behaviours inappropriate for the situation, even seemingly purposeless (Stolba, Baker and Wood-Gush, 1983; Cronin and Wiepkema, 1984) and, or potentially harmful to the animal's health (Ewbank, 1978).

In the process of adaptation to tether-housing, sows pass through a number of stages as described by Cronin, Wiepkema and Hofstede (1984; 1985a). The different behavioural stages are associated with different categories of behaviour. For example, the first stage is characterized by a normally violent resistance and much aggressive behaviour, but appears to occur only on the first tethering occasion. Subsequent stages are noted for the differences observed in the level of activity (immobility to "over" activity) and the class of behaviour (non-stereotyped to stereotyped acts of a vigorous to gentle nature). Thus after initial tethering sows may be inactive, but following the successful development of stereotypies, they may become highly active. Furthermore, each individual sow progresses through this adaptation process at her own pace. Therefore, when comparing tethered and group-housed sows for example, one must know the current stage of adaptation to the housing system for each individual sow.

Stolba et al. (1983) and Cronin and Wiepkema (1984) report that a large proportion of the activity performed by "experienced" tethered sows was in the form of stereotypies. Stereotypies are classed as disturbed behaviours (Wiepkema, Broom, Duncan and Van Putten, 1983) composed of seemingly purposeless, repetitive actions which are performed for abnormally long durations per day. Cronin, Wiepkema and Van Ree (1985b) argue that these behaviours are symptomatic of current or past insoluble conflict and are therefore ethological indicators of reduced animal well-being. It could be argued that husbandry systems which evoke such behavioural disturbances are unacceptable from the point of view of animal welfare. Some authors, however, do not agree. For example, Ludvigsen (1980) proposes that tethering sows during pregnancy is an acceptable method of confinement for the benefit of the sow, provided that the tether does not inflict physical damage to the neck of the wearer.

Very limited behavioural data exist in the literature on the incidence and performance of disturbed behaviour patterns such as stereotypies by tethered sows. It is not understood what effect such behaviour may have on the productivity of the sow. As a first step towards answering this question, it is necessary to investigate the relationship between the level of activity performed by sows (both tethered and group-housed) and some productivity parameters, such as feed conversion efficiency or growth rate.

The aim of this experiment therefore was to measure the energy expenditure of sows as affected by tethering and by the degree of experience to tethering. Data on heat production and energy gain were used to calculate the effects of tethering on energy requirement for maintenance and the cost of feed for the sows. As a control comparison, a group-housing treatment was included.

## Material and methods

### Animals and treatments

This experiment was performed with Dutch Landrace (DL) and Yorkshire x DL crossbred sows in 2 large respiration chambers of the Department of Animal Husbandry, Agricultural University of Wageningen (Verstegen, Van der Hel, Brandsma and Wallinga, 1985). Five sows were housed in each chamber.

Because the rate of stereotypy development, and adaptation to tether-housing, is variable between sows, it was decided to select animals that would be in one of two different developmental stages (treatments) at the start of the experiment. Thus instead of using the same sows at 2 different times, perhaps 6 to 12 months apart, 2 sets of 5 sows were selected which represented sows in an early (low activity) and late (high activity) stage, respectively. Unavoidably therefore, the sows in the 2 treatments were of different ages and had had different experiences after 37 weeks of age. Prior to this however, the sows had been group-reared in a similar manner.

Chamber 1 sows had a dual role. Firstly they were tethered (T) then later group-housed (G) (see Table 1). In order to avoid the confounding effect which initial tethering versus retethering of sows would introduce, the chamber 1 sows were conditioned to being tethered during 8 weeks of their first pregnancy. By the end of this conditioning period, the sows were released and returned to a group-housing situation until farrowing. Thus the sows were accustomed to being neck tethered (as well as group-housed together) and are referred to as the T/LOW treatment when tethered and G/LOW when group-housed as a control treatment.

Chamber 2 sows were known from the extensive historical behaviour records maintained on these pigs, to be individuals that actively performed stereotypies during at least 6 hours per day. Thus they are referred to as the HIGH (activity) treatment. Because these sows remained tethered during the entire occupation of the respiration chamber, except for brief periods each week when they were weighed, they are simply referred to in the text as HIGH sows.

Prior to entry to the chambers, the LOW and HIGH sows, respectively, had experienced 8 and 27 weeks of tethering and their average ages at entry were 64 and 98 weeks. The LOW sows had a mean litter size at birth of 10.0 piglets at the first farrowing, compared with the HIGH sows at the first and second farrowings of 10.6 and 9.0 piglets, respectively.

All five individuals in the LOW treatment had been weaned for at least 10 days prior to the experiment and had not been reinseminated. Four HIGH sows were experiencing their second- and one her third-tethering period, prior to entry to the chamber. It was recognized that pregnancy itself may change energy metabolism. According to data of a study group of the Agricultural Research Council (1981) and of Geuyen et al. (1984), this increase may be about 1 kJ of extra heat per $kg^{0.75}$ liveweight per day after day 40 of pregnancy. Since the maintenance level is about 460 $kJ/kg^{0.75}$, pregnancy would increase heat production per sow by about 40 kJ at day 80, that is, less than 10% in one sow and less than 2% when averaged over the 5 animals per treatment. The 2 HIGH sows that were pregnant in the present experiment were an average of 41 and 97 days pregnant, respectively, during the experimental period. Thus the disturbance to the measurement of heat production in the HIGH treatment is at the most about 2-3%. While these differences introduced some lack of homogeneity between the HIGH treatment sows, most importantly, all 5 sows were considered to be at the same stage of adaptation to tether-housing and had similar stereotypies.

## Plan of experiment

At entry to the chambers the sows were weighed and tethered in partial stalls within the chambers. The sows were restrained by conventional neck tethers (Model 2013; Brouwers, Holland) fitted according to the neck size of each individual sow. Each HIGH sow had access to a supplementary chain (40 cm,medium gauge) suspended in her stall. All five HIGH sows directed their main stereotypies on these chains. Artificial fluorescent lighting illuminated the chambers between 06.00 and 18.00 h daily. Water was available at all times from nipple drinkers and food was presented twice daily at 08.00 and 16.00 h All sows were individually fed with a commercial diet containing 12.5 MJ of metabolizable energy (ME) and 145 g crude protein per kg. Feed to maintenance requirement was given (460 KJ ME per $kg^{0.75}$) plus an additional 400 g was allowed per sow for production (reproductive and maternal gain). Sows had access to the individual feed troughs for 15 min only at each feeding time. Feed was dropped into the troughs moments before access was permitted. Within the 15-min. period following 08.00 h each day, an experimenter entered both chambers in turn to clear away accumulated faeces. A period of 4 days was allowed for the sows to accustom themselves to their new environments before the start of the experiment. Oestrus detection was not performed and no sows were inseminated during the experiment.

## Heat production

Heat production was determined from the measurements of gaseous exchange of carbon dioxide and oxygen during successive 18-min. trials continuously throughout twelve, 48-hour respiration sessions over a period of 4 weeks (three sessions per week). Some details of the experimental plan are shown in Table 1. The temperature of the chambers was maintained at thermoneutrality (21°C; Geuyen et al., 1984) and relative humidity at 65%.

Nitrogen and energy retention by the sows in the 2 chambers were determined for each of the 4 week periods in the following manner:

a) Nitrogen gain = N intake (food) - N in faeces and urine - N in air - N in collected condensed water from heat exchanger used for humidity control.

b) Metabolizable energy (ME) = E intake (food) - E in faeces and urine.

c) Energy gain = Metabolizable energy - E as heat production = E retained as protein and fat.

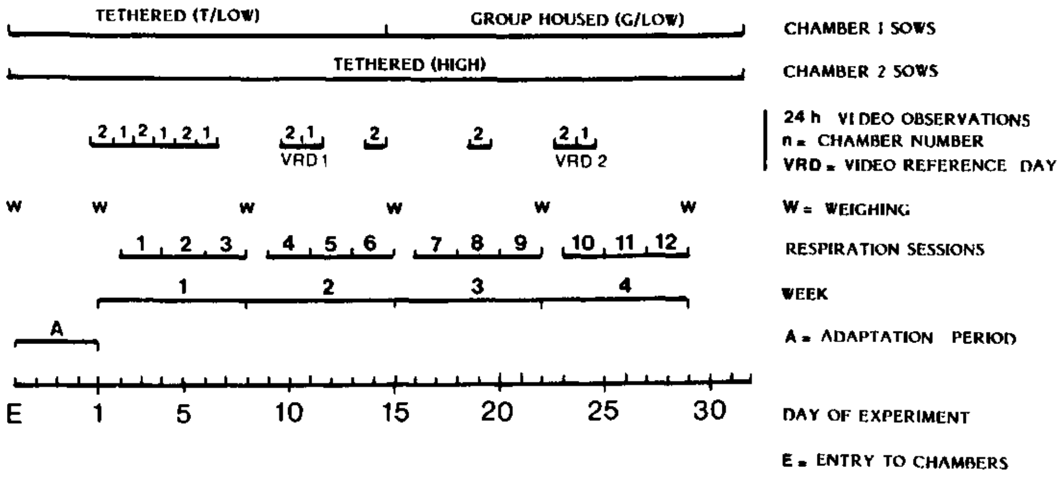
Protein gain was calculated from the N gain x 6.25 and fat gain was calculated by substracting energy in protein gain from total energy gain, divided by 39.7, the calorific value of 1 g of fat.

