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ANIMAL RESEARCH PAPER

Objectively measuring behaviour traits in an automated restraint-test for ungulates: towards making temperament measurable

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SUMMARY

The personality of an animal is described by traits that cause consistent actions and reactions to environmental stimuli. An important part of personality is the reaction to unpleasant or uncontrollable situations. Methods described in the literature to measure personality in animals are often based on measuring or rating escape behaviour in these situations. In the methods described, human handlers are frequently part of the experiment or the animals' personalities are scored by humans. Thus, these methods are at least partly subjective.

In the current study, an appliance to measure objectively the escape behaviour of ungulates and their reluctance during an uncontrollable situation (restraint) with a rather simple and comprehensible methodology is presented using a force transducer with adequate peripheral equipment. While the animals were restrained, a tractive force-time diagram describing escape behaviour was recorded and later analysed with software developed specifically.

To evaluate this newly developed technical method, 24 three-month-old calves were restrained by being tethered for 30 min on a halter that was connected to the force transducer. From the tractive force-time diagram, tractive force, maximal tractive force and the number of pulls that the calves performed during 5-min intervals were calculated. The multivariate results were analysed with a *k*-means-algorithm (function 'kcca') and a hierarchical clustering (function 'hclust') included in R version 2.12.1.

Both analyses revealed two clearly separated clusters including the same individuals in each analysis. The animals of cluster 1 showed a continuously higher reaction level than those of cluster 2 with a strong reaction in the beginning, a short decrease before increasing during the middle of the experiment and a final decrease at the end of the test. The animals of cluster 2 had a lower and quite steady reaction level throughout the experiment, although even here a slight increase during the middle of the experiment could be detected before a final decrease towards the end of the test was shown. There was no significant difference in weight between the two clusters.

The results showed that this newly developed method was able to detect differences in the animals' escape behaviour patterns and reluctance with the measured parameters.

INTRODUCTION

The general strategy an individual employs to act with and react to environmental stimuli describes his or her personality and is thought to be innate and consistent over time (Grandin 1993; Grignard *et al.* 2001) and in different situations (Forkman *et al.* 2007). Individual differences in behaviour between animals can not only be caused by sex, age, reproductive status and environment; hence, they reveal the personality of an individual (Manteca & Deag 1993; Locurto 2007). In cattle, personality traits influence the ease of handling (Matthews *et al.* 1997; Burrow 1998), live weight gains in feedlots (Voisinet *et al.* 1997*a*; Fell *et al.* 1999) and on pasture (Fordyce *et al.* 1985, 1988*a*), carcass damage (Fordyce *et al.* 1988*b*) and meat quality

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(Voisinet *et al.* 1997*b*; Fordyce *et al.* 1988*b*). Since the welfare of an animal depends on its ability to cope with its environment (Broom 1988), personality is an important factor in animal welfare and in breeding. Some official breeders have already added certain personality traits to their breeding goals (e.g. Fleischrind Stölln GmbH 2007; Traditional Herefords 2008).

According to Manteca & Deag (1993) there are three ways of assessing personality-relevant behaviours: (i) standard behavioural observation; (ii) observers' rating with the help of predefined categories; and (iii) behavioural tests. In many of these tests, human interaction with the tested animals is inevitable or part of the tests themselves (for descriptions of common methods of personality trait and temperament measurements, see, e.g. Manteca & Deag 1993; Burrow 1997; Lanier *et al.* 2000; Waiblinger *et al.* 2006; Forkman *et al.* 2007). Some methods are therefore at least partly subjective and judgemental, especially when categories are used. According to the mood-biased judgement hypothesis, human judgements will be positive during a good mood and negative during a bad mood (Mayer 1986). Thus, when measuring personality traits, the results of judgemental methods are always influenced by the mood of the observer during the rating and by what the observer thinks is a positive or a negative judgement of the animals. Thus, inter- and even intra-observer reliability are difficult to obtain (Welfare Quality® 2009); however, an objective, reliable and observer- and mood-independent method of measuring personality traits is required, especially for practical purposes such as when animals are selected for breeding.

The measurement or rating of the motivation of an animal to elude an unpleasant or frightening situation either while restrained or while moving freely is common for many behavioural tests, such as the crush-test or the human-approach-test. The behaviour shown in these situations is either fear-related escape behaviour or an expression of the animal's dislike of the situation. It describes an important part of personality (Kilgour *et al.* 2006; Benhajali *et al.* 2010) and with regard to restraint situations, it is characterized by three main features: the number of escape attempts per time unit, the maximal force and the force per time unit. However, the often-used crush-test measures the behaviour indirectly by having observers judge the strength, frequency and duration of escape attempts and rating the animals according to a predefined category scale (Grandin 1993; Kilgour *et al.* 2006; Benhajali *et al.* 2010; Gibbons *et al.* 2011). Other tests developed, such as the docility test, can be time-consuming and rather complicated to execute (Le Neindre *et al.* 1995; Boivin *et al.* 2009), and human interaction with the animals (Boissy & Bouissou 1988) and observer-dependent rating are fundamental parts of the tests (Grandin 1993).

