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Assessment of different on-farm measures of beef cattle temperament for use in genetic evaluation[1]

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ABSTRACT: The aim of this study was to find a simple measure for calf temperament discrimination, which can be useful as a selection criterion for on-farm French beef cattle breeding schemes. Behavioral records were registered at an average age of 5 and 7 mo, respectively, for 1,282 and 1,440 Limousin calves born in 24 French farms between August 2007 and April 2008. Measures were repeated for 810 calves at the 2 ages. The test procedure consisted of individually restraining the calves in a chute, then exposing them to a stationary human situated in front of the chute for 10 s. For every calf and each period of the test, the number of rush movements and the total number of movements were scored by visual appraisal using a continuous scale ranging from 0 (no movements) to 60 (continuous movements). Initial scores were also transformed to categorical scores and analyzed. Genetic correlation across ages were very high for all the traits (above 0.84 ± 0.20) suggesting that these traits are governed by the same pool of genes at the 2 ages. The corresponding phenotypic correlations were about 0.3 for all the measures. Heritabilities were moderate for all measures (from 0.11 to 0.31) with the total number of movements during weighing measured at 7 mo being the greatest. All the measures were highly correlated (from 0.73 ± 0.26 to 0.99 ± 0.02). Genetic correlation across sexes was not statistically different from 1. However, traits measured during weighing showed different genetic variance estimates for females and males. Similar results were obtained for the transformed categorical scores. According to these results, the total number of movements during weighing seems to be the most promising trait for on-farm genetic evaluation of French beef cattle temperament.

Key words: beef cattle, behavior, docility, genetic evaluation, genetic parameter, on-farm temperament

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INTRODUCTION

There is currently a growing interest in European beef cattle for genetic improvement on temperament, defined as "the animal's behavioral response to handling by humans" (Burrow, 1997). This is in part reflective of the fact that less labor on farms has been an industry trend over last several decades, but also the need to fit the international request to improve animal temperament. Animal temperament has been shown to be moderately heritable in beef cattle and therefore could respond to selection (Burrow, 1997). In some countries, such as Australia or the United States, animals are already selected on their temperament using a chute test (Tier et al., 2001). In these countries, animals receive little human contact and may be much more reactive to handling than European animals. In European husbandry conditions, this chute test may not reveal enough genetic variability to discriminate animals based on their temperament. In France, only Limousin bulls in performance and progeny test stations have been evaluated on a docility test in an arena involving direct human exposure (Le Neindre et al., 1995). However, this test is not suitable for use in standard farm conditions. Therefore, there is actually a need to establish an on-farm test which will allow for early selection of all the breeding stock in French beef cattle. In French progeny test stations, Grignard et al. (2001) found significant phenotypic correlations between animal responses in the chute test and in the docility test, confirming the chute test as a potential

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on-farm selection criterion for temperament. However, they suggested that the human presence in the chute test could need to be more clearly defined (e.g., in front of the chute). This study aimed at finding a practical, heritable, and repeatable measure of temperament that can be carried out during existing situations of on-farm performance recording.

MATERIALS AND METHODS

Animal Care and Use Committee approval was not necessary because the data were obtained from routine practices in nucleus herds.

Animals

This study was conducted between October 2006 and September 2008 in 24 French pedigree farms recruited by the French Limousin Breed Association to contribute to this project.

To ensure good family structure and connection across farms, 12 experimental bulls were chosen among the French Limousin bulls selected for AI use. Their semen was disseminated over the 24 cow herds to produce at least 40 calves per bull. The bulls were chosen on the basis of EBV calculated from behavioral criteria collected in progeny test station during the docility test (Le Neindre et al., 1995) using daughters of AI bulls. These criteria are related to the general activity of the heifers during the different stages of the test. The criteria are described in detail in Phocas et al. (2006) and included the running time, the number of escapes of the animal, and a 4-point score that indicates if 1) the animal could be restrained and stroked, 2) the animal was restrained but not stroked, 3) the animal could not be restrained, and 4) the animal was aggressive. The 12 AI bulls were chosen to have 6 bulls likely to produce calm calves and 6 bulls likely to produce agitated calves. The first objective of this disruptive selection was to be almost certain to capture any potential genetic variation in the chute test because the first aim of the study was to establish if this test may be useful for genetic evaluation of temperament under French husbandry conditions. It was also thought that it may compensate for some bias in the estimation of the genetic variance because no semen is available on the market (and consequently for on-farm experimentation) for bulls that are found aggressive either on performance or progeny test.

