# SPECIAL PROBLEMS IN GENETIC EVALUATION OF PERFORMANCE TRAITS IN HORSE

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## SUMMARY

Performance is separated in two ways : success and stayability which allows success. The first one is treated as an underlying performance responsible for the ranking observed in the race or competition. Heritability of such criteria on jumping is 0.16 and repeatability 0.29. The model is validate by calculation of *a posteriori* probability of event. The second one is treated with survival analysis. Heritability of functional stayability in jumping is near 0.18. Particularity of horse's models is approached through examples on trainer effects and on the efficiency of animal model used since several years.

## INTRODUCTION

In recent years, lot of people in lot of countries have studied and developed genetic evaluation programs for riding and racing horses. Very good review are available on the measure and breeding of performance traits, as in Klemetdsal during the last World Congress at Edinburgh (1990) or Ohlsson & Philipsson in the European Meeting (1992). So, this paper will only focus on special topics of our work during recent past years in the measurement of the performance and the particularity of horse's models . The goal is to use racing and sports results in genetic improvement of horses. We first introduce how to measure the ability to success in any discipline, how to use competition results to measure the physical resistance of the horse (instead of using particular biological analysis), and we conclude with the validity of new and old models applied to horse's evaluation : a test of the new model for ranks, an example of trainer's effect and a test of the validity of the use of an animal model since number of years in France.

## A MEASURE OF SUCCESS

### *Standing the problem*

Results available from races or competitions are the ranks of the horse in each event. According to these ranks and the level of the race or competition, the horse earns more or less money. A natural measure of the performance is then the number of different places of a horse or a combination of earning and eventually places or starts. Problems concerned by the use of earning or number of places are detailed in Tavernier, 1990. Summarizing, difficulties are found to determine the value allocated to non-earning horses, to standardize the performance (to a normal distribution) and to account for repeated performances. In any cases, these measures correspond to an arbitrary scale attributed to each rank depending on arbitrary rules more or less controlled. We tried to get free of this rules with the use of a method assuming that performance is the expression of an unmeasurable underlying variable and that only the ranking of the performances of the different horses are observable.

### *Model*

The details of model and methods to estimate genetic effects and variance components are in Tavernier (1990,1991). The underlying performance follows a normal distribution with mean explained by the classical model including environmental fixed effects (commonly age and sex effects), genetic effects (animal model or sire model according to computing facilities) and permanent environmental effect to take into account repeatability of performances. The ranking of horses in each event is the only recorded result, so the likelihood of one event may be written as :

$$P(y_1 > y_2 > .... > y_n) = \int_{-\infty}^{+\infty}\int_{y_n}^{+\infty}...\int_{y_{i+1}}^{+\infty}...\int_{y_2}^{+\infty}\prod_{i=1}^{n}\varphi(y_i-\mu_i)dy_i \qquad (1)$$

with $y_i$ the underlying performance of the horse ranked $i$ $\mu_i$ the location parameter associated to the horse ranked $i$ (genetic + environmental effects), $\phi$ the standard normal density, $n$ the number of horses in the event. The evaluation of each effect is then obtained traditionally by maximization of the posterior density associated to this likelihood through the Bayes theorem. Variance components are estimated by a methodology similar to EM algorithm applied to REML under normality. Tow applications will be shown here : first estimation of heritability and repeatability with a sire model on jumping results, second estimation of additive genetic effect with an animal model and a multiple trait model adding ranking and earnings.

*Jumping application : estimation of variance components*

The model applied to the underlying performance is :

$$y_{ijklm} = a_i + b_j + s_k + c_{kl} + e_{ijklm}$$

with :

$a_i$ : sex effect : female ; males and geldings

$b_j$ : age effect : 4 to 10 years by 1 year, a 11-12 years class and more than 13 years class.