In the current study, an appliance is introduced that allows objective measurement of the escape behaviour and reluctance in young cattle restrained by being tethered on a halter, independently of the impact and rating of a more or less subjective observer or handler.

MATERIALS AND METHODS

Animals and housing

Animals in an existing breeding experiment were used to test this new measuring appliance. Twenty-four calves (12 male, 12 female) of the F_2 generation of a cross-breeding of Holstein–Friesian and Charolais were tested at 90 days (±3 days) of age. All calves were bred via embryo transfer into unrelated Holstein Friesian heifers as recipient mothers and born and tested between 2004 and 2010.

The calves were kept in various small groups of up to nine animals of similar age separate from their recipient mothers from day one. Pens were 6 × 7 m and were covered with deep litter. Each pen contained two hay racks, one milk feeder, one concentrate feeder and one drinking trough for water supply. Until 90 days of age, the calves were not subject to any other experiment, and handling did not exceed routine handling by the animal keepers except in the case of animals requiring treatment for sickness.

After weaning, the animals were weighed at an age of 111 days (±3 days). The weight at the day of the experiment was calculated with the help of the average daily weight gain from birth to weaning and the exact age at the experiment. On average the calves weighed 115 kg (range: 89–144 kg, S.D. ±13 kg) at the day of the experiment.

Measuring appliance and experimental outlay

To measure escape behaviour and reluctance in calves, the animals' expended power was recorded during a restraint situation (further called pulling-test) with the force transducer Megatron KT1400 (Megatron Elektronik AG & Co., Putzbrunn, Germany; Fig. 1). Its measuring principle is a DMS Wheatstone bridge.

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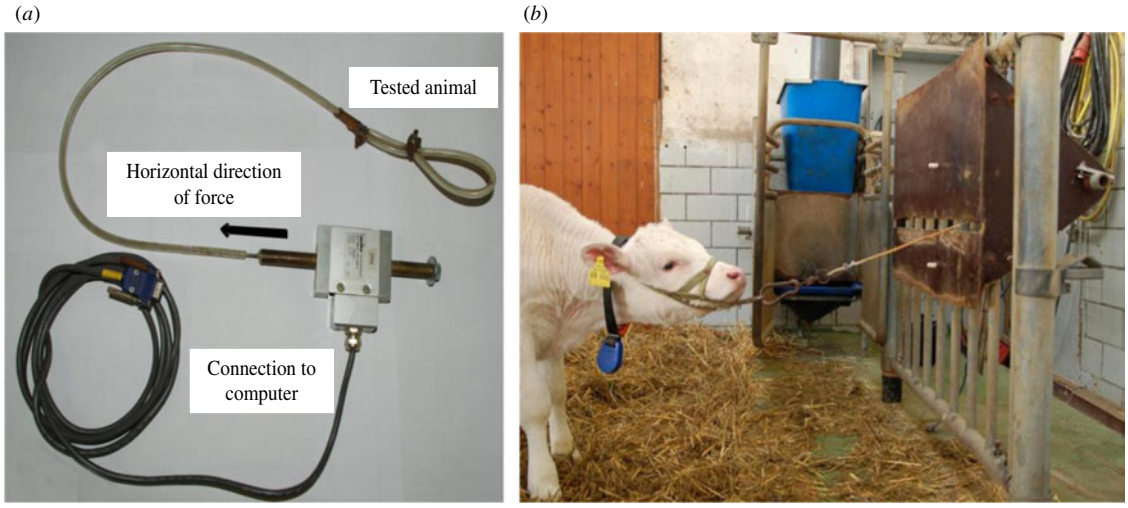


Fig. 1. (*a*) Force transducer Megatron KT1400 with the cable leading to the tested animal and the computer-interface connection; (*b*) a calf restrained during the pulling-test, put on a halter and tied with the cable to the force transducer hidden behind the wooden shield to the right.

With a signal of 0–5 V, it is calibrated from 0 to 1 kN, and it is useful for applications with traction force because of its S-beam shape. An M8 internal screw thread is used for force application.

The force transducer was connected with an analogue/digital interface (NI PCI-6503, National Instruments Germany GmbH, Munich, Germany) to a PC (Fig. 1*a*) and was built onto a metal bar of the home pen of the animals so that the cable elongated the force direction of the transducer (see pulling calf in Fig. 1*b*), which was essential to avoid resultant force.