Limousin calves were weighed 3 times for purposes of on-farm genetic evaluation on weaning weight. The aim of the current study was to test temperament during these weighing procedures. As recommended by a preliminary study, we focused on the second and third weighing of animals, which occur on average at 5 and 7 mo of age. During this period of life, whatever their BW, animals are not limited in the number of movements they can do within the chute. Animals were tested twice to assess the consistency of their behavior over time, repeatability of the measurements, and to determine for practical purposes the recommended age of measurement for a possible genetic evaluation. Therefore, 2 visits per farm were performed between February 2008 and September 2008 during on-farm performance test weighing. A total of 2,141 Limousin calves were tested.

Test Procedure and Measures

The test was performed during on-farm performance test conducted by state agricultural service technicians. Calves were individually restrained in the chute, but the head of the calf was not captured within the head stanchion. The test consisted of assessing their behavior during weighing, then when exposed to a stationary human situated in front of the scale for 10 s. Three persons were involved in the test: the farmer who led animals to the chute, the weigher who also identified animals by their ear tag, and the experimenter who scored animals.

There were 2 periods in the test. The first period was during weighing, the experimenter was on the side of the chute next to the weigher. The duration of the first assessment period was at least 10 s. When, in a few cases, the weighing machine could not stabilize the measure within the 10 s because the animal was too agitated, a maximal score was given to the calf. In the second period, the experimenter stood in front of the animal (at the exit door of the chute, so as to be visible and identifiable as a human by calves) and stood motionless for 10 s. All the tests were performed by the same experimenter who was always dressed the same way (blue coveralls) in the 24 farms at the 2 visits.

Therefore, for each calf and each period of the test, the total number of movements and the number of rush movements were scored by visual appraisal using the same continuous scale (Figure 1) ranging from 0 (no movements) to 60 (continuous movements). These continuous measures were later converted to 6 categorical scores, and both were analyzed to determine which was the most appropriate for genetic evaluation purposes.

For each calf, 4 measures were recorded: the total number of movements during weighing (**TW**), the number of rush movements during weighing (**RW**), the total number of movements during exposure to the human (**TH**), and the number of rush movements during exposure to the human (**RH**). Every movement of the calf involving feet and every movement of the head that exceeded 30° of deviation were counted as true movements. Rush movements were defined as fast and sudden movements that were of short duration. Some calves were small enough to be able to turn around in the chute, and therefore the experimenter also noted the position (**Pos**) of the calf [head facing the exit (Pos = 0) or head facing the entrance door of the chute (Pos = 1)] during each period of the test.

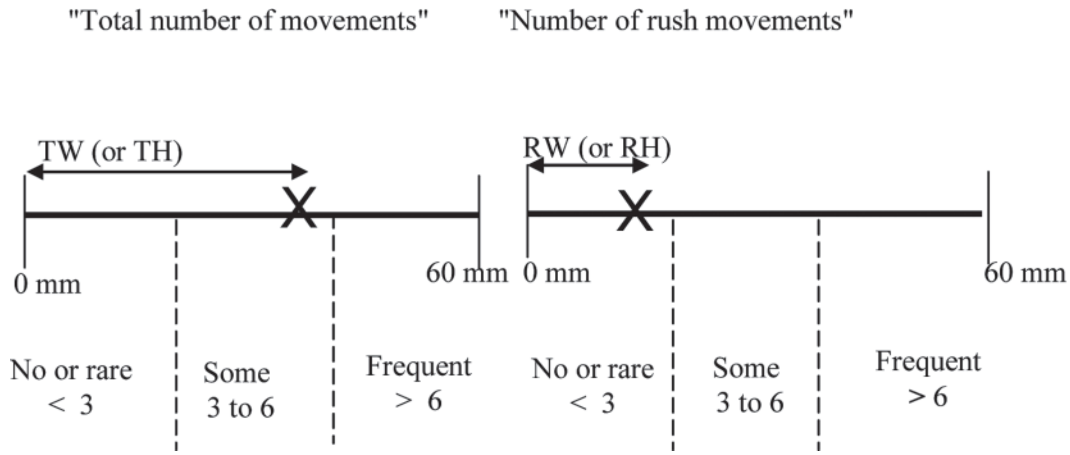

Figure 1. Illustration of the ruler scales used to score calf movements. The distance (mm) from origin to marking by evaluator was used to generate the continuous data points for the various measures of temperament. TW = total number of movements during weighing; RW = number of rush movements during weighing; TH = total number of movements during exposure to the human; and RH = number of rush movements during exposure to the human.