## Housing treatments

As shown in Table 1, the LOW sows were tethered from day 1 to 14 (T/LOW) and group-housed (G/LOW) thereafter. Individual feeding of the G/LOW sows occurred as follows. One kg of feed was placed in each of the sows' troughs in the usual manner. An experimenter then entered the chamber, tethered the sows while they were feeding, fed them their remaining due feed and left the chamber. The sows were unfastened 15 min. later when the experimenter reentered the chamber. Access to the feed troughs was then blocked.

The differences in the quantity of the behaviour of HIGH and LOW sows were investigated while the latter sows were firstly tethered then group-housed. In addition, the activity-related and activity-free heat productions of the sows in the different treatments - HIGH, T/LOW and G/LOW - were determined in relation to the quantity of the activity and, or the housing system.

Table 1. Plan of experiment.



## Behaviour observations

Video cameras inside both chambers were positioned so as to present a clear picture on a monitor of the sows when T- or G-housed. A Sony time-lapse (TL) video recorder with date-time generator synchronized with the respiration chamber time-clock was located outside the chambers. Continuous TL video recordings at 1/40th normal tape speed (normal speed = 3000 frames/min.) were made of the sows in both chambers during selected 24 h periods (see Table 1). Night time video recording was assisted by illumination from a 40 watt incandescent white bulb in both chambers.

In addition, two ultra-sound activity detectors (meters) in each chamber recorded quantitatively the total level of "activity" within the chambers during every 18-min. trial. The 4 individual meters however, had different sensitivities and were not calibrated with each other prior to the experiment. Thus, "X" amount of activity during an 18 min. trial would be registered as different "activity scores" by the different meters. During a 48-hour respiration session, 160 pairs of activity scores were registered per chamber. To help equilibrate the within-chamber activity scores per trial, the available TL video records were examined for 18 min. trials in which the activity (quantity and quality) of all 5 sows was as even as possible. In these trials, it was assumed that the levels of activity registered by the 2 separate meters were equivalent. The ratio of the scores from the meters was then calculated

After release from the tethers, G/LOW sows were less active (as determined by the ultra-sound meters) than the HIGH sows (Figure 1), despite an initial rise in activity on the days following release and a gradually declining level of activity from the HIGH sows over the same period. On video reference day 2 (VRD2), the mean frequency of occurrence of active behaviours per sow were 33.4 and 16.6%, respectively, for the HIGH and G/LOW sows. In contrast, the LOW sows were less, although not significantly less, active when T/ than G/housed (12.8 and 16.6%, respectively; $\chi^2_1 = 1.34$, NS). The change in the frequency of occurrence of active behaviours during 24 h. for the G/LOW sows on VRD2 is shown in Figure 2.

The mean proportion of total activity (TA) that was recorded as walking-about by the G/LOW sows (33.8% of TA) was apparently at the expense of decreased drinker use (41.6 and 10.0% of TA, respectively, for T/ and G/LOW sows; $\chi^2_1 = 9.61$, $P < 0.01$). The mean frequency of observations per 24 h (plus standard deviations) that sows were observed to express different categories of behaviour are presented in Table 2.

Table 2. Mean frequency (plus standard deviation) of observations recorded at 6-min. intervals per 24 h period that HIGH, T/LOW and G/LOW sows performed different categories of behaviour on video reference days (VRD). Values presented are percentages.

|  | VRD1 |  |  |  | VRD2 |  |  |  |
|---|---|---|---|---|---|---|---|---|
| Treatment | HIGH |  | T/LOW |  | HIGH |  | G/LOW |  |
| Behaviour category | mean | s.d. | mean | s.d. | mean | s.d. | mean | s.d. |
| i) active behaviours |  |  |  |  |  |  |  |  |
| stereotypies | 26.6 | 4.9 | 3.1 | 2.8 | 21.4 | 7.4 | 4.0 | 2.9 |
| drinker use | 5.1 | 3.9 | 5.3 | 2.5 | 4.4 | 2.7 | 1.7 | 0.5 |
| other non-stereotypy actions | 3.2 | 1.0 | 4.4 | 1.9 | 7.6 | 2.0 | 5.3 | 1.3 |
| walking about | -- | -- | -- | -- | -- | -- | 5.6 | 2.2 |
| TOTAL ACTIVITY | 34.9 | 8.8 | 12.8 | 4.3 | 33.4 | 7.5 | 16.6 | 4.1 |
| ii) inactive behaviours |  |  |  |  |  |  |  |  |
| idle/rest/sleep | 65.1 | 8.8 | 87.2 | 4.3 | 66.6 | 7.5 | 83.4 | 4.1 |

## Energy balances

Mean values for the liveweight (plus s.d.), ME intake, heat production per metabolic live weight and energy balance (EB) from the sows in each of the 4 weeks are shown in Table 3 along with protein and fat gain per sow per day. In both treatments sows gained some live weight.

Table 3. Mean values for liveweight (plus s.d.), metabolizable energy (ME) intake, heat production (H), energy balance (EB: kJ/$kg^{0.75}$) and gain in protein and fat per sow per day by HIGH, T/LOW and G/LOW sows.

| Treatment | Week | Liveweight (kg) mean | Liveweight (kg) s.d. | ME intake (kJ/$kg^{0.75}$) | H (kJ/$kg^{0.75}$) | EB (kJ/$kg^{0.75}$) | Gain (g) per sow per day Protein | Gain (g) per sow per day Fat |
|---|---|---|---|---|---|---|---|---|
| HIGH | 1 | 164.6 | 11.4 | 606 | 572 | 34 | 57.4 | 4.8 |
| | 2 | 165.4 | 13.5 | 612 | 590 | 22 | 64.2 | -13.5 |
| | 3 | 167.1 | 14.5 | 607 | 580 | 27 | 71.6 | -11.3 |
| | 4 | 170.7 | 15.5 | 613 | 566 | 47 | 80.1 | 7.5 |
| T/LOW | 1 | 187.0 | 13.9 | 605 | 485 | 120 | 103.0 | 91.0 |
| | 2 | 186.3 | 12.5 | 595 | 477 | 118 | 91.3 | 94.5 |
| G/LOW | 3 | 187.7 | 12.3 | 574 | 527 | 48 | 101.3 | - 0.5 |
| | 4 | 188.4 | 13.0 | 605 | 512 | 93 | 93.9 | 63.1 |

Data presented in Table 3 show that the level of energy metabolism was greater for HIGH than LOW sows. This was despite the fact that feeding levels (expressed per $kg^{0.75}$) were similar in both treatments. Heat production expressed in this way was 20.8% greater in HIGH than LOW sows. As a consequence, energy balances were reduced in the HIGH sows.

Table 3 shows data of protein gain measured by the balance technique and the derived fat gain. Averaged over the first 2 weeks of the experiment, protein and fat gain were both less in HIGH than LOW sows. These differences were partly associated with differences in live weight, but were most certainly associated with differences in metabolic rate.

In comparison, heat production from the G/LOW treatment in weeks 3 and 4 combined was in between that of the 2 tether treatments: 11.8% lower than the HIGH and 8.0% higher than the T/LOW sows.

Heat production of the T/LOW sows but not of the HIGH sows in the present experiment was in accordance with the expected values that can be derived from maintenance requirement for tethered sows. Maintenance requirement ($ME_m$) in metabolizable energy per $kg^{0.75}$ can be calculated from energy metabolized from the feed eaten (ME) by subtracting the ME associated with energy gain (EB). Thus, $ME_m = ME - EB/k_g$, in which $k_g$ is the partial efficiency (assumed as 0.7) for energy gain (Geuyen et al., 1984) Thus for T/LOW sows in weeks 1 and 2 combined, $ME_m = 600 - 119/0.7 = 430$ KJ/$kg^{0.75}$. $ME_m$ for the HIGH sows in the same weeks was 569 kJ/$kg^{0.75}$ and the G/LOW sows in weeks 3 and 4 was 489 kJ/$kg^{0.75}$.

### Metabolic rate, the diurnal pattern of heat production and activity levels

The total heat production (H) in all treatments was affected by the time of day and the activity level within the day. As an example, Figure 3 shows the fluctuations in H during 24 h from HIGH and T/LOW sows over the first 6 respiration sessions (weeks 1 and 2). While the sows in both tether treatments were most active (see Figure 2), and therefore produced most heat, around feeding times, the HIGH sows also maintained higher diurnal levels of H than the T/LOW sows. In the light period (06.00-18.00 h) the HIGH sows produced 35.7% more heat than the T/LOW sows (Table 4). During the "dark" period however, this difference was reduced to 4.5% for the HIGH sows.