$s_k$ : sire effect

$c_{kl}$ : horse effect nested sire effect

$e_{ijklm}$ : residual

The file contains results in show jumping from 1985 to 1989. For each competition, the rank of the 25% first horses and the participation to the competition for the other horses (if they are not in the best ones) are recorded . During these 5 years, we have 1 328 660 starts in 32 731 events realized by 39 348 different horses. A horse participates in 33.8 events and a competition represents 40.6 horses in average. These horses are born from 3645 different stallions, that is 10.8 offspring by sire in average. The posterior density of parameters may be written :

$$f(\boldsymbol{\Theta}, \sigma_s^2, \sigma_c^2, \sigma_e^2 / Y) \propto (\sigma_s^2)^{-1/2} \exp(-1/2s'G^{-1}s)(\sigma_c^2)^{-1/2} \exp(-1/2c'H^{-1}c) \prod_{k=1}^{m} P_k \qquad (2)$$

with $\boldsymbol{\Theta} = \boldsymbol{a, b, s, c}$. $\boldsymbol{G} = \boldsymbol{I}\sigma_s^2$ and $\boldsymbol{H} : \boldsymbol{I}\sigma_c^2$, $P_k$ : the likclihood of one show defined in (1).

To estimate variance components, the mode of $f(\sigma_s^2, \sigma_c^2 / Y)$ had to be found. Developing arguments comparable to those of Foulley *et al* (1987) for discrete analysis, We can show that this mode may be obtained by an iterative procedure involving :

$$\left(\sigma_s^2\right)^{[t+1]} = \{s's + tr(C_{ss})\}^{[t]} / q \qquad (3)$$

where $C_{ss}$ is the inverse matrix of second derivatives of the posterior density with regard to $s$ and $q$ the number of sires. The same formulas may be obtained for $\sigma_c^2$

The major problem is to calculate the trace of the inverse matrix, taken into account that this matrix is fuller than in a classical mixed model matrix because all horses which participated to the same event have a coefficient between them. The size of the matrix is equal to the number of fixed effects added to the number of sires and horses, that is 43004 effects. Two bounds, lower and upper, were found to evaluate this trace from particular partitioning of matrices inspired from Van Raden and Freeman (1985).

Results give good approximations of variance components : differences between bounds are equal to 5% of the variances. The deviation between the lower and upper estimation of heritability and repeatability is 0.01 in the 2 cases. The sire variance is between 0.0535 and 0.0565, the variance of horse effect is between 0.3433 and 0.3611. The additive genetic variance is then equal to 0.22, the permanent environmental variance is then equal to 0.19 and the error variance was fixed to 1.00, so the phenotypic variance is equal to 1.41. The heritability is 0.16 and repeatability 0.29.

On the contrary of results obtained with underlying variable for discrete traits, the heritability found for this trait is lower than those obtained from performances on continuous scale in jumping. However, these measures of performance most often concern cumulative measures : annual or life time totals. In France, the logarithm of annual earning has heritability of 0.25 and repeatability 0.47 (Henderson method II, sire model, 2996 sires, 34141 horses, 84235 annual performances, Tavernier 1986). The heritability varies from 0.21 to 0.33 with the age of the horse and phenotypic correlation between years from 0.20 to 0.50 (REML method, animal model, 66153 horses, 39395 annual performances, Tavernier 1992). In Netherlands, the heritability of a criterion based on cumulative points from 4 to 6, 7 and 8 years varies from 0.10 to 0.20, the last estimation is the most reliable (REML method, sire model, 104 sires, 4504 performances, Huizinga 1989). It is logical that a trait which represents multiple repetition of an elementary performance (for each event) has higher heritability than the performance measured in each event. In Germany, Meinardus & Bruns (1987) used the logarithm of earning obtained in each jumping competition, they suppressed non earning horses and made a pre-adjustment for level of riders (measured from their horse's results). The heritability is 0.18 and repeatability 0.42 (Henderson Method III, 360 547 performances, 1303 sires and 30 112 horses). The same criteria applied to our file but without pre-adjustment or adjustment for rider, give an heritability of 0.27 and a repeatability of 0.41. (388 036 performances, 3184 sires , 30 125 horses). The main difference with the data used for our "rank model" is that the use of single results with earning measures only the level of the competition in which the horse is placed sometimes, but do not measure the capacity of the horse to success regularly in this level, since all the failures of the horse are not registered. The heritability of logarithm of earnings with each start without earning set to a "zero" performance and using this measure as a normal variable (which is not) in a REML sire model, is 0.04 with a repeatability of 0.10 in the same file as used to measure heritability on the underlying performance. This measure is the true visible criteria given by the underlying variable. So, when the data are not selected, and when using elementary performance, the earning give a very low heritability which express the loss of information between underlying variable and earning. More work is needed to quantify the importance of the structure of the competition rules in the genetic parameters of earnings.