Data Description

The first objective of the study was to test animals twice at an average age of 5 and 7 mo. However, because testing was done on-farm during weighing, animals were evaluated from 14 to 400 d of age. A preliminary analysis about the variations of measures according to the age of the calf was performed before the genetic analysis of the data. This analysis showed 4 main phases. Calves tested before 80 d of age were handled for the first time, and therefore, corresponding data were eliminated from the analysis (7.7% of records). Between 80 and 179 d of age, all the measures of temperament increased almost linearly with advancing age. Between 180 and 280 d, there was almost no age effect on the measures of temperament. After 280 d, all the measures decreased with advancing age. This may be due to the increase of the BW of the calf and its increasing difficulty to move in the chute (i.e., not enough space to move). Data after 280 d of age (8.3% of records) were also eliminated from the final data set because of this potential problem with calf size.

First, data editing for the analysis consisted of selecting records corresponding to animals tested between 80 and 280 d of age. Second, data editing consisted of selecting animals from known sires with at least 5 progeny records and from contemporary groups with at least 3 records per farm-management group. Pedigrees were obtained from the French National Cattle Genetic Database. Data related to calves that were progeny of unknown sires were also eliminated. The final research data set included data of 1,678 calves, offspring of 73 sires with 706 animals tested twice. Data were split into 2 data sets according to the age of the calf (Table 1). In the following, we refer as measures at age 1: those measurements recorded between 80 and 179 d of age, and measures at age 2: those measurements recorded between 180 and 280 d of age. Sex ratio (number of males/total number of animals) was 0.48 at the 2 ages. Hereafter, the name of a measure (e.g., TW) will be followed by the suffix 1 if measured at the age 1 (e.g., TW1) and the suffix 2 if measured at the age 2 (e.g., TW2).

Data Distribution

Data clearly followed a Poisson distribution because measures involved counting of the number of movements of each calf during a certain period of time. It was therefore easy to transform initial continuous variables into categorical ones. The measures TW, RW, TH, and RH were so transformed into categorical scores (**CTW**, **CRW**, **CTH**, and **CRH**, respectively) with 6 classes: 0 to 2 movements, 3 or 4 movements, 5 or 6 movements, 7 or 8 movements, 9 or 10 movements, and more than 10 movements.

Figures 2 and 3 show data distribution for CTW and CRW at age 1. Almost 50% of the animals had 4 or fewer movements in total and at most 2 rush movements. Data distributions were similar at age 2 and during exposure to humans.

Preliminary Analysis for Fixed Environmental Effects

Preliminary analyses were performed to investigate the nongenetic factors influencing the traits using the GLM procedure for continuous variables and GENMOD procedure for discrete variables (SAS Inst. Inc., Cary, NC). Preliminary analyses of traits were carried out using a linear model that included the fixed effects

Table 1. Final data sets according to calf age

Item	Data set 1	Data set 2
No. of observations	1,113	1,271
Age interval, d	80,179	180,280
Average age ± SD, d	142 ± 25	218 ± 60
No. of sires	73	65

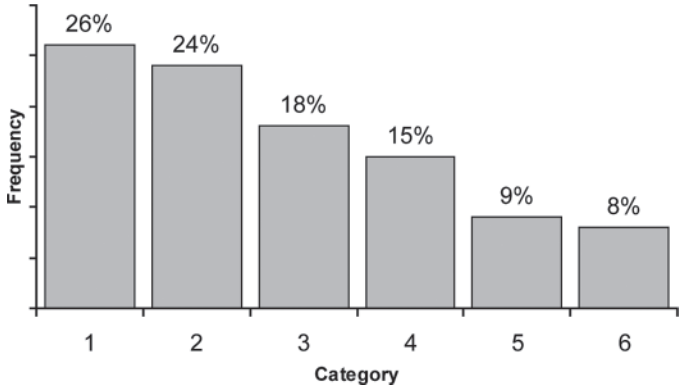

Figure 2. Frequency distribution of the total number of movements during weighing at age 2 expressed in 6 categories. Age 2: measurements recorded between 180 and 280 d of age.

of the farm (24 levels), sex of the calf (2 levels), type of birth of the calf (2 levels), dam parity (2 levels), Pos of the calf at birth at the start of the second period of the test in 2 levels (head facing the exit or the entrance door of the cage), age of the calf was used as a covariate or as a categorical variable (**catage**, 5 levels), the management group (11 levels) within farm, and the farm × sex, farm × parity, Pos × sex, type of birth × catage, parity × catage, sex × catage interactions. The weigher effect could not be tested because it was confounded with the farm effect. There were almost as many technicians as farms. Only significant effects from this set of preliminary analyses were included in the mixed model analysis aimed at estimating genetic parameters.