During the pulling-test the tested calf stayed in one-half of its home pen, while the pen mates were confined to the other half of the pen using metal bars to avoid falsifying the measurement. Visual, acoustic and olfactory contact between the test calf and its pen mates therefore persisted, in the hope of minimizing the effects and influences of isolation. The test calves were captured, put on a halter and tied to the cable leading to the force transducer (Fig. 1*b*). The software recording the tractive force developed for the current study was then initiated and all human handlers left the barn. After a 30 min recording period, a handler entered the barn, released the test calf and reunited it with its pen mates, which were allowed back into the experimental part of the pen.

All procedures involving animal handling and treatment were approved by the Committee for Animal Use and Care of the Ministry of Agriculture, the Environment and Consumer Protection of the federal state Mecklenburg-Vorpommern, Germany.

Recording and parameters of tractive force

Data measured by the force transducer were digitized with a sampling rate of 20 Hz and were transferred to a computer. A software program using LabView 6.1 (National Instruments GmbH Germany, Munich, Germany) was developed to save the tractive force-time diagram and to calculate the parameters from this diagram. The software included two applications: a recording program, which saved the force-time diagram with a time stamp during the complete recording period (Fig. 2), and an analysing program, which analysed the force-time diagrams in the lab. With the recording program one could freely choose sampling rate and the start time and duration of the recording period. The analysing program made it possible to choose interval length for analysis.

In the experiment, the 30-min recording period was divided into six 5-min intervals, and for each interval, the following parameters were calculated:

- Total force: an integral of the tractive force diagram in kNs consisting of:
  - Tractive force: an integral of positive values of the derivation of the tractive force diagram (meaning only the upward tractive phases) in kNs (force multiplied by time that a calf pulls upwards on the cable).
  - Holding force: an integral of zero values of the derivation of the tractive force diagram (meaning only the holding tractive phases) in kNs (force multiplied by time that a calf pulls on the cable

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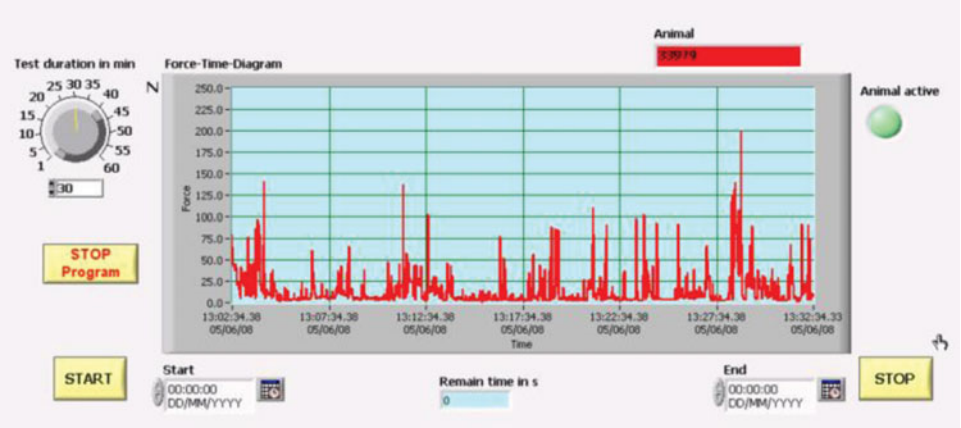


Fig. 2. Screenshot of a force-time diagram from the recording program in the barn.

with stable effort; i.e. 'hanging' in the cable without moving).

- Dwindling force: an integral of negative values of the derivation of the tractive force diagram (meaning only the downward tractive phases) in kNs (force multiplied by time that a calf pulls on the cable with downward effort; i.e. stops pulling on the cable).

– Number of pulls: a local maxima of the tractive force diagram above a threshold level of 60 N (empirical value).
– Maximal tractive force: the highest amplitude of the tractive force diagram (global maximum) in N.

To eliminate high-frequency perturbations, the recorded diagram was smoothed with a moving average ($n = 10$).

The procedures 'integral' and 'derivation' used to calculate the parameters were part of the program library of LabView. The numerical integration was performed with the trapezoidal rule, which calculates the integral with consecutive applications of the basic formula. The basic formula to calculate the partial sum with the trapezoidal rule is:

$$\text{partial sum} = \frac{1}{2}(x_i + x_{i+1}) \times \mathrm{d}t \tag{1}$$

for $i = 0, 1, 2, 3, 4, \ldots,$ whole-number part of $(N–1)$, where N is the number of points of the whole plot and x is the initial array.

The result was the sum of these consecutive partial calculations:

$$\text{result} = \int_{t_0}^{t_1} f(t)\mathrm{d}t = \sum_j \text{partial sum} \tag{2}$$

where j is the range depending on the number of measuring points.