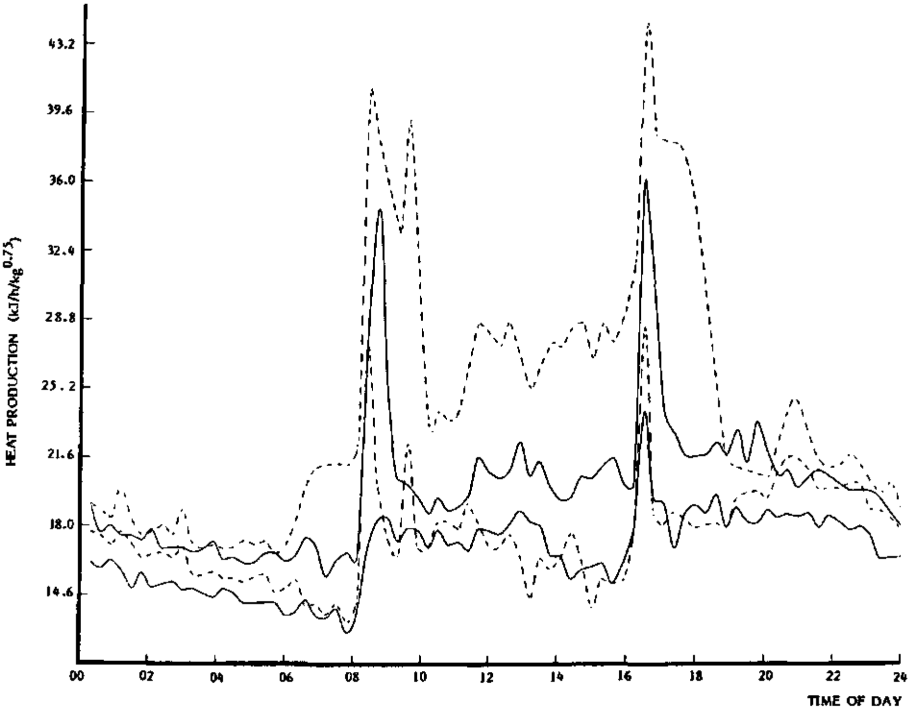


Fig. 3. Heat production in kJ/kg$^{0.75}$ per hour during 24 h: upper line = heat production as measured; lower line = activity-free heat production (---- = HIGH sows; —— = T/LOW sows).

Table 4. Total heat production (H) and activity-free heat production (AFHP) for HIGH, T/LOW and G/LOW sows during the light and dark periods. Values shown in the table are kJ/kg$^{0.75}$/h.

| Time of day | | 06.00-18.00 h (light) | | 18.00-06.00 h (dark) | |
|---|---|---|---|---|---|
| Treatment | Week | H | AFHP | H | AFHP |
| HIGH1 | 1 | 28.4 | 17.1 | 19.4 | 17.7 |
| | 2 | 29.1 | 17.1 | 20.2 | 18.0 |
| | 3 | 27.3 | 16.9 | 20.9 | 17.8 |
| | 4 | 26.2 | 17.4 | 21.1 | 18.6 |
| T/LOW | 1 | 21.2 | 17.2 | 19.3 | 17.0 |
| | 2 | 21.2 | 16.6 | 18.6 | 16.1 |
| G/LOW | 3 | 23.7 | 17.7 | 20.2 | 16.8 |
| | 4 | 22.7 | 17.7 | 20.0 | 16.7 |

In Table 4, values are presented per week for H and activity-free heat production (AFHP). The latter was calculated from activity scores at various times of the day and the regression coefficients calculated for the various 48 h. respiration sessions. Fluctuations in the mean AFHP during 24 h. from the HIGH and T/LOW sows over the first 6 respiration sessions are shown in Fig. 3. While there were no differences between the treatments in AFHP during the light period, the HIGH sows produced an average of 8% more heat in the "dark" than the LOW sows (Table 4).

The heat production associated with activity can therefore be derived from Table 4 by subtracting AFHP from H. During the light period, 40.2% of heat production was associated with activity by the HIGH sows in weeks 1 and 2. In comparison, 20.1% of H from the T/LOW sows could be accounted for by activity during the light period. The diurnal activity of G/LOW sows was associated with 23.5% of H.

## Discussion

High diurnal levels of activity by the experienced tethered (HIGH) sows resulted in greater levels of heat production and reduced protein and fat gain compared with the less active T/LOW tethered sows. The large difference in activity levels and the much greater activity-related heat production by the HIGH sows were mostly due to the performance of stereotypies. The present study also indicates that activity-free heat production in the HIGH sows was increased during the dark period. This may probably reflect increased resting metabolic rate associated with their poorer body condition and increased thermal demand compared with the T/LOW sows.

The present results are based on comparisons of tethered sows expressing different activity levels in experimental situations. However, it is essential to know whether one or both tethered treatments (HIGH and T/LOW) were indeed representative of commercial breeding sows adapting to tether housing. That the T/LOW sows differed at the time of the experiment from HIGH sows is obvious from the results. During the course of the experiment, however, the T/LOW sows maintained a relatively constant level of activity per day (see Figure 1). In contrast, after the first week of experiment, there was a decline in activity levels per day in the HIGH treatment, due to one sow becoming increasingly inactive during the last 3 weeks of her pregnancy. Once this sow was removed from chamber 2 (day 28 of the experiment), mean activity levels per sow increased. A leg injury to another HIGH sow also contributed to depressed activity levels of HIGH sows after day 13.

Interestingly, the T/LOW sows gradually increased the proportion of their activity that was in the form of stereotypies. However, since total activity was not increased (see Figure 1, days 9-14), the results support the contention that stereotyped movements are more efficient than non-stereotyped movements. One of the LOW sows was retained as a tethered breeding sow after the end of the experiment. When video-recorded 9 months later, this sow performed stereotypies for 6 hours per 24 h. period. Thus from the detailed historical behaviour data available on all these sows, it seems reasonable to conclude that after entry to the chambers, the T/LOW sows were indeed following a path of adaptation to tether-housing similar to that formerly experienced by the HIGH sows. This inturn suggests that the HIGH sows might be typical "experienced" tethered sows. In additional support of this, Cronin and Wiepkema (1984) reported data from 36 tethered breeding sows at a semi-commercial pig research facility in Holland. Their results indicated that tethered sows performed stereotypies on average for 39% (s.d. = 28%; range = 1 - 89%) of the observation period between 10.00-14.00 h. Variations in the level of performance of these behaviours between sows was largely due to differences in the time spent tethered within each pregnancy. The relationship between the proportion of time spent performing stereotypies between 10.00-14.00 h and over the whole 24 h period was determined for 20 tethered sows and will be reported at a later time. Based on this relationship, the mean stereotypy performance time by the 36 sows of Cronin and Wiepkema can be derived at 6 h per 24 h period (s.d. = 3.4 h). From Table 2 the mean times per 24 h that sows in the present experiment performed stereotypies can be calculated. On VRD1 and 2, HIGH and LOW sows, respectively, performed on average 6.4 and 5.1 h, and 0.7 and 1.0 h of stereotypies per 24 h.

Although the LOW sows were more active when group- than tether-housed, they were less active than the HIGH sows. According to a number of other studies investigating the behaviour of tethered and group-housed sows, experienced tethered sows are as active as group-housed sows (Svendson and Bentsson, 1983; Barnett et al., 1984; Geuyen et al., 1984). After grouping the LOW sows on day 15 of the present experiment, increased activity levels occurred which were reflected in lower EB and negative liveweight and fat gain during week 3. These trends were reversed in the subsequent week. Thus, as a control treatment, G/LOW sows perhaps may not have fully adapted to the group-housing situation when the experiment ended. However, it seems reasonable to assume that sows in the HIGH, and G/LOW treatments in week 4, were generally representative of experienced tethered and group-housed sows, respectively.

The sows in both tether treatments performed drinking for an average of about one hour per day. The performance of stereotypies and excessive drinking by animals have both been associated with stress reduction (Brett and Levine, 1979; Dantzer and Mormède, 1983; Cronin et al., 1985b).

The T/LOW sows in particular expressed a generally higher incidence of drinker use than the G/LOW sows. A similar result was reported by Barnett et al. (1984) in respect to tethered and loose sows. These authors, as well as Ödberg (1981) who studied the development of stereotypies in voles, observed that the incidence of stereotypies was inversely related to the degree of environmental richness. Loss of controllability over the environment (Mason, 1978) as a result of physical restraint (e.g. tether-housing) and habituation to environmental stimuli in the typically barren unchanging environment provided for breeding sows, was probably reversed by the sows used in the present experiment through the selection of behavioural coping strategies. This is consistent with the model of adaptation to adverse environmental conditions proposed by McBride (1980).