The models used assumed a normal distribution of data. However, data distribution was skewed at the left side for all the traits. Initial variables were transformed by Box-Cox transformation to ensure a normal distribution (Neter et al., 1996) and to determine that significance of effects did not change compared with the untransformed measurements. The same fixed effects were significant when using the transformed variables showing that linear modeling was robust enough to handle the initial measures. This was also true for categorical variables, which were analyzed with Poisson regression models.

Genetic Analysis

For all traits (either continuous or discrete variables), estimates of variance components were performed under linear animal models by REML using the average information algorithm (Gilmour et al., 1995) and ASREML-R1 software (Gilmour et al., 2002).

The following animal model was considered:

$$\mathbf{y} = \mathbf{X}\boldsymbol{\beta} + \mathbf{Z}\mathbf{u} + \mathbf{e},$$

where $\mathbf{y}$ is the vector of observations, $\boldsymbol{\beta}$ is the vector of fixed effects and $\mathbf{X}$ is the corresponding incidence matrix, $\mathbf{u}$ is the vector of random genetic effects and $\mathbf{Z}$ is the corresponding incidence matrix, and $\mathbf{e}$ is the vector of random residual effects. Under the single trait model, random effects $\mathbf{e}$ and $\mathbf{u}$ were assumed to be normally distributed with expectation zero and variance matrix equal to $\mathrm{I}\sigma_e^2$ and $\mathrm{A}\sigma_a^2$, respectively. The matrix I is the identity matrix. The relationship matrix (A) between animals included 3 generations of ancestors that accounted for 5,363 animals in total.

Fixed factors included in the models for the estimation of genetic parameters for the analyzed traits were the contemporary group (farm-management group interactions), the position of the calf during the test (Pos) for all the traits, the type of birth, the interaction farm × sex and Pos × sex for RW1 and TW1, the interaction farm × parity of the dam and calf age as a covariate for all the measures recorded at age 1.

To check if the accuracy of genetic evaluation can be significantly improved by including repeated measures, a repeatability model was used for each trait (combining data across age 1 and 2 into a single trait analysis and adding a permanent environmental effect of the animal to the previous animal model).

Heritabilities were first estimated for each of the 8 traits with observed and transformed data points (TW1, RW1, TH1, RH1, TW2, RW2, TH2, RH2, CTW1, CRW1, CTH1, CRH1, CTW2, CRW2, CTH2, and CRH2) using single trait models. Correlations between the same measures considered across ages were estimated using linear bivariate animal models. For each given age, a multitrait linear model including the 4 traits was initially tested to estimate genetic correlations between the different traits. Due to extremely high genetic correlations (above 0.95) between RW and TW or RH and TH measures, convergence could not be reached. Consequently, for each age, 3 different multitrait analyses were performed: 1) TH, TW, and RW, 2) RH, TW, and RW, and 3) RH and TH. Similar analyses were performed with categorical variables.

Categorical traits were also analyzed under threshold mixed models using the software CATKIT developed by V. Ducrocq (INRA, Jouy-en-Josas, France, personal communication) for French dairy cattle calving ease evaluation. For discrete traits, EBV were compared be-

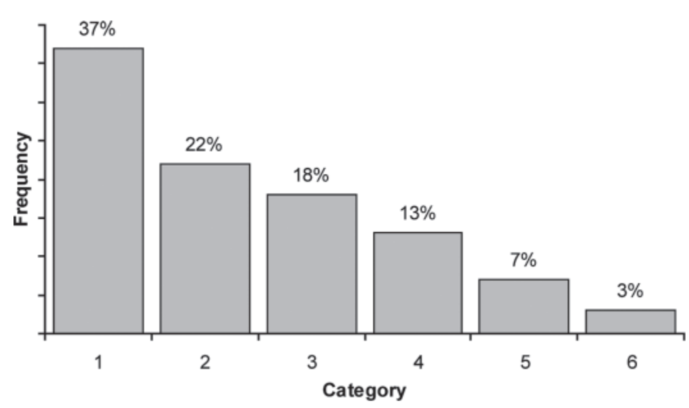

Figure 3. Frequency distribution of the number of rush movements during weighing at age 2 expressed in 6 categories. Age 2: measurements recorded between 180 and 280 d of age.