The discrete differentiation was carried out with a second-order differentiation method. The differentiation $f(t)$ of the function $F(t)$ is defined as follows:

$$f(t) = \frac{\mathrm{d}}{\mathrm{d}t}F(t) \tag{3}$$

Y is given as sampled start sequence $\mathrm{d}X/\mathrm{d}t$. When using the second-order method, Y is calculated with the following equation:

$$Y_i = \frac{1}{2\mathrm{d}t}(x_{i+1} - x_{i-1}) \tag{4}$$

for $i = 0, 1, 2, \ldots, n–1$, where n is the number of values in $x(t)$, x_{-1} is the first value in the start constraint and x_n is the first value of the final constraint.

The local and global maxima of the tractive force-time diagram were calculated with the subprogram 'peak detection' from the program library of LabView, which works with an algorithm fitting a quadratic polynomial to moving data blocks. The width of the quadratic polynomial determines the number of measuring points; in these analyses, a width of 5 was convenient (empirical value).

Statistical analysis

The parameters tractive force, maximal tractive force and number of pulls were used in the current exemplary analysis. The other two parameters were left aside to improve clarity in the results; therefore a parameter vector with a dimension of 18 (three parameters at six 5-min intervals) was used. Since the measured parameters of the vectors were multivariate, multivariate analyses with the statistics program R

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version 2.12.1 (R Development Core Team 2008) were conducted. The aim was to classify the different reactions of the tested animals on the basis of the parameter vectors without *a priori* knowledge. The *k*-means-algorithm ('kcca') was used to perform a *k*-centroids clustering on the data matrix (Leisch 2006). The algorithm forms a predetermined number of *k* differing clusters with similar subjects from the data volume. Since the number of clusters *k* is unknown per default, the algorithm was conducted iterative from $k=2$ to $k=20$. The *k*-means-algorithm is dependent on the initial conditions and can yield different results. Thus, the algorithm was conducted 20 times with randomly differing initial conditions for each number of clusters *k*. By using the score of the 'silhouette' function, the optimal number of clusters was determined. For each observation *i*, the silhouette score S_i is defined as follows:

$$S_i = \frac{b_i - a_i}{\max(a_i - b_i)} \quad (5)$$

where a_i is the average dissimilarity between *i* and all other points of the cluster to which *i* belongs, and b_i is the minimum of all average dissimilarity of *i* to all observations and can be seen as the dissimilarity between *i* and its neighbouring cluster, i.e. the nearest one to which it does not belong.

A hierarchical cluster analysis (Euclidean distance, complete linkage) was performed with the function 'hclust', which uses a set of dissimilarities for the clustered objects. At first, each object is allocated to its own cluster and then the algorithm proceeds iteratively by stepwise combining of the two most similar clusters and continuing until there is only one single cluster. At each stage, metric Euclidean distances between clusters are recomputed by the Lance–Williams dissimilarity. The result of this clustering can be shown graphically in a dendrogram. The animals' weights were tested for differences between the clusters with Welch's two-sample *t*-test.

RESULTS

Raw data

The escape behaviour and reluctance of the calves were described by tractive force, maximal tractive force and the number of pulls during 5-min intervals (Fig. 3). The majority of the calves showed a very similar behavioural pattern, especially with regard to the tractive force and number of pulls. The tractive force decreased from about 2 kNs at the beginning to 1 kNs at the end of the restraint situation. The number of pulls ranged from 5 to 10 for most calves and showed only a slight decrease across the 30 min. Several animals, however, showed higher values in both these parameters (Fig. 3).