The performance of high levels of activity, most of which was in the form of seemingly unnecessary, repetitious behaviours (stereotypies) by experienced tethered sows compared with group-housed sows, represents a large cost in feed conversion efficiency. "Unnecessary activities" however, were performed by the sows in all treatments in the present experiment. Stereotypies, as well as drinker use above the level performed by the G/LOW sows, accounted for 86, 52 and 24% of total activity per 24 h, respectively for the HIGH, T/LOW and G/LOW sows. From Table 4, the activity-related heat production (Hac) per 24 h of sows in these 3 treatments were 163.2, 80.4 and 99.6 $kJ/kg^{0.75}$. The average ME intakes of the sows (from Table 3) were 609, 600 and 590 $kJ/kg^{0.75}$, respectively, indicating that the percentage of ME intake required for unnecessary activities were 23, 7 and 4%, respectively, for HIGH, T/LOW and G/LOW sows. These percentages were calculated from Hac/24 h x the percentage of total activity that was in the form of unnecessary behaviours, divided by ME intake/24 h. The somewhat lower ME content of feed eaten during group-housing (G/LOW) in week 3 compared to other weeks, may be related to the change in housing circumstance for which there was no adaptation time as occurred before the start of the present experiment. The initially increased activity levels by the LOW sows after grouping, of which most extra activity would have been in the form of locomotive activity, may have stimulated an initially higher rate of faecal excretion. These factors may have contributed to the lower rate of body weight gain (Table 3) by the G/LOW sows, especially in week 3.

Sows are fed during pregnancy at a level of about 20% above maintenance (see ARC, 1981; pp. 51-56). When sows have normal maintenance requirements (assumed to be about 460 $kJ/kg^{0.75}$: Verstegen, 1984) they may gain about 40 kg liveweight during pregnancy. If however, metabolic rate and thus heat production is increased due to increased activity, then animals will retain less energy for production. As a result, maternal gain and development by the sow will be reduced. It is therefore important that housing systems are evaluated with respect to energy requirement of sows for maintenance (Close and Cole, 1984). The results of the present experiment question the validity of assumptions of maintenance requirements for experienced tethered sows.

In conclusion, the results of the present experiment may be interpreted to indicate that tethering is stressful because of the necessity for tethered sows to develop, and then perform large quantities of, coping behaviours and the association with increased metabolic rate. Since the increased activity and heat production of experienced tethered sows were largely related to the performance of stereotypies, then the rationale of tethering sows to achieve increased productivity must be questioned. Further research on the incidence of energy-costly, unnecessary behaviours amongst larger numbers of tethered sows is thus urgently needed. In addition, investigation of the association between body condition of the sow and activity level may also contribute to our understanding of the thin-sow syndrome.

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## References

ARC, 1981. The nutrient requirements of pigs. CAB, pp. 1-307.

Barnett, J.L., Cronin, G.M., Winfield, C.G. and Dewar, A.M., 1984. The welfare of adult pigs: the effects of five housing treatments on behaviour, plasma corticosteroids and injuries. Appl. Anim. Beh. Sci. 12: 209-232.

Brett, L.P. and Levine, S., 1979. Schedule-induced polydipsia suppresses pituitary-adrenal activity in rats. J. Comp. Physiol. Psychol. 93: 946-956.

Close, W.H. and Cole, D.J.A., 1984. Principles and strategies involved in the nutrition of the sow. 35th Annual EAAP Meeting. The Hague, August 1984. Paper NP2, pp. 1-11.

Cronin, G.M. and Wiepkema, P.R., 1984. An analysis of stereotyped behaviour in tethered sows. Ann. Rech. Vét. 15: 263-270.

Cronin, G.M., Wiepkema, P.R. and Hofstede, G.J., 1984. The development of stereotypies in tethered sows. Proc. Int. Cong. on Applied Ethology in Farm Animals. 1-4 August 1984, Kiel, F.R.G., pp. 97-100.

Cronin, G.M., Wiepkema, P.R. and Hofstede, G.J., 1985a. The development of abnormal stereotyped behaviours in sows in response to neck tethering. Submitted for publication in Appl.Anim.Beh.Sci.

Cronin, G.M., Wiepkema, P.R. and Van Ree, J.M., 1985b. Evidence for a relationship between endorphins and the performance of abnormal stereotyped behaviours in tethered sows. Submitted for publication in Appl. Anim. Beh. Sci.

Daelemans, J., 1984. Confinement of sows related to their productivity. Ann. Rech. Vét. 15: 149-158.

Dantzer, R. and Mormède, P., 1983. De-arousal properties of stereotyped behaviour: evidence from pituitary-adrenal correlates in pigs. Appl. Anim. Ethol. 10: 233-244.

Ewbank, R., 1978. Stereotypies in clinical veterinary practice. Proc. 1st World Cong. on Ethology Appl. to Zootechnics. Madrid, October 1978. pp. 499-502.

Geuyen, T.P.A., Verhagen, J.M.F. and Verstegen, M.W.A., 1984. Effect of housing and temperature on metabolic rate of pregnant sows. Anim. Prod. 38: 477-485.

Ludvigsen, J.B., 1980. Production hazards in technically advanced confinement systems for pigs. Anim. Regulation Studies 3: 99-103.

Mason, W.A., 1978. Social experience and primate cognitive development. In The Development of Behaviour: Comparative and Evolutionary Aspects (ed. G.M. Burghardt and M. Bekoff), pp. 233-251. Garland Press, New York.

McBride, G., 1980. Adaptation and welfare at the man-animal interface. In Behaviour in Relation to Reproduction, Management and Welfare of Farm Animals (ed. M. Wodzicka-Tomaszewska, T.N. Edey and J.J. Lynch). Reviews in Rural Science No. IV, The University of New England, pp. 195-198.

Ödberg, F.O., 1981. Environmental and pharmacological determinants of pathological stereotypies in voles (Clethrionomys glareolus britannicus). Ph.D. Thesis, State University of Gent.

Stolba, A., 1983. The pig park family system: housing designed according to the consistent patterns of pig behaviour and social structure. In The Behaviour and Welfare of Farm Animals (ed. W.F. Hall). Proc. conf. on the human-animal bond. Minneapolis, Minnesota, pp. 38-65.

Stolba, A., Baker, N. and Wood-Gush, D.G.M., 1983. The characterization of stereotyped behaviour in stalled sows by information redundancy. Behaviour 87: 157-182.

Svendsen, J. and Bengtsson, A.C., 1983. Housing of sows in gestation. Guelph Pork Symposium, Waterloo, Ontario, Canada, April 1983.

Verstegen, M.W.A., 1984. Energy and nutrient requirements of sows for pregnancy. 35th Annual EAAP meeting. The Hague, August 1984, Paper NP3, pp. 1-18.

Verstegen, M.W.A., Van der Hel, W., Brandsma, H.A. and Wallinga, J.H., 1985. Indirect calorimetry with large groups of animals. Neth. J. Agric. Sci., in press.

Wiepkema, P.R., Broom, D.M., Duncan, I.J.H. and Van Putten, G., 1983. Abnormal behaviours in farm animals. A report of the Commission of European Communities, Autumn, 1983.

# CHAPTER 7

## General discussion

Non-lactating sows were tether-housed during long periods of time in which they experienced physical restraint and its consequent restrictions on movement, and the performance of social and exploratory behaviours. Abnormal stereotyped behaviours (stereotypies) that developed as a result of tether-housing, are accepted to be symptomatic of a current or past serious conflict (Maier, 1949; Duncan and Wood-Gush, 1974). Any study of stereotypy behaviour therefore, cannot avoid conclusions on the welfare of the individuals that perform these behaviours.

Three important points concerning the present work on stereotypies have been selected for further discussion. Since it is suggested that stereotypies are indicators of poor welfare, we first of all need to know more about how to define and measure welfare. For example, via a biological approach, "welfare science" may move in from the periphery of the natural sciences, and allow more objective assessments to be carried out. Second, we need to investigate the potential use of certain characteristics of stereotypies to measure welfare status. In the present context, the function of stereotypy variability seems to be important. Third, it is essential to apply the results of this research to the practical situation.

### Stereotypies and animal welfare

From the literature relevant to farm animal welfare, it is apparent that the more-intensive housing systems are associated with lower welfare status of sows, compared with less restrictive systems. From an ethological view point, it is clear that a high proportion of intensively-housed sows perform stereotypies and other abnormal behaviours (e.g. Sambraus and Schunke, 1982; Stolba et al., 1983). At first sight, such results should leave us in no doubt over the need to discourage the use of "bad" housing systems. Unfortunately, the issue of animal welfare has become extremely emotive, within public, practical and even scientific discussions. Furthermore, discussions are often clouded and conflicting through the use of different language by different parties. The use of quasi-scientific and layman language, and varied interpretation of terms derived from different scientific disciplines, thus makes the discussion of "animal welfare" overly complicated, or may even result in the mis-interpretation of some findings on welfare.

What is needed is to make statements on animal welfare that can be tested and are measurable. While such statements need to be reliable and unambiguous, they should as far as possible enable the assessment of welfare status. The most promising approach would appear to be one with a purely biological perspective.

In the study of animal behaviour, different approaches occur, for example between German- compared with English-speaking ethologists. Furthermore, different models of behaviour have been proposed, e.g. Lorenzian versus the regulatory model, as described by Wiepkema (1983). Depending upon which model is chosen for the study of animal welfare, it is possible to evoke conflict over conclusions. The Lorenzian model considers that animals suffer if the performance of a certain behaviour does not occur, even though the stimuli to elicit the behaviour are permanently absent. In the regulatory model, the non-performance of some behaviour programs during undefined periods of time does not necessarily indicate problems for the welfare of the animals. We must of course know why the animal needs to perform the behaviour.