Table 2. Descriptive statistics for all the traits at ages 1 and 2[1]

	Age 1		Age 2	
Trait	n	Mean ± SD	n	Mean ± SD
Total No. of movements during weighing	1,279	24.8 ± 18.7	1,439	28.2 ± 18.8
No. of rush movements during weighing	1,278	16.8 ± 17.2	1,439	22.0 ± 18.8
Total No. of movements during exposure to the human	1,282	23.4 ± 16.5	1,440	22.7 ± 16.9
No. of rush movements during exposure to the human	1,282	15.8 ± 15.7	1,440	16.8 ± 16.9
Total No. of movements during weighing expressed in 6 categories	1,279	2.6 ± 1.5	1,439	2.9 ± 1.6
No. of rush movements during weighing expressed in 6 categories	1,278	2.0 ± 1.3	1,439	2.4 ± 1.4
Total No. of movements during exposure to the human expressed in 6 categories	1,282	2.4 ± 1.4	1,440	2.4 ± 1.4
No. of rush movements during exposure to the human expressed in 6 categories	1,282	1.9 ± 1.1	1,440	2.0 ± 1.3

[1]Age 1: measurements recorded between 80 and 179 d of age; age 2: measurements recorded between 180 and 280 d of age.

tween predictions of linear and threshold models. Because similar ranking of EBV were predicted (rank correlations over 0.99), multitrait analysis were performed under linear models whatever the nature (continuous or discrete) of the trait. Because a previous study (Sapa et al., 2006) showed some heterogeneity of variance across sexes, records of males and females were treated as different traits in bivariate analysis to determine whether or not the same biological roots were behind male and female temperament measures.

Reliability of each EBV ($\hat{u}$) was derived as $R = 1 - Var(u - \hat{u})/Var(u)$. Rank and Pearson correlations between EBV estimated for initial data and categorical data were performed for each trait using the procedure CORR within SAS. Probability values <0.05 were regarded as statistically significant.

RESULTS AND DISCUSSION

Descriptive Statistics

Descriptive statistics for all the traits are shown in Table 2. Except for TH, all trait means increased between age 1 and 2, which meant that older animals were the most agitated. On the contrary, the raw SD remained stable over ages and very large CV were observed (from 70 to 100%).

Animals at age 2 were weighed for the third time of their life, and one might expect them to be less agitated with experience as increased amounts of handling experience often results in animals having decreased fear responses to new environments and handlers. Indeed, Crookshank et al. (1979) and Kadel et al. (2006) showed that agitation and cortisol concentrations in cattle were decreased over multiple handling experiences. However, present results agreed with those reported by Müller and von Keyserlink (2006) and Petherick et al. (2002) who found increases in flight speed over repeated tests and Grandin (1993) who mentioned that European Continental cattle that were worked through a squeeze chute repeatedly in a single day became increasingly agitated. Different results between studies are likely due to different levels of animal fear and aversion to the test. The increase of agitation during weighing observed at age 2 may also be due to physiological changes with age.

Heritabilities and Genetic and Phenotypic Correlations

Estimates of heritabilities and genetic and phenotypic correlation across ages for all the measures are presented in Table 3. Results obtained for categorical variables analyzed under linear models were very similar to those obtained for the initial scores (Table 3), confirming that categorizing the continuous data did not create a significant loss of information. When analyzing categorical variables under threshold models, assuming an underlying normal variables, the heritability of the corresponding liabilities were slightly (+0.01 to 0.05) greater than the heritability estimated using linear models, as expected for multinomial variables (Vinson et al., 1976).

Heritabilities ranged from 0.11 to 0.22 at age 1 and 0.16 to 0.31 at age 2, which meant that all the measures were moderately heritable as it was often shown in the literature for temperament traits (Shrode and Hammack, 1971; Le Neindre et al., 1995; Burrow and Corbet, 2000; Burrow, 2001; Tier et al., 2001; Kadel et al., 2006; Phocas et al., 2006). The greatest genetic variations were observed during weighing at age 2, and the total number of movements seems to better discriminate animals than the number of rush movements.