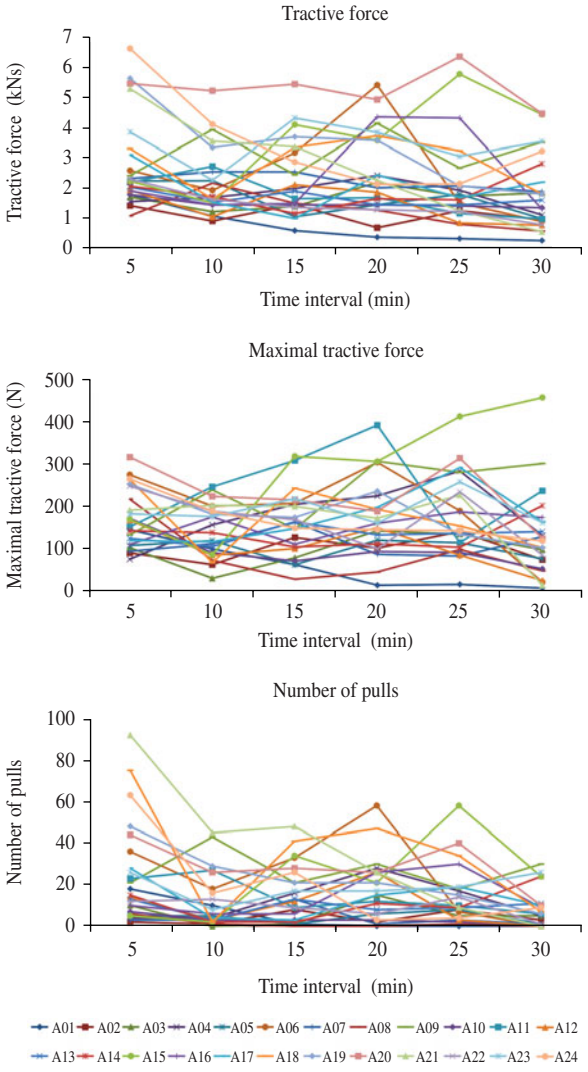


Fig. 3. Tractive force in kNs, maximal tractive force in N and number of pulls of calves tied to a force transducer for 30 min summarized in 5-min intervals.

Clustering

The silhouette function commended a cluster number of two when clustering with the *k*-means-algorithm 'kcca' without *a priori* knowledge and also when using the function 'hclust'. The latter function enabled the data structure and clustering to be displayed graphically via a dendrogram (Fig. 4). Both clustering

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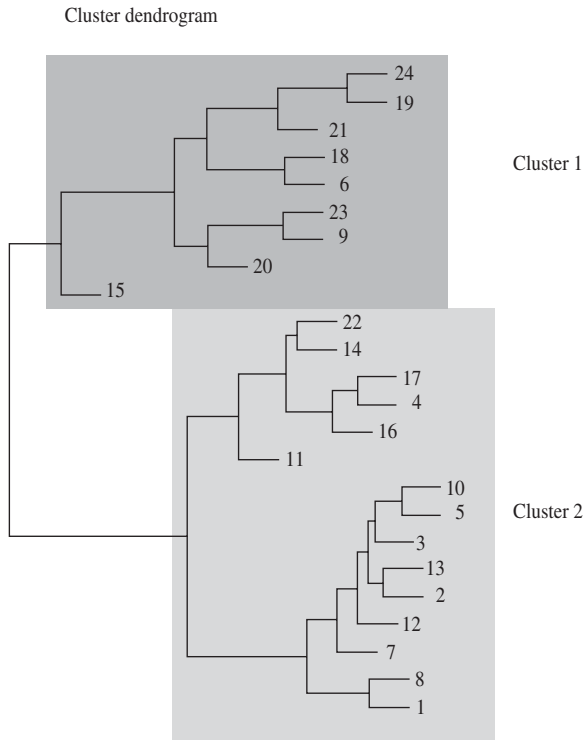


Fig. 4. Graphical display of the data structure of the 24 calves during the pulling-test shown as a cluster dendrogram.

methods allocated the same individuals into two clusters (Table 1). The first sub-structure to be found was named cluster 1 (four male and five female calves), and the next was named cluster 2 (eight male and seven female calves). Table 1 lists each individual in the clusters, its weight and sex. In cluster 2, two sub-clusters could be determined. The animal A15 could clearly be determined as an outlier in all three parameters and A06 showed a strong increase in reaction until the 20-min interval in all parameters (Fig. 3). A20 showed a continuously high tractive force level and A11 increased its maximal tractive force until the 20-min interval (Fig. 3). The mean weight of the animals in the two clusters was 117 kg (S.D. ±11 kg, range: 101–135 kg) for cluster 1 and 114 kg (S.D. ±14 kg, range: 89–144 kg) for cluster 2, and did not significantly differ from each other ($t = 0.77$; $P = 0.452$).

The mean values over time (± S.D.) in each cluster are shown in Fig. 5 for the three measured parameters showing a distinct differentiation. In all parameters, the curve for cluster 1 is clearly above that for cluster 2. The curves of both clusters showed similarities with the highest values in the beginning of the pulling test, a decrease over time and a slight increase in the middle of the test before decreasing even further towards the end. However, this pattern was far more distinctive in cluster 1 than in cluster 2. Furthermore, the variability in the tractive force and number of pulls was larger in cluster 1 than in cluster 2, although the latter consisted of more animals. Despite slight decreases and increases, the calves in cluster 2 displayed a relatively stable reaction level throughout the recording period.

Table 1. *Animal, sex and weight (kg) of the calves to cluster 1 and 2 analysed with the functions 'kcca' and 'hclust' in R; the number of an animal indicates the number in the cluster dendrogram (Fig. 4); m = male, f = female*

Animal	Sex	Weight (kg)	Clustering method	
			k-means	hclust
A01	f	106	2	2
A02	m	116	2	2
A03	f	118	2	2
A04	m	112	2	2
A05	f	101	2	2
A06	f	103	1	1
A07	m	98	2	2
A08	m	89	2	2
A09	m	135	1	1
A10	m	122	2	2
A11	f	112	2	2
A12	f	108	2	2
A13	m	108	2	2
A14	m	125	2	2
A15	f	110	1	1
A16	f	131	2	2
A17	m	144	2	2
A18	m	117	1	1
A19	m	124	1	1
A20	m	126	1	1
A21	f	123	1	1
A22	f	114	2	2
A23	f	117	1	1
A24	f	101	1	1