***Jumping application : animal model and multiple trait***

This measure of performance is going to be applied in a large scale to the routine genetic evaluation of French jumping horses. From practical constraints, only annual earning were registered from 1972 to 1984, ranking are available since 1985. So for national evaluation, two traits are taken into account in a multiple trait model : logarithm of annual earning until 1984 and ranking in each competition since 1985. The two traits : one continuous and second on the underlying variable follow the same model :

$$y = Xb + Zu + Wm + Zp + e$$

with :

$b$ : vector of fixed effects : sex (females, males and geldings) for the two traits, a combination of age and year for earnings (with 5 classes for the age : 4,5,6-7,8-910,11+) which involve 65 levels, age only for ranking (11 classes , as in the sire model : from 4 to 10 by 1 year, 11-12, 13+), the year effect is not estimable because in one competition, all horses are affected by the same effect.

$u$ : vector of additive genetic values

$m$ : vector of herd-maternal effects (Tavernier, 1988)

$p$ : vector of permanent environmental effects

$e$ : vector of residuals

Likelihoods, knowing the parameters, are constructed independently (as errors are independent) and the prior density takes into account correlations between each random variable. The maximization of the posterior density requires an iterative scheme as Newton Raphson process. The second derivatives are mixed of classical equations of mixed model and those obtained from the maximization of the likelihood for the ranks. So the matrix has non-zero coefficients due to performances on diagonal and off-diagonal between effects (fixed and random) of horses in the same event, and due to variance covariance matrices according to the rules of the inverse relationship matrix for additive genetic effects and correlation between random effects for the two traits. Absorption of herd maternal effect and permanent environmental effect for earning is trivial. To solve the remaining system, coefficients between effects due to the derivation of the likelihood of each competition are multiplied by solutions and added to the right hand side, except for coefficient between maternal half-sibs. So the system keep the structure used in Tavernier 1988, which allows the absorption of maternal and permanent environmental effect for ranking and genetic value of mares and non-parents horses for the two traits. The remaining system is solved by Gauss-Siedel iterations, its size is the number of fixed effects added to the number of stallions multiplied by 2. Different level of iterations were overlapped : first, coefficient of second derivatives of the likelihood for ranks were calculate by iterations on global solution of each horse, second this coefficient are used in animal model evaluation, after absorptions, iterations are performed on stallions and then, obtaining new solutions for all effects, agree to up to date right hand side, as this right hand side contains elements from multiplication of matrix and solutions. The convergence for coefficients for ranks were good, but convergence of the whole system was rather slow, the main problem is the stabilization of fixed effects comparing to random effects.

This application is a good example of computer problems in official genetic evaluation : as the treatment of performance becomes complicated, the number of horses increases and strategies to solve systems must to be developed, as well as computer possibility has to extend. During the period 1972-1992, 6790 stallions, 63218 mares of horses with performances and 78862 non parents horses (with only performances) were evaluated for the two traits. Correlations between estimations on earning and on underlying variable for ranking are 0.92, 0.91 and 0.94 respectively for stallions, mares and horses without progeny. Correlations were also calculated between theses two estimations and an evaluation on one trait only as it was for the previous official evaluation: based on the logarithm of earnings on the same data until 1984 and earning instead of ranking from 1985 to 1992. Correlation between the single trait earnings evaluations and earning evaluations from the multiple trait model was 0.90, 0.92, 0.91 respectively for stallions, mares and horses without progeny. Correlation between the single trait earnings evaluations and evaluations for the underlying performance explaining ranks from the multiple trait model was 0.80, 0.82, 0.83 respectively for stallions, mares and horses without progeny.