For each trait, genetic correlation between measures recorded at age 1 and age 2 was not significantly different from 1 ($P < 0.01$). This suggests that traits are governed by the same pool of genes at the 2 ages and could consequently be measured at either age for inclusion in a genetic evaluation of a given temperament trait. Heritabilities of traits recorded during exposure to the human were stable with age, contrary to those of traits recorded during weighing, which were greater at age 2 than age 1 (Table 3). Although the same pool of genes influenced the temperament phenotypes at both ages, a greater expression of genetic potential is observed at age 2 during weighing. Such age differences have been

Table 3. Phenotypic and genetic parameters for the continuous and categorical scores across ages[1]

	Phenotypic variance		Phenotypic correlation	Genetic variance		Heritability		Genetic correlation
Trait[2]	Age 1	Age 2	Between ages	Age 1	Age 2	Age 1	Age 2	Between ages
TW	264 ± 13	278 ± 13	0.27 ± 0.04	38 ± 22	87 ± 30	0.14 ± 0.08	0.31 ± 0.10	0.84 ± 0.20
RW	222 ± 11	288 ± 14	0.32 ± 0.04	24 ± 16	81 ± 29	0.11 ± 0.07	0.28 ± 0.09	0.99 ± 0.19
TH	247 ± 12	243 ± 11	0.32 ± 0.04	55 ± 20	41 ± 18	0.22 ± 0.08	0.17 ± 0.07	0.84 ± 0.21
RH	217 ± 10	250 ± 11	0.31 ± 0.04	44 ± 17	47 ± 18	0.20 ± 0.08	0.19 ± 0.07	0.95 ± 0.19
CTW	1.8 ± 0.1	2.0 ± 0.1	0.29 ± 0.04	0.33 ± 0.2	0.55 ± 0.2	0.16 ± 0.08	0.29 ± 0.10	0.94 ± 0.17
CRW	1.3 ± 0.1	1.6 ± 0.1	0.29 ± 0.04	0.14 ± 0.1	0.37 ± 0.1	0.11 ± 0.07	0.23 ± 0.09	0.98 ± 0.19
CTH	1.7 ± 0.1	1.7 ± 0.1	0.33 ± 0.04	0.34 ± 0.1	0.28 ± 0.1	0.20 ± 0.08	0.16 ± 0.07	1.00[3]
CRH	1.2 ± 0.0	1.4 ± 0.1	0.34 ± 0.04	0.18 ± 0.1	0.22 ± 0.1	0.15 ± 0.07	0.16 ± 0.07	1.00[3]

[1]Age 1: measurements recorded between 80 and 179 d of age; age 2: measurements recorded between 180 and 280 d of age.

[2]TW = total number of movements during weighing; RW = number of rush movements during weighing; TH = total number of movements during exposure to the human; RH = number of rush movements during exposure to the human; CTW = total number of movements during weighing in categories; CRW = number of rush movements during weighing in categories; CTH = total number of movements during exposure to the human in categories; CRH = number of rush movements during exposure to the human in categories.

[3]Fixed at the boundary value of the parameter space.

already reported for flight speed heritability estimated by Burrow et al. (1988), which was 0.54 at 6 mo and only 0.26 at 18 mo of age.

For a given trait, phenotypic correlation between measures at age 1 and 2 corresponded to the trait repeatability because the same biological character was measured at the 2 ages. Repeatability was about 0.3 for all traits, indicating that environmental influences on these temperament traits changed greatly over time. This is similar to the repeatability of chute score (0.36) reported for tropically adapted beef (Kadel et al., 2006) measured on average at 246 and 564 d of age and less than repeatability for Angus cattle (0.44; Johnston and Halloway, 2003) measured 73 d apart. Behavioral traits often have reduced stability over time, and the few studies that looked at the consistency of behavioral reactivity in beef cattle often reported moderate repeatability. This retesting variability can be explained 2-fold. First, the effect of the experience/age of the animal is expected because juveniles are undergoing dramatic developmental change and therefore do not show repeatable behavior (Bell et al., 2009). Second, environmental changes in animal management or testing conditions might also cause repeatability to decrease particularly with the increase of the time interval between observations. When this time is long, it is unlikely that the animals are of similar state (e.g., size, condition, dominance, social group) during both observations and are experiencing similar environments (Bell et al., 2009). Repeated measures in this study were undertaken over a time interval of 3 mo, and in those 3 mo, the environment of the animal may have undergone several changes that could influence its behavior in the chute.

Heterogeneous Variance Components Between Sexes

Results showed no effect of calf sex on any of the studied traits. However, previous studies reported frequently phenotypic differences between sexes with females often more difficult to handle (Tulloh, 1961; Shrode and Hammack, 1971; Sato, 1981; Gauly et al., 2001; Sapa et al., 2006). Even if genetic correlations were estimated close to unity between sexes for all traits indicating that the same pool of genes was involved in female and male temperament, large significant differences in genetic variability were estimated between male and female measures recorded during weighing. As shown in Table 4, females exhibited less genetic variability at age 1 than males and, on the contrary, greater genetic variability at age 2. However, genetic variability of measures recorded during exposure to the human was homogeneous across sexes. Female genetic variance changed substantially between the 2 periods of the test, which meant that they might be more sensitive to the human presence than males.