The problems associated with discussions of animal welfare (and the associated phenomena well-being and suffering) have been elucidated by Duncan and Dawkins (1983), amongst others. Definitions of welfare typically encompass the notions of "physical and mental health", "feelings", "harmony with the environment" and "adaptation without suffering". Welfare needs however, an operational definition. As a first step in that direction, the following definition of welfare is proposed. Welfare is a state of the animal in which the quality and quantity of information gathered from the external and internal environments (the "Umwelt") enables the individual to control and predict the events in its environment through the performance of its own behaviour. Short- and long-term deficiencies in controllability/predictability of the environment thus constitute acute and chronic states of lowered welfare, respectively. Since controllability and predictability are operational terms, welfare should thus be assessable. Techniques are available from a number of scientific disciplines that would allow, for example, the measurement of animals' responses to changes in "welfare status". A combination of such techniques into a multi-disciplinary approach is strongly advised by Smidt (1983), and would be vital in the assessment of the acceptability of different housing systems for animal welfare.

Finally, it is necessary to extend these findings into practical terms, terms which are unambiguous to farmers, zoo-keepers, pet owners, politicians and the general public alike.

## Biological significance of stereotypies

A surprising feature of the stereotypies of individual sows was the existance of sometimes considerable variability of performance in the short-term. According to the "classic" definition as presented by Ödberg (1978) for example, a stereotypy should contain morphologically identical movements from one cycle of repetition to the next. In addition, the movements should be regularly repeated and have no apparent function.

Certainly, the stereotypies recorded for tethered sows fulfilled the latter requirements and were considered abnormal. Furthermore, these stereotypies developed out of chronic stress situations, and thus were indicative of past or current welfare problems.

However, rather than dispense with the term "stereotypy", it would seem more appropriate to incorporate an allowance for some degree of variability of performance in the present definition. The behaviours remain far more stereotyped than most normal ones, and in addition, the connotation of abnormality associated with the word "stereotypy" is not lost.

Examples of the variability of stereotypy performance by individual sows have been described in Chapters 2 to 4. While other authors have surely been aware of this phenomenon, it appears to have been largely over looked and left unmeasured, or perhaps interpreted as an indication that the behaviours were still developing.

Amongst the higher vertebrates, "normal" behaviours are often variable. Plasticity of behaviour is a characteristic that enables individuals to meet the demands of their environment (Feldman, 1978). While each species has its own capability in this regard, animals respond to changes in their environment in an individualistic manner. Plasticity, or overt variability, is closely connected with learning processes. In natural circumstances animals learn via a cognitive approach to problem solving. Inglis (1983) emphasizes that animals are primarily information-processing systems that use previously encoded knowledge to impose upon their environment certain a priori interpretive assumptions. Thus in the process of adaptation, an animal confronted by a problem draws on past experiences, and adjusts its behaviour to suit the situation. Overt variability results when the outcome of a behaviour is worse than expected. Logically, an animal should adapt its behaviour so that repeated performance increases the probability of a favourable outcome. Variability then, may be a sign that the animal has still not adapted to its environment.

Just as the variability of normal behaviour may be indicative of an on-going adaptation process, perhaps the same also holds for abnormal behaviours such as stereotypies. Indeed according to Berkson (1968), stereotypies are in effect normal behaviours functioning in an abnormal situation and gradually conditioned by the environment. In the monotonous and highly predictable environment endured for long periods by tethered sows, variability of behaviour should be absent. Therefore one may well ask why should stereotypies be variable if the environment is so predictable?

Knowing that stereotypies develop out of chronic stress situations, it may be expected that stereotypy performance somehow alleviates stress. Dantzer and Mormède (1983) have demonstrated the latter phenomenon in pigs via the measurement of blood corticosteroid levels. In Chapters 3 and 4, the hypothesis was proposed that endorphins (endogenous opiates) may be the factor underlying the development and continued performance of stereotypies. Tethered sows develop, in time, an association between the performance of behaviour and the release of endorphins, although these may have been originally independent phenomena. Endorphins are released in response to conflict, as discussed in Chapters 3 and 4. Through the intensive performance of behaviour, the tethered sow may suspect that its behaviour effects its feeling of well-being. As with the development of a normal behaviour, the sow subsequently narrows the range and reduces the complexity of behaviours that result in the feeling of improved well-being. Eventually, the performance of stereotypies will self-stimulate the release of endorphins. Endorphins have a rôle in reducing negative emotions (Lewis et al., 1981) and physical pain (Berger et al., 1982). Thus stereotypies probably function to block out undesirable aspects of the real environment. While the environment of tethered sows may be highly predictable, when restrained, sows may lose the ability to control the events in their environment. Therefore we must consider that the stereotypies of tethered sows were a response to loss of controllability. By developing a stereotypy, the animal may "rebuild" a new and possibly much reduced environment, over which it once again maintains good control. Experience of lowered controllability and, or predictability are demonstrably stressful (Overmier et al., 1980), and the perception of such states in the long-term constitute chronic stress (Wiepkema and Cronin, 1985). However, we have little or no idea whether the sows have successfully adapted to tethering via the development of stereotypies. For example, at the time of initial tethering, sows resisted vigorously, suggesting that they perceived their predicament in an extremely negative way. After how long, if ever, does this negative perception disappear?

The development of a stereotypy is a long-term, dynamic process comparable in many respects to the development of normal behaviours. In the latter process, a change in behaviour occurs in response to information from the environment, processed by the animal and matched with some expected value. On the basis that the outcome of the behaviour was as good as, or better than, expectation, the animal perceives positive information that reinforces existing behavioural strategies and leads to the reduction of variability. This results in the development and reinforcement of behaviours that can be performed automatically. Such behaviours are in fact stereotyped, but above all, the probability that their outcome is correct is unity. A negative response on the other hand, leads the animal to alter its behaviour. Thus it may be implied that variability reflects negative information.

A stimulus that requires the animal to alter an existing behaviour may be considered a stressor. Acute stress, as occurs in normal every day situations, is short-lasting and enhances learning by the animal. Acute stress responses, not surprisingly, occur during the performance of many normal behaviours, e.g. mating in sows (Barnett et al., 1982). Furthermore, it seems that endorphins, which are released in response to stress, are involved in the development of normal behaviours, e.g. social behaviours and emotional responses (Panksepp et al., 1980). Thus, stress should also have an emotional component. The function of emotion would be to inform the animal of the success rate of its behaviours in predicting/controlling the events in the environment (Wiepkema, 1985). Continued negative emotions promote variability whereas positive emotions enhance the development of non-variable behaviour. Non-variability, as seen in routine behaviours, implies maximal predictability/controllability and makes emotion superfluous. Real stereotyped behaviour should therefore be emotionless.

In abnormal circumstances animals may be faced with insoluble problems. The tethering of sows is one such example. As described here and elsewhere, tethering constitutes a chronic stressor and often results in sows developing stereotypies. Thus tethering appears to be a severe (long-lasting), negative emotional experience for sows. Variability of stereotypy performance may reflect a continued experience of negative feelings. It is understandable that in response to chronic stress, sows learn to self-stimulate endorphin release, which induces a positive emotional state that would tend to reduce variability. Therefore, variability of stereotypy performance may have important consequences for understanding animal welfare. In fact, the level of variability may be indicative of a sow's perception of her own welfare status, and hence welfare is at least assessable.

From a biological view point, it could be concluded that the welfare of stereotyping sows is no longer at risk, when the stereotypy is performed invariably and the level of performance is "stable" over time. Although "stable" performance of stereotypies may indicate some level of welfare, this does not mean that tethering is acceptable. Let us not forget that the animals had to endure severe stress loads in order to develop the stereotypies in the first place.

Thus the measurement of stereotypy behaviour characteristics may be an important addition to the existing techniques from different scientific disciplines currently used to measure welfare. Biologically, stereotypies are significant indicators of poor welfare, either in the past or present situation of the performer.

## Practical significance of stereotypy behaviour

The performance of stereotypies by tethered sows is clearly associated with intensive housing systems (Wood-Gush et al., 1975; Sambraus, 1982). Of the variety of different housing systems in common use, the incidence of abnormal behaviours (including stereotypies) was highest amongst tethered sows and lowest although not absent, amongst group-housed sows (Barnett et al., 1984). A factor of intensive housing that seems to be largely responsible for the development of stereotypies is physical restraint. As the degree of restraint increases, so the proportion of sows that stereotype, and their level of stereotypy performance, increases. Thus restraint per se may be the most stressful aspect for intensively housed sows. Habituation to a monotonous environment, another known cause of stereotypies (Keiper, 1969), may be less stressful compared with restraint. However, once sows learn to cope with restraint, they may encounter (further) problems with habituation.

Attempts to inhibit stereotypies by removing the object of use (e.g. water) may be futile, since sows can redirect their behaviour onto other fixtures, or even themselves. Minor improvement to the quality of sow housing, such as the provision of straw, has been shown by Fraser (1975) to reduce the level of abnormal behaviours performed by stalled gilts. The stereotypies of older sows however, were little affected by the provision of straw (Broom and Potter, 1984). Thus it is apparent that the quality of the environment of tethered sows needs to be radically improved before the development and performance of stereotypies can be avoided.