## A MEASURE OF FITNESS

The primary trait required for sport or race horse is his capacity to win. However this capacity requests a long learning and training, therefore, the involuntary culling of a horse, which becomes physically incapable, represents always an important economic loss and physical resistance is a large share of the performance. The causes of culling are various but difficult to record because of the veterinary professional secrecy. The most frequent causes are probably lameness (fracture, bone diseases, calcification of the articulation) and breathing diseases adding to mortality from accidents and colics. A direct genetic study of these diseases is so difficult because of the difficulty to obtain registered informations on a subsequent data. Use of performances in competition may be a good help to appreciate this problem instead of the construction of an expensive experimentation. The horse's physical resistance will be studied through an aggregate trait, the length of the life in competition or race. The analysis of the measure of performance proved that, in measuring the performance of the horse, his physical resistance is often take into account through annual or life results considered as cumulated trait and not repeated trait. The better model will be to distinguish success, through the model applied to elementary ranking, and longevity. However, the first work made on this subject and presented here only takes into account annual measure of time. So, the objective is only to illustrate the ease to applied survival analysis on such data and first original results obtain from them.

### *Data*

The annual results of all the horses in jumping competition in France between 1972 and 1991 were available. The real number of years in competition, i.e. the number of years with at least one start, without the years with no start, seemed to be the measure the closest to the trait searched. Only males and geldings were studied. The expression of the likelihood requires the knowledge of effects assigned to the horse during his entire sport life of the horse. The structure of the present file gave some left censored data : the history of the horses aged more than 4 in 1972 was not known. So, the horses born before 1968 were deleted. They represented 10.9% of the total number of the horses. The horses still present in 1991, including 31.6% of the total number of horses, had a censored length of life, analyzed as it should be. The horses exported were also censored data, representing 6.4% of the number of horses. The horses reimportated during their sport life were deleted (0.3%). The national stallions which participated to special competition to test their jumping capacity and then returned compulsory to the stud were considered as censored (0.4%). The final file included 42,393 length of jumping life, out of which 43,3% were censored, realized by an equal number of male and gelding horses. This represented 155,570 years of performance, and 15 time intervals of one year were estimable.

### *Model*

The semi-parametric model of Cox (1972) was used for the hazard function. The complete model was :

$$\lambda(t,z_i) = \lambda_o(t)\exp\left[z_{Y,i}(t)'\beta_Y + z_{A,i}(t)'\beta_A + z_{F,i}'\beta_F + z_{N,i}(t)'\beta_N + z_{P,i}(t)'\beta_P + z_{s,i}'s\right] \qquad (1)$$

$\lambda_O(t)$ : the baseline hazard function,

$\beta_Y$ : vector of "year" effect. It included 19 levels (1972-1990). Because the year 1991 contained only censored data, its effect was not estimable.

$\beta_A$ : vector of "age" effect. Usually, this effect is described by the baseline hazard function. In the present study, the baseline hazard function described the survival process in regard to the number of years in competition. However, this number of years in competition might differ from age, because the age at first competition varied among horses, and because the horses might have years without performances. An accurate description of the ageing effect required explicitly the inclusion of an age factor, which was defined with 15 levels : from 4 years old to 18 years old and more, by step of one year.

$\beta_F$ : vector of "age at the first start" effect. The baseline hazard function measured the common effect to horses with the same number of years in competition ; the "age" effect measured the common effect to horses at the same age, at different moment of their sport life. The "age at first start" effect measured the influence of age at first start on the whole sport life. This effect had 6 levels : from 4 years old to 9 years old and more, by step of one year.