Results related to age 2 are similar with those reported by Sapa et al. (2006) who found that heritabilities of running time and number of escapes during the docility test (Le Neindre et al., 1995) were significantly greater for heifer temperament than for bull temperament. On the contrary, Sapa et al. (2006) found no differences between sexes for the docility score itself, similar to Burrow (2001) who found similar heritability of flight speed test for both sexes. This heterogeneity can be explained by differences between sexes in responses to environmental stress. DeNise et al. (1988) and De Nise and Torabi (1989) show that genetic parameters change in response to level of environmental stress, and the sexes respond differently to these conditions.

Estimates of Genetic Correlations Between Traits

Genetic correlations between categorical traits at age 2 are presented in Table 5. Similar results were obtained at age 1 and, whatever the age, for the initial continuous variables. At a given age, the 4 traits were genetically highly correlated to each other (from 0.77 to

Table 4. Phenotypic and genetic parameters of all categorical traits according to sex of calf

Trait[1,2]	n		Mean		Phenotypic variance		Heritability	
	Male	Female	Male	Female	Male	Female	Male	Female
Measure at age 1								
CTW	622	657	2.6 ± 1.5	2.6 ± 1.5	1.9 ± 0.1	1.8 ± 0.1	0.27 ± 0.14	0.05 ± 0.07
CRW	622	656	2.0 ± 1.3	2.0 ± 1.2	1.2 ± 0.1	1.2 ± 0.8	0.24 ± 0.14	0.04 ± 0.07
CTH	626	656	2.5 ± 1.4	2.4 ± 1.4	1.7 ± 0.1	1.7 ± 0.1	0.21 ± 0.11	0.19 ± 0.10
CRH	626	656	1.9 ± 1.1	1.9 ± 1.2	1.1 ± 0.1	1.2 ± 0.1	0.18 ± 0.11	0.15 ± 0.09
Measure at age 2								
CTW	697	742	2.9 ± 1.6	2.8 ± 1.6	1.9 ± 0.2	2.1 ± 0.1	0.14 ± 0.09	0.52 ± 0.15
CRW	697	742	2.4 ± 1.5	2.3 ± 1.4	1.6 ± 0.1	1.6 ± 0.1	0.10 ± 0.08	0.50 ± 0.16
CTH	699	741	2.5 ± 1.5	2.4 ± 1.4	1.9 ± 0.1	1.6 ± 0.1	0.17 ± 0.09	0.16 ± 0.09
CRH	699	741	2.0 ± 1.3	2.0 ± 1.3	1.5 ± 0.1	1.4 ± 0.1	0.14 ± 0.09	0.19 ± 0.10

[1]CTW = total number of movements during weighing in categories; CRW = number of rush movements during weighing in categories; CTH = total number of movements during exposure to the human in categories; CRH = number of rush movements during exposure to the human in categories.

[2]Age 1: measurements recorded between 80 and 179 d of age; age 2: measurements recorded between 180 and 280 d of age.

0.99). The genetic correlations between the total number of movements and the number of rush movements during weighing or during exposure to the human were not significantly different from unity, suggesting that these measures represent exactly the same trait at the genetic level. Therefore, the quality of the movement can be ignored when assessing calf behavior in the chute. Almost all the scores used in the literature to assess the behavior of the calf by visual appraisal take in account the quality of the movement (e.g., degree of violence, speed; Burrow, 1997), which increases the amount of subjectivity accounting for in these measures. The total number of movements, in addition of its greater heritability, reduces risks of subjectivity when assessing calf temperament.

Genetic correlations between measures recorded during the 2 periods of the test (during weighing and exposure to the human) were also very high at both ages (from 0.79 to 0.86, Table 5). The second test period where the calf is exposed to human presence extends the duration of the test and requires additional work besides the weighing procedure. Results showed that the reaction of the calf to the human exposure can be predicted by its reactivity during weighing and suggested that the test can be shortened to only the weighing period.

Residual correlations between the total number of movements and the number of rush movements measured in the same period of the test were greater than 0.89 (Table 5). This was expected as measures were recorded simultaneously and were influenced by the same environmental effects as proved by the statistical analysis. On the contrary, residual correlations between measures recorded at different periods of the test did not exceed 0.38 (Table 5). That meant that animals were not experiencing exactly the same environment during weighing or exposure to the human. This can be explained by the presence of the human in the front of the cage but also by the increase of time spent in restraint.