The performance of stereotypies has some direct consequences for sow productivity. Through stereotypy performance, sows may become highly active even though they are unable to locomote. Tethered sows with high activity levels had an increased metabolic rate and poorer feed conversion efficiency/growth than less-active tethered sows. As suggested by Cariolet and Dantzer (1984), "over activity" amongst tethered sows, and the consequent performance of stereotypies, may be associated with the occurrence of the "thin-sow" syndrome.

Stereotypies are responses to chronic stressors present in the environment of an animal. As such, the effectiveness of stereotypies in reducing stress has important consequences for all aspects of productivity. In response to adverse environmental conditions, pigs had a poorer immune response (Metz and Oosterlee, 1980), growth rate and feed conversion efficiency (Hemsworth et al., 1981), delayed sexual maturity (Hemsworth et al., 1983), and a higher culling rate due to reproductive failure (Cronin et al., 1982/83). The results reported in the present dissertation indicate an association between stereotypy performance level and litter size, and a possible association with mothering ability. Furthermore, the results indicate that not all sows can adequately cope with the stress of tethering, which in turn, may influence their chance of being culled due to poor productivity at an early stage in their productive life.

In view of the involved economic advantages of intensive housing, it would seem scarcely likely that extensive pig farming systems will return in the near future. However, improvement in the quality of present housing systems, such that chronic stressors are reduced and welfare is improved, will result in better productivity per sow. The causes of poor welfare lie in only some aspects of intensive housing. Tethering and long-term individual stalling, with their consequent restraints over the performance of exercise, comfortive and social behaviours, and the lack of bedding material/dietary roughage i.e. straw, would seem to be the worst aspects.

One of the most serious problem areas in modern pig production is the high culling rates amongst younger parity sows. The age structure of the herd is consequently heavily biassed towards younger sows and gilts. Possibly as much as 70% of breeding females are culled before their fourth parity, although precise figures are not known. In view of the fact that sows do not reach their most efficient reproductive phase (biologically and economically) until between the 4th and 7-8th parities (Verstegen, 1985, pers. comm.), this represents a potentially large loss in profitability to farmers.

Due to their high proportions in the breeding herd then, gilts and young sows make significant contributions to the overall productivity of the herd. Ironically, many of the factors reported to limit productivity of these animals, which further increase their chance of being culled out of the herd, are environmental in origin (e.g. Cronin, 1981; King et al., 1982). Thus in order to make gains in sow productivity, it is obvious that culling pressures on younger sows must be eased, so that sows can produce during a longer lifetime. Since poor welfare contributes towards these losses, improvements to the welfare status of animals is likely to provide significant improvements in the total profitability of pig enterprises.

Stereotypies are indicators of a poor environment and thus low welfare status. It should be the aim of all pig producers therefore, to achieve better welfare for their animals. Better welfare will undoubtedly result in higher profits, but also in reduced public displeasure at the current intensive husbandry systems which disregard the welfare of sows.

Farm animal welfare however, is a public issue with a wider level of interest than just farmers. It is the personal (moral and, or legal) responsibility of each member of society to ensure the best welfare (i.e. the absence of mental and physical suffering) for animals subjected to man's influence.

## References

Barnett, J.L., Hemsworth, P.H. and Cronin, G.M. 1982. The effect of mating on plasma corticosteroids in the female pig and the influence of individual and group penning on this response. Gen. Comp. Endocrin. 47: 516-521.

Barnett, J.L., Cronin, G.M., Winfield, C.G. and Dewar, A.M. 1984. The welfare of adult pigs: the effects of five housing treatments on behaviour, plasma corticosteroids and injuries. Appl. Anim. Beh. Sci. 12: 209-232.

Berger, P.A., Akil, H., Watson, S.J. and Barchas, J.D. 1982. Behavioural pharmacology of the endorphins. Ann. Rev. Med. 33: 397-415.

Berkson, G. 1968. Development of abnormal stereotyped behaviours. Develop. Psychobiol. 1: 118-132.

Broom, D.M. and Potter, M.J. 1984. Factors affecting the occurrence of stereotypies in stall-housed dry sows. In Proc. Int. Cong. on Appl. Ethol. in Farm Animals (ed. J. Unshelm, G. van Putten and K. Zeeb), pp. 229-231, Kiel, FRG.

Cariolet, R. and Dantzer, R. 1984. Motor activity of tethered sows during pregnancy. Ann. Rech. Vét. 15: 257-261.

Cronin, G.M. 1981. Oestrous behaviour in the gilt. M. Agr. Sci. Thesis, Uni. of Melbourne.

Cronin, G.M., Hemsworth, P.H., Winfield, C.G., Muller, B. and Chamley, W.A. 1982/83. The incidence of, and factors associated with, failure to mate by 245 days of age in the gilt. Anim. Repro. Sci. 5: 199-205.

Dantzer, R. and Mormède, P. 1983. De-arousal properties of stereotyped behaviour: evidence from pituitary-adrenal correlates in pigs. Appl. Anim. Ethol. 10: 233-244.

Duncan, I.J.H. and Dawkins, M.S. 1983. The problem of assessing "well-being" and "suffering" in farm animals. In Indicators Relevant to Farm Animal Welfare (ed. D. Smidt), pp. 13-24, Martinus Nijhoff Publishers, Boston, USA.

Duncan, I.J.H. and Wood-Gush, D.G.M. 1974. The effects of rauwolfia tranquillizer on stereotyped movements in frustrated domestic fowl. Appl. Anim. Ethol. 1: 67-76.

Feldman, R.S. 1978. Environmental and physiological determinants of fixated behaviour in mammals. 1st World Cong. on Ethol. Appl. to Zootech., Edit. Garsi, pp. 487-493. Madrid.

Fraser, D. 1975. The effect of straw on the behaviour of sows in tether stalls. Anim. Prod. 21: 59-68.

Hemsworth, P.H., Barnett, J.L. and Hansen, C. 1981. The influence of handling by humans on the behaviour, growth and corticosteroids in the juvenile female pig. Horm. and Behav. 15: 396-403.

Hemsworth, P.H., Barnett, J.L. and Cronin, G.M. 1983. The influence of the human-animal relationship on the productivity and welfare of the pig. Paper presented at the 34th EAAP Meeting, Madrid 1983. (mimeograph).

Inglis, I.R. 1983. Towards a cognitive theory of exploratory behaviour. In Exploration in Animals and Humans (ed. J. Archer and L. Birke), pp. 72-116, Van Nostrand Reinhold, UK.

Keiper, R.R. 1969. Causal factors of stereotypies in caged birds. Anim. Beh. 17: 114-119.

King, R.H. Williams, I.H. and Barker, I. 1982. Reproductive performance of first litter sows in a commercial intensive piggery. Anim. Prod. in Australia 13: 557-560.

Lewis, M.E., Mishkin, M., Bragin, E., Brown, R.M., Pert, C.B. and Pert, A. 1981. Opiate receptor gradients in monkey cerebral cortex: correspondence with sensory processing hierarchies. Science 211: 1166-1169.

Maier, N.R.F. 1949. Frustration. The Study of Behaviour Without a Goal.McGraw-Hill, New York.

Metz, J.H.M. and Oosterlee, C.C. 1980. [Behavioural and immunological responses in sows farrowed in crates compared with open pens with straw]. Actuelle Arbeiten zur artgemässen en Tierhaltung. KTBL-Schrift 264: 39-50.

Ödberg, F.O. 1978. Abnormal behaviours (stereotypies). 1st World Cong. on Ethol. Appl. to Zootech., Editorial Garsi, pp. 475-480, Madrid.

Overmier, J.B., Patterson, J. and Wielkiewicz, R.M. 1980. Environmental contingencies as sources of stress in animals. In Coping and Health (ed. S. Levine and H. Ursin), pp. 1-38, Plenum Press, New York and London.

Panksepp, J., Herman, B.H., Vilberg, T., Bishop, P. and De Eskinazi, F.G. 1980. Endogenous opioids and social behaviour. Neurosci. and Biobehav. Rev. 4: 473-487.

Sambraus, H.H. 1982. [Sow husbandry: how it is and how it could be]. In Ethologische Aussagen zur artgerechten Nutztierhaltung (ed. D.W. Fölsch and A. Nabholz), pp. 49-70, Birkhäuser Verlag, Basel.

Sambraus, H.H. and Schunke, B. 1982. [Behavioural disturbances in breeding sows kept in boxes]. Wien. tierarzl. Mschr. 69 Jahrgang heft 6/7: 200-208.

Smidt, D. 1983. Advantages and problems of using integrated systems of indicators as compared to single traits. In Indicators Relevant to Farm Animal Welfare (ed. D. Smidt), pp. 201-207, Martinus Nijhoff Publishers, Boston.

Stolba, A., Baker, N. and Wood-Gush, D.G.M. 1983. The characterization of stereotyped behaviour in stalled sows by information redundancy. Behaviour 87: 157-182.