DISCUSSION

The current paper presents a technical method to record objectively the individual escape behaviour and reluctance in calves during restraint. The appliance can be used by anyone anywhere in the world, trained or untrained, educated or not, in any housing system (except for old-fashioned tied-barns) and will yield objective comparable results. Escape behaviour in a restraint situation is an important element of

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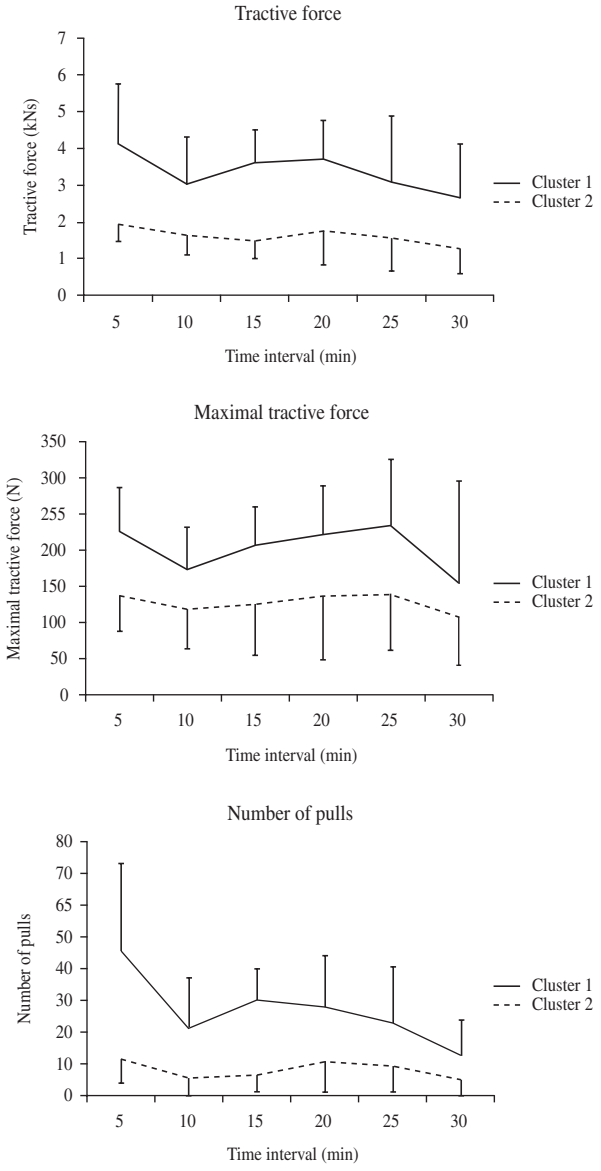


Fig. 5. Diagrams of the mean values over time (±S.D.) of the three measured parameters tractive force in kNs, maximal tractive force in N and number of pulls for cluster 1 and 2.

personality in prey animals (Boissy 1995; Koolhaas *et al*. 2010). One can expect that animals with different personality traits display differing behaviour patterns that can be classified according to their main features. Therefore, its standardized measurement has the potential to become an element of an easily applicable test in future breeding programme when phenotyping animals' personalities (Benhajali *et al*. 2010). So far, beef producers willing to include personality to the breed value of their cattle are instructed to measure flight time when leaving a crush once and use this simple measure to describe an animal's temperament (Gaden *et al*. 2004). To our knowledge, the behaviour of cattle during a restraint or tethered situation has either been described with temperament scores (e.g. Grandin 1993; Lanier *et al*. 2000) or has been observed and measured behaviourally (Boissy & Bouissou 1988), but until now this behaviour has only rarely been measured physically (Veissier *et al*. 1989).

With the animals tested in the current experiment, two different behaviour patterns revealing two intensities in the reaction were found. It is likely that more behaviour patterns would be found when testing more animals, e.g. one that shows an increase towards the end of the recording period or one with a constantly high reaction level. The first decrease in the reaction of the calves of cluster 1 could reflect exhaustion but could also be due to an initial evaluation of other possibilities for escaping from the restraint, since pulling has not worked so far. When no possibility was found and the calves had rested briefly, a new increase in reaction level could be detected. Calves of cluster 2 consistently showed a low level of reaction. Coleman *et al*. (2005) found that rhesus macaque monkeys that showed a quick reaction to an unknown stimulus were faster in learning a task by operant conditioning than individuals showing a slower or no reaction to an unknown stimulus; thus the animals of cluster 1 in the current study might be disadvantaged in other, different, situations. However, to evaluate this statement, further research needs to be conducted.