Correlations Between EBV Estimated for Initial Scores and Categorical Traits

Correlations between EBV estimated for initial scores and the corresponding categorical variables were above 0.98 ($P < 0.01$) for all the measures recorded at both ages and also when using a repeatability model on the overall data set. As expected from estimates of variance components, scoring the behavior of the animal using a categorical score gave similar information and is easier to implement for further on-farm data collection than the continuous scale used in the present study. In addition, categories adequately discriminate animals as well as the initial continuous score. Therefore, it is recommended for the implementation of a routine ge-

Table 5. Genetic and residual correlations (respectively above and below the diagonal) between the different categorical traits recorded at age 2[1] for the Limousin calves

Trait[2]	CTW	CRW	CTH	CRH
CTW		0.99 ± 0.01	0.79 ± 0.20	0.82 ± 0.21
CRW	0.90 ± 0.01		0.73 ± 0.26	0.77 ± 0.20
CTH	0.33 ± 0.01	0.38 ± 0.06		0.99 ± 0.02
CRH	0.37 ± 0.04	0.36 ± 0.01	0.89 ± 0.01	

[1]Age 2: measurements recorded between 180 and 280 d of age.

[2]CTW = total number of movements during weighing in categories; CRW = number of rush movements during weighing in categories; CTH = total number of movements during exposure to the human in categories; CRH = number of rush movements during exposure to the human in categories.

Table 6. Sire EBV reliability (mean ± SD) according to the number of recordings per progeny

Trait[1]	1 record/progeny (at age 2)[2] ≥25 progeny	1 record/progeny (at age 2)[2] <25 progeny	2 records/progeny ≥25 progeny	2 records/progeny <25 progeny
CTW	0.73 ± 0.12	0.39 ± 0.12	0.74 ± 0.13	0.42 ± 0.14
CRW	0.70 ± 0.13	0.34 ± 0.13	0.71 ± 0.13	0.38 ± 0.14
CTH	0.61 ± 0.14	0.27 ± 0.11	0.76 ± 0.09	0.46 ± 0.11
CRH	0.64 ± 0.13	0.29 ± 0.11	0.69 ± 0.14	0.36 ± 0.14

[1]CTW = total number of movements during weighing in categories, CRW = number of rush movements during weighing in categories; CTH = total number of movements during exposure to the human in categories; CRH = number of rush movements during exposure to the human in categories.
[2]Age 2: measurements recorded between 180 and 280 d of age.

netic evaluation that on-farm evaluators use a categorical scale rather than the continuous scale to assess the behavior of the calf in the chute.

Sire EBV Reliability

Mean reliability values of sire EBV and associated number of progeny records per sire are shown in Table 6. Because a minimum number of 25 progeny records is required in French on-farm breeding scheme for a proven bull, bull index accuracies were calculated for bulls above and under this threshold. For sires with more than 25 progeny records, EBV reliability was above 0.61 for all the traits using only measures recorded at age 2. The EBV reliability increased significantly when considering the repeated measures for the number of movements and the rush movements during exposure to the human (Table 6). Considering these traits as selection criteria, it will be better to test animals at both ages to increase the accuracy of selection (i.e., above 0.50). However, considering that sires with more than 25 progeny records had sufficient EBV reliability, a single observation of temperament per progeny is sufficient for routine genetic evaluation using field data.

Because of greater heritabilities, including the repeated measures only slightly increased the evaluation accuracy for the total number of movements and the number of rush movements measured during weighing if compared with a single measure evaluation performed at age 2. Therefore, repeat measures are not worth doing when we consider these traits as selection criteria for genetic evaluation.

Implications for the Implementation of Genetic Evaluation of Calf Temperament

The purpose of the current study was to collect field data that was as close as possible to practical conditions. All the measures of temperament used in this study were heritable and repeatable and could therefore respond to selection. The number of movements during weighing recorded at age 2 seems to be the most useful selection criterion. It had the greatest heritability and was easier to measure than the number of rush movements, which implied a qualitative evaluation of the movements of a calf. To improve the accuracy of the genetic evaluation, the analysis model should take in account the heterogeneity of variance components between sexes.

These results are a start to the practical use of genetic evaluation on calf temperament. However, before defining the selection criterion to be used on-farm, further studies are required to investigate the relationship between these traits recorded on-farm and those collected in progeny test station for the 12 bulls used for connection in this study. This will allow a better choice of the selection criterion to be used on-farm for genetic evaluation in terms of the breeding goals of breeders related to aggressiveness or wildness of animals.

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