Wiepkema, P.R. 1983. On the significance of ethological criteria for the assessment of animal welfare. In Indicators Relevant to Farm Animal Welfare (ed. D. Smidt), pp. 71-79, Martinus Nijhoff Publishers, Boston.

Wiepkema, P.R. 1985. Physiological aspects of fear. Proc. 2nd. World's Poultry Sci. Assoc., Celle, FRG. (in press).

Wiepkema, P.R. and Cronin, G.M. 1985. [Behavioural responses to stress]. Vakblad voor Biologen. (in press).

Wood-Gush, D.G.M., Duncan, I.J.H. and Fraser, D. 1975. Social stress and welfare problems in agricultural animals. In The Behaviour of Domestic Animals (ed. E.S.E. Hafez), pp. 182-200, Baillière Tindall, London.

## General summary

The development and performance of abnormal stereotyped behaviours (stereotypies) by tethered sows were studied in order to investigate the consequences of the behaviours for animal welfare and sow productivity.

In Chapter 2, the behaviour of 36 tethered sows in a commercial herd was analysed to determine the characteristics of stereotypies, and to enable their definition. The proportion of observation time that sows performed stereotypies was related to the stage of pregnancy, i.e. the time spent tethered in the current parity. Sows increased the proportion of time spent stereotyping between 10.00-14.00 h up to day 80 of pregnancy, after which stereotyping decreased.

Chapter 3 describes the process of development of stereotypies in sows after tethering. Sows were initially very vigorous and aggressive in their response to tethering. Stereotypies eventually developed after the sows had passed through a number of distinct stages, termed 1) escape attempt, 2) inactivity, 3) outward-directed activity and 4) basic stereotypy stages. The median durations (and ranges) of the first 3 stages were 45 min (10 to 180 min), 1 day (140 min to 16 days) and 15.7 days (7.8 to 55 days), respectively. Once a basic stereotypy was developed, random aggressive-like acts were rarely observed. The stereotypies that developed in response to tethering contained components that were directed at features in the sows' external environment (e.g. chains, drinker, bars, etc.), and were in part derived from redirected aggressive acts. Over time, the level of aggression declined and the actions were "rounded off". In stage 4, sows built larger stereotypies through the addition of new elements, although they could always revert to the performance of just the basic components.

It was concluded that environment-directed stereotypies develop as a result of frustration/conflict at being restrained, and the consequent loss of controllability over the environment.

An hypothesis was proposed which implicated endorphins (endogenous opiates) in the development and performance of stereotypies by tethered sows. Evidence to support this hypothesis is presented in Chapter 4. Eight tethered and 3 loose-housed sows were treated with saline and the specific opioid antagonist naloxone on consecutive days. The tethered and loose sows were treated while they performed stereotypies and exploratory behaviours, respectively.

Stereotypy performance levels were reduced in the 2 h following naloxone (median = 33% of the time) compared with saline (86%), but there was no effect on the performance of exploratory behaviour by loose sows. Many of the behaviours performed by the tethered sows after naloxone treatment were similar to behaviours performed by sows in response to initial tethering. Seven of the 8 tethered sows ceased the performance of their stereotypies in the short-term following naloxone. The latency to cease performance was positively related to the "age" of the particular stereotypy.

The results strongly suggest that endorphins may be the factor underlying the development and performance of stereotypies. Endorphins are released in response to stress, and in time, sows may learn to self-stimulate the release through the performance of stereotypies. Stereotypies probably function to reduce the perception of the negative aspects of the real environment, over which tethered sows have no control, and "rebuild" a new and possibly much reduced environment that they control through the performance of stereotypies. The results suggest that sows perceive tethering in a very negative way.

In Chapters 2, 3 and 4, it is reported that the stereotypies of tethered sows contain a certain amount of variability. For example, sows could vary the duration of stereotyped components between cycles of the stereotypy, or even omit components, and so on. Thus stereotypies were found to be considerably more variable than indicated by the classic definition of these behaviours.

It is suggested in Chapter 7 that this variability may be an indication that the sow had not adapted to the stress of tethering. The continued perception of negative aspects in the environment may stimulate the release of endorphins, but also introduces variability into the performance of stereotypies.

Stereotypies are behavioural indicators of past or current poor welfare status, a phenomenon which may be quantifiable via measurement of the degree of variabilitiy in stereotypy performance.

Since stereotypies develop out of chronic stress situations, and since it has been reported that chronic stress influences the productivity of pigs, it was expected then that the performance of stereotypies may have consequences for sow productivity.

In Chapter 5, tethered sows in a commercial herd were categorized according to the proportion of observation time between 10.00 and 14.00 h that they performed stereotypies. Within parity x pregnancy stage classes, non-lactating sows were classed as either HIGH or LOW stereotypers if they performed more or less than the mean level. At the farrowing prior to observation, HIGH stereotypers produced larger litters in parities 2 and 3, but smaller litters in parities 5 and 6, than LOW stereotypers. At the farrowing after observation, HIGH stereotypers tended to produce smaller litters in parities 5 and 6 than LOW stereotypers. Low parity number sows were less stable than older sows, in that more than half of the younger sows observed in successive parities changed stereotypy performance class between observations. Hence, the effects of stereotypy performance level on litter size of low parity number sows at the farrowing after observation were not consistent with those from the farrowing before observation.

Contrary to expectation, the LOW stereotypers also tended to be less reactive to novel stimuli than HIGH stereotypers, suggesting that the former sows were "less normal" than the latter. The results further suggest that sows may be subject to chronic stress for at least 2 to 3 parities before adapting to tether housing. Young sows that were able to develop a stereotypy more rapidly (i.e. HIGH stereotypers), coped better in the short-term than LOW (non-coping) stereotypers.

In Chapter 6, the metabolic rate and behaviour of sows were measured. The 2 treatments of sows had different degrees of adaptation to tethering. The experienced tethered sows were active stereotypers (HIGH sows) and the inexperienced tethered sows (T/LOW) were relatively inactive at the time of the experiment. The latter sows were released into a group (G/LOW) half-way through the experiment, for a comparison of tethered versus loose-housed sows.

HIGH sows were about 3 times more active than T/LOW sows, due mostly to high stereotypy performance levels amongst the former sows. HIGH sows produced 35.7% more heat than the T/LOW sows during the 12 h light period of the day. During this period, 40.2% and 20.1% of heat production from HIGH and T/LOW sows was associated with activity. In comparison, G/LOW sows were slightly more active than T/LOW sows, with 23.5% of heat production being associated with activity.

Stereotypy behaviour and excessive drinker manipulation by the HIGH, T/LOW and G/LOW sows accounted for 86, 52 and 24% of activity. The proportion of metabolizable energy intake required for these activities were 23, 7 and 4%, respectively, for sows in the 3 treatments. The results of the experiment indicate that tethering is stressful because of the need for sows to develop and perform large quantities of "coping behaviours", and the association with increased metabolic rate. It was also suggested that during the experiment, the T/LOW sows were following a path of adaptation to tether housing similar to that experienced earlier by the HIGH sows.

Thus it is apparent that there is a positive association between welfare status and productivity of sows. Improvements in the welfare status of non-lactating sows will result in improved sow productivity. In the situation of the commercial environment, improvements to welfare status can only occur through improvements in the quality of the environment, for example by the removal of chronic stressors such as restraint.

## Samenvatting

De ontwikkeling en het uitvoeren van abnormale stereotype gedragingen (stereotypieen) werden bij aangebonden zeugen onderzocht met de bedoeling inzicht te verkrijgen in de betekenis van deze gedragingen voor het welzijn en de productiviteit van deze zeugen.

Hoofdstuk 2 biedt een analyse van het gedrag van 36 onder praktijkomstandigheden gehouden zeugen. Deze analyse was gericht op het karakteriseren en definiëren van stereotypieën. De tijdsduur besteed aan stereotypieën bleek af te hangen van het stadium van de dracht of wel van de tijd die de zeug reeds aangebonden had doorgebracht sedert het begin van de betrokken dracht. Tot dag 80 ging deze tussen 10.00 en 14.00 uur gemeten "stereotypietijd" omhoog, daarna nam deze tijd af.

Hoofdstuk 3 beschrijft de ontwikkeling van stereotypieën bij zeugen vanaf het moment van aanbinden. De zeugen verzetten zich aanvankelijk heftig en agressief tegen dit aanbinden, maar uiteindelijk ontstaan stereotypieën in een proces waaraan een viertal fasen zijn te onderscheiden: 1) fase vanpogen te ontsnappen, 2) fase van inactiviteit, 3) fase met op de omgeving gerichte activiteit en 4) de fase met de stereotypieën. De mediane duren van de eerste 3 fasen waren respectievelijk 45 min (10-180 min.), 1 dag (140 min. - 16 dagen) en 15.7 dagen (7.8-55 dagen). Na het verschijnen van echte stereotypieën waren agressieve uitingen zeldzaam. De stereotypieën die als reactie op het aanbinden ontstonden bevatten elementen, die op onderdelen van het externe milieu waren gericht (bijv. ketting, drinknippel, stangen). Deze stereotypieën bleken afgeleid te kunnen worden van omgerichte agressieve handelingen. In de loop van de tijd verdween het agressieve karakter van deze handelingen. Ze werden afgerond. In fase 4 ontwikkelden de zeugen omvangrijker stereotypieën door nieuwe elementen aan reeds bestaande toe te voegen. Ze konden echter te allen tijde terugkeren naar de uitvoering van alleen de basiselementen.