In the current study, data from one single measurement per animal at 90 days of age are presented. The young age of the calves tested made it possible to ensure similar housing conditions for both male and female animals. However, the repeatability and hence the reliability of the assessed behaviour pattern of each calf needs to be investigated. Grandin (1993) suggested three repetitions of temperament-scoring in her study on slightly older male cattle, to gain reliable results.

The reaction to the restraint is clearly not the only parameter defining the personality of cattle. Reactions toward humans may be similarly important. However, these reactions depend on the experience an individual has had with humans and are therefore not only dependent on personality traits but also highly influenced by the age of the animals, previous experience and the human himself (de Passillé *et al*. 1996). The behavioural reaction towards a restraint situation where the animals have the possibility to accept the restraint or not, as in the docility test

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(Le Neindre *et al.* 1995; Boivin *et al.* 2009), are especially important for agricultural practice but are not entirely objective since humans are a fundamental part of the test (see intra- and inter-observer reliability in the introduction of the current paper). Moreover, their results are also dependent on previous experience of the test animal with humans (de Passillé *et al.* 1996). Reactions to an unknown object, as in the classic novel-object-test, give further important information on an animal's personality, which are not primarily covered with the method presented in the current paper. Possible correlations between the pulling-test and other tests named above need further research.

As a result of the current investigation, it is concluded that animals with different behaviour patterns can be successfully detected on the basis of their pulling behaviour during a 30-min period of restraint. The newly developed method, including the suggested statistical procedures, can be applied easily in research and in practice. It is suitable for phenotyping in breeding programmes, because it offers a standardized objective procedure independent of human observers and handlers. However, more research on the long-term reliability of the results needs to be conducted. Other aspects of personality also need to be accounted for in addition to those measured with the pulling-test. Therefore, the pulling-test should be seen as an objective and practicable basis-test.

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REFERENCES

Benhajali, H., Boivin, X., Sapa, J., Pellegrini, P., Boulesteix, P., Lajudie, P. & Phocas, F. (2010). Assessment of different on-farm measures of beef cattle temperament for use in genetic evaluation. *Journal of Animal Science* **88**, 3529–3537.

Boissy, A. (1995). Fear and fearfulness in animals. *Quarterly Review of Biology* **70**, 165–191.

Boissy, A. & Bouissou, M.-F. (1988). Effects of early handling on heifers' subsequent reactivity to humans and to unfamiliar situations. *Applied Animal Behaviour Science* **20**, 259–273.

Boivin, X., Gilard, F. & Egal, D. (2009). The effect of early human contact and the separation method from the dam on responses of beef calves to humans. *Applied Animal Behaviour Science* **120**, 132–139.

Broom, D. M. (1988). The scientific assessment of animal welfare. *Applied Animal Behaviour Science* **20**, 5–19.

Burrow, H. M. (1997). Measurements of temperament and their relationship with performance traits of beef cattle. *Animal Breeding Abstracts* **65**, 477–495.

Burrow, H. M. (1998). The effects of inbreeding on productive and adaptive traits and temperament of tropical beef cattle. *Livestock Production Science* **55**, 227–243.

Coleman, K., Tully, L. A. & McMillan, J. L. (2005). Temperament correlates with training success in adult rhesus macaques. *American Journal of Primatology* **65**, 63–71.

de Passillé, A. M., Rushen, J., Ladewig, J. & Petherick, C. (1996). Dairy calves' discrimination of people based on previous handling. *Journal of Animal Science* **74**, 969–974.

Fell, L. R., Colditz, I. G., Walker, K. H. & Watson, D. L. (1999). Associations between temperament, performance and immune function in cattle entering a commercial feedlot. *Australian Journal of Experimental Agriculture* **39**, 795–802.

Fleischrind Stölln GmbH (2007). *Charolais-Rinder aus dem Havelland*. Wilfried Zachert. Available online at: http://www.charolais-stoelln.de/zuchtziel.php?id=3 (verified 7 March 2012).

Fordyce, G., Dodt, R. M. & Wythes, J. R. (1988*a*). Cattle temperaments in extensive beef herds in Northern Queensland. 1. Factors affecting temperament. *Australian Journal of Experimental Agriculture* **28**, 683–687.

Fordyce, G., Goddard, M. E., Tyler, R., Williams, G. & Toleman, M. (1985). Temperament and bruising of *Bos indicus* cattle. *Australian Journal of Experimental Agriculture* **25**, 283–288.

Fordyce, G., Wythes, J. R., Shorthose, W. R., Underwood, D. W. & Shepherd, R. K. (1988*b*). Cattle temperaments in extensive beef herds in Northern Queensland. 2. Effect of temperament on carcass and meat quality. *Australian Journal of Experimental Agriculture* **28**, 689–693.

Forkman, B., Boissy, A., Meunier-Salaün, M.-C., Canali, E. & Jones, R. B. (2007). A critical review of fear tests used on cattle, pigs, sheep, poultry and horses. *Physiology and Behaviour* **92**, 340–374.

Gaden, B., Burrow, H. & Pettiford, S. (2004). Flight time – a practical way to improve feedlot performance, temperament and tenderness. In *Producing Quality Beef – Opportunities for Beef Producers from the CRC for Cattle and Beef Quality* (Ed B. Gaden), pp. 26–28. Armidale, NSW, Australia: CRC for Cattle and Beef Quality.

Gibbons, J. M., Lawrence, A. B. & Haskell, M. J. (2011). Consistency of flight speed and response to restraint in a crush in dairy cattle. *Applied Animal Behaviour Science* **131**, 15–20.

Grandin, T. (1993). Behavioral agitation during handling of cattle is persistent over time. *Applied Animal Behaviour Science* **36**, 1–9.

https://doi.org/10.1017/S0021859612000408 Published online by Cambridge University Press

Grignard, L., Boivin, X., Boissy, A. & Le Neindre, P. (2001). Do beef cattle react consistently to different handling situations? *Applied Animal Behaviour Science* **71**, 263–276.

Kilgour, R. J., Melville, G. J. & Greenwood, P. L. (2006). Individual differences in the reaction of beef cattle to situations involving social isolation, close proximity of humans, restraint and novelty. *Applied Animal Behaviour Science* **99**, 21–40.

Koolhaas, J. M., De Boer, S. F., Coppens, C. M. & Buwalda, B. (2010). Neuroendocrinology of coping styles: Towards understanding the biology of individual variation. *Frontiers in Neuroendocrinology* **31**, 307–321.

Lanier, J. L., Grandin, T., Green, R. D., Avery, D. & McGee, K. (2000). The relationship between reaction to sudden, intermittent movements and sounds and temperament. *Journal of Animal Science* **78**, 1467–1474.

Le Neindre, P., Trillat, G., Sapa, J., Ménissier, F., Bonnet, J. N. & Chupin, J. M. (1995). Individual differences in docility in Limousin cattle. *Journal of Animal Science* **73**, 2249–2253.

Leisch, F. (2006). A toolbox for *k*-centroids cluster analysis. *Computational Statistics and Data Analysis* **51**, 526–544.

Locurto, C. (2007). Individual differences and animal personality. *Comparative Cognition and Behaviour Reviews* **2**, 67–78.

Manteca, X. & Deag, J. M. (1993). Individual differences in temperament of domestic animals: a review of methodology. *Animal Welfare* **2**, 247–268.

Matthews, L. R., Carragher, J. F. & Slater, J. L. (1997). Effects of flightiness, sociability and previous handling experience on the behaviour of cattle in yards (abstract). In *Proceedings of the 31st International Conference of the ISAE, 13–16 August 1997* (Eds M. Špinka, G. Illmann, J. Maletìnská, Z. Štìtková & L. Bartoš), p. 94. Prague, Czech Republic: International Society of Applied Ethology.

Mayer, J. D. (1986). How mood influences cognition. In *Advances in Cognitive Science* (Ed. N. E. Sharkey), pp. 290–314. Chichester, West Sussex, UK: Ellis Horwood Limited.

R Development Core Team (2008). *R: A Language and Environment for Statistical Computing*. Vienna, Austria: R Foundation for Statistical Computing.

Traditional Herefords (2008). *The Official Traditional Hereford Web Site*. Available online at http://www.traditionalherefords.org/ (verified 7 March 2012).

Veissier, I., Le Neindre, P. & Trillat, G. (1989). Adaptability of calves during weaning. *Biology of Behaviour* **14**, 66–87.

Voisinet, B. D., Grandin, T., O'Connor, S. F., Tatum, J. D. & Deesing, M. J. (1997b). *Bos indicus* cross feedlot cattle with excitable temperaments have tougher meat and a higher incidence of borderline dark cutters. *Meat Science* **46**, 367–377.

Voisinet, B. D., Grandin, T., Tatum, J. D., O'Connor, S. F. & Struthers, J. J. (1997*a*). Feedlot cattle with calm temperaments have higher average daily weight gains than cattle with excitable temperaments. *Journal of Animal Science* **75**, 892–896.

Waiblinger, S., Boivin, X., Pedersen, V., Tosi, M.-V., Janczak, A. M., Visser, E. K. & Jones, R. B. (2006). Assessing the human-animal relationship in farmed species: a critical review. *Applied Animal Behaviour Science* **101**, 185–242.

Welfare Quality® (2009). *Training in the Welfare Quality® Assessment Protocols*. Lelystad, The Netherlands: Welfare Quality®. Available online at: http://www.welfarequality.net/downloadattachment/43299/20259/2009-Nov_adapted_leafletWQTrainingAssessmentProtocols.pdf (verified 3 March 2012).

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