Deze gegevens leidden tot de conclusie dat op de omgeving gerichte stereotypieën het resultaat zijn van frustratie of conflict veroorzaakt door het vastgezet worden en, daaruit volgende verlies van beheersbaarheid van de omgeving.

In hoofdstuk 4 wordt de hypothese geopperd dat endorfines betrokken zijn bij de ontwikkelingen en uitvoering van stereotypieën bij aangebonden zeugen. Om deze veronderstelling te toetsen werden 8 aangebonden en 3 loslopende zeugen behandeld met achtereenvolgens een fysiologische zoutoplossing (injectie op dag 1) en een specifieke opioide antagonist naloxon (injectie op dag 2). De dieren kregen de injectie op een tijdstip dat ze veel stereotypieën vertoonden (de aangebonden zeugen) of veel exploratief gedrag (de loslopende zeugen). In de 2 uren na de naloxon injectie werd nog maar 33% van de waarnemingstijd besteed aan stereotypieën in vergelijking met 86% na fysiologische zout injectie. Naloxon had geen invloed op het optreden van exploratief gedrag van de loslopende zeugen. Veel van de gedragingen die bij de aangebonden dieren optraden na de naloxon behandeling leken sterk op die welke te zien waren als reactie op het eerste aanbinden. Zeven van de acht aangebonden zeugen stopten volledig met stereotypieën in de periode direct na de naloxon toediening. De latentietijd van dit stoppen bleek positief gecorreleerd met de "leeftijd" van de betrokken stereotypieën.

Deze resultaten wijzen er sterk op dat endorfines te maken hebben met het ontstaan en optreden van stereotypieën. Endorfines worden vrijgegeven bij stress en in de loop van de tijd zouden zeugen kunnen leren via een soort zelfstimulatie deze afgifte in de hand te krijgen. Stereotypieën hebben zodoende als waarschijnlijke functie de perceptie van de negatieve aspecten van de omgeving te verminderen. Zo'n negatief aspect is in dit geval het ontbreken van enige invloed op de omgeving. Stereotypieën dragen bij aan de vorming van een nieuwe, maar vermoedelijk zeer gereduceerde omgeving die wel door de dieren beheerst wordt. Deze gegevens pleiten als geheel voor de conclusie dat zeugen het aangebonden zijn als zeer negatief ervaren.

In de hoofdstukken 2, 3 en 4 wordt vermeld dat stereotypieën van aangebonden zeugen toch nog een zekere variabiliteit bezitten. Zo kon de duur van een stereotype element van cyclus tot cyclus variëren of konden zelfs van tijd tot tijd elementen van een gegeven cyclus ontbreken. Stereotypieën bleken aanzienlijk meer variabel dan de gebruikelijke definities van deze gedragingen doen vermoeden.

In hoofdstuk 7 wordt besproken in hoeverre deze variabiliteit een aanwijzing is van een nog niet bereikte aanpassing aan de situatie (aangebonden zijn). De voortdurende perceptie van negatieve aspecten van de omgeving mag de afgifte van endorfines bevorderen, het kan tegelijkertijd ook de genoemde variabiliteit veroorzaken. Stereotypieën zijn gedragsindicatoren voor een vroeger of huidig laag welzijnsniveau, waarbij de variabiliteit van deze stereotypieën mogelijk een meer kwantitatief licht werpt op de mate van het welzijnstekort.

Aangezien stereotypieën bij chronische stress ontwikkelen en omdat zulk een chronische stress de productiviteit van varkens beïnvloedt, mag verwacht worden dat het optreden van stereotypieën de één of andere samenhang met maten voor productiviteit zal vertonen. In hoofdstuk 5 wordt dit aspect onderzocht, door in een praktijksituatie de zeugen in 2 groepen te verdelen; dieren die veel en dieren die weinig stereotypieën vertonen (tussen 10.00 en 14.00 uur). De dieren werden verder gerangschikt naar pariteit en fase van de dracht bij het waarnemen. Het bleek dat de "veel stereotypie" dieren in vergelijking met de "weinig stereotypie" in pariteiten 2 en 3 grotere tomen hadden voorafgaand aan de waarneming, in pariteiten 5 en 6 echter kleinere.

De tomen na de waarneming waren voor de "veel stereotypie" dieren in pariteiten 5 en 6 echter wat kleiner dan die van de "weinig stereotypie" dieren. Jongere zeugen veranderen vaker van klasse (veel of weinig stereotypieën) in opeenvolgende pariteiten; zo'n verandering kwam bij meer dan de helft van de jongere zeugen voor. Dit draagt ertoe bij dat de relatie tussen stereotypie niveau in een gegeven waarnemingsperiode (dracht) met toomgrootte daarvoor of daarna verschillend is.

Anders dan verwacht leken de "weinig stereotypie" dieren minder op onbekende stimuli te reageren dan de "veel stereotypie" dieren. Dit suggereert dat de eerste groep "minder normaal" was dan de tweede. De gegevens doen vermoeden, dat de chronische stress toestand waarin de dieren verkeren niet vóór de 2e of 3e pariteit tot een zekere aanpassing leidt. Jonge zeugen die in staat waren snel veel stereotypieën te ontwikkelen lijken beter te reageren dan de dieren die in eerste instantie weinig stereotypieën tonen.

Metabolisme en gedrag van zeugen worden in hoofdstuk 6 beschreven. De 2 behandelingen van de zeugen brachten een verschillende mate van adaptatie aan het vastzetten mee. Er was een ervaren groep aangebonden zeugen die veel stereotypieën vertoonde (H zeugen) en een minder ervaren aangebonden groep die relatief weinig activiteiten tijdens de proef vertoonde (T/L zeugen). Halfweg de proef werden de laatste dieren losgemaakt en als groep gehuisvest (G/L zeugen). De H dieren waren ongeveer 3 maal zo actief als de T/L dieren en dit was hoofdzakelijk het gevolg van het hoge stereotypie niveau in de H groep. De H dieren produceerden 35.7% meer warmte dan de T/L dieren gedurende de lichtperiode (12 uren) van een etmaal. In deze periode was 40.2% en 20.1% van de warmteproduktie van respectievelijk de H en de T/L dieren toe te schrijven aan de waargenomen activiteit. De G/L dieren waren wat actiever dan de T/L dieren, waarbij 23.5% van de warmteproduktie met activiteit was geassocieerd.

Stereotypieën en overdreven bezig zijn met de drinknippel verklaarden bij de H, de T/L en de G/L dieren respectievelijk 86%, 52% en 24% van deze activiteit. Het deel van de opgenomen en metaboliseerbare energie benodigd voor deze activiteiten was voor de 3 gevallen respectievelijk 23%, 7% en 4%. De resultaten van dit experiment wijzen erop, dat aanbinden veel stress meebrengt getuige het vele en intensieve aanpassingsgedrag en de waargenomen stijging van het metabolisme. De gegevens suggereren bovendien, dat de T/L dieren een adaptatieproces doormaken dat vergelijkbaar is met wat de H dieren reeds zijn gepasseerd.

Het is vrij duidelijk dat er een positieve samenhang bestaat tussen de mate van welzijn en productiviteit van de zeug. Verbeteringen van welzijn van drachtige zeugen zal dan ook de productiviteit van deze zeugen verbeteren. In de huidige praktijk kan een beter welzijn alleen gerealiseerd worden door verhoging van de kwaliteit van de omgeving der dieren. Zulk een kwaliteitsverhoging wordt gerealiseerd als zeugen niet meer door het vastzetten in haar bewegingsvrijheid worden beperkt.

## Curriculum vitae

Gregory Michael Cronin was born at East Melbourne, Victoria, Australia, on 5 December, 1954. His secondary education was undertaken at Marcellin College, Bulleen, and on 19 January 1973 he matriculated at the University of Melbourne. On 19 March, 1977 he graduated as a Bachelor of Agricultural Science (Melb). In the following September he was promoted to the position of Agricultural Scientific Officer, Animal Behaviour Section, Department of Agriculture, Animal Research Institute, Werribee. During the ensuing 5 year period he carried out research and extension activities in the area of production losses due to inadequate reproductive behaviour of gilts and maiden ewes, and sow welfare. In March 1982, he was awarded the degree of Master of Agricultural Science (Melb) for his thesis "oestrous behaviour in the gilt". In July 1982, he began Ph.D. studies under the supervision of professor P.R. Wiepkema, in the Ethology Section, Department of Animal Husbandry, Landbouwhogeschool, Wageningen, on the development and significance of stereotyped behaviour in the sow. These studies are being financially supported by a post-graduate scholarship from the Australian Pig Industry Research Committee, while he is on study leave from the Victorian Department of Agriculture.