$\beta_P$: vector of "level of performance" effect., $\beta_N$ : vector of "number of starts" effect. These two effects need more explanations. The introduction of such effect allows to reach the "functional" stayability which measures the robustness of the horse for a given jumping quality. The major problem is to choose a measure of the level of performance, which remains as independent as possible of the precise date of a possible failure in the time interval. Unfortunately, all measures based on earnings, including earning per start or earning regressed on the number of starts, are related to the number of annual starts. And the number of starts is partially related to the possibility of failure in the time interval : the horses culled into the time interval have a number of starts smaller (7.3) than horses still alive in this year (15.6). To appreciate the influence of the level of earning independently of the influence of the number of starts, two models were used in two successive steps. The first model was defined in order to obtain adjustment factors for earning, as independent as possible of the number of starts. Consequently, this model included a "number of starts" effect and a "log(earning)" effect, and tried to estimate their respective effects jointly. The "number of starts" effect had 8 levels : 6 levels from 1 to 30 starts by step of 5 starts, 1 level from 31 to 40 starts and 1 level for more than 40 starts. As the number of starts is limited for young horses by the regulation, only the first 3 and 5 levels were considered at the age of 4 years and 5 years, respectively. The logarithm of earning was standardized by age and year (mean 100, standard deviation 20), assuming that the culling choice was between horses in the same year of performance and age group. Horses aged 4 and 5 have special competitions reserved to their age class, while after 6 years, a horse is compared to any other horse of any age. Consequently, three level of performance classes were distinguished : at 4 years, at 5 years, and after 6 years. Nine levels of performances were defined : 1 for the horses which did not earn any money (30% of horses each year), 6 between 70 and 130 by step of 10 and 2 at the extremes (≤70 and >130). At 4 years old, the extremes classes were merged and only 7 levels were considered, because the distribution deviates too much from a normal one, and because the variance was too small. "Earning" effects, estimated in the first model and assumed to be independent of the number of starts, were used as pre-adjustment factors in the second model, which did not include the effect of the number of starts. So this second model became (with $\hat{\beta}_P$ the estimation of $\beta_P$ from the complete model):

$$\lambda(t,z_i)=\lambda_o(t)\exp\left[z_{Y,i}(t)'\beta_Y+z_{A,i}(t)'\beta_A+z_{F,i}'\beta_F+z_{P,i}(t)'\hat{\beta}_P+z_{s,i}'s\right] \qquad (2)$$

$s$ : vector of sire effect. This effect was the only random effect. 4851 sires were considered, with 8.7 offsprings on average. More than 800 sires had more than 15 offsprings.

The vectors $z_{Y,i}(t), z_{A,i}(t), z_{F,i}, z_{P,i}(t), z_{N,i}(t), z_{s,i}$ were design vectors of the different effects for the horse $i$. For some effects the design vector was a function of time. This function was discontinuous and followed by step the time intervals of the hazard function. This method allowed to take into account effects as the "year" effect, which changed at each time interval, or the "level of performance" effect which was measured annually and followed the variations of the horse capacity.

***Prior Density***

The sire distribution is usually a normal one. But, in the present model, the additive polygenic effect might be defined on the exponential scale exp($s$) (noted $w$) or on the scale of $s$. To make the distribution of $w$ more flexible, a gamma density with parameters $\gamma$ and $\gamma$ was chosen as prior density, as in Ducrocq (1987).

***Likelihood***

The measure of the length of life is annual in the present data set. In this case of discrete failure time, the particular calculation of the survivor function is applied from Prentice et Gloecker (1978). The time intervals are noted $A_j=[a_{j-1},a_j]$ with $j=1,...m$, $a_0=0$ and $a_m=+\infty$. A culling or a censoring during the time interval $A_j$ is noted $t^j$. The censoring is supposed to happen in the beginning of the time interval : the horse is only supposed to live until the start of the time interval in which he is censored. We have :

$$\lambda(t^j,z_i)=P(a_{j-1}\le T_i<a_j|T_i\ge a_{j-1})=1-\alpha_j^{\exp(z_i'\beta)} \text{ with } \alpha_k=\exp\left(-\int_{a_{k-1}}^{a_k}\lambda_0(x)dx\right) \qquad (4)$$

$$\text{The likelihood is then : } L\propto\prod_{k=1}^{m}\left[\prod_{i\in D_k}\left(1-\alpha_k^{\exp(z_i'\beta)}\right)\prod_{i\in R_k}\alpha_k^{\exp(z_i'\beta)}\right] \qquad (5)$$

with $D_k$ the set of horses culled into the time interval $k$ and $R_k$ the set of horses alive during the interval $k$.

***Parameters estimation***

The *a posteriori* density of the parameters given the data is the product of the likelihood and the *prior* density (Let $\eta$ the number of sires and $\beta=(b,s)$ with $b=(\beta_Y,\beta_A,\beta_F,\beta_P,\beta_T)$.)

$$f(\beta,\alpha,\gamma|Y)\propto\prod_{k=1}^{m}\left[\prod_{i\in D_k}\left(1-\alpha_k^{\exp(z_i'\beta)}\right)\prod_{i\in R_k}\alpha_k^{\exp(z_i'\beta)}\right]\prod_{l=1}^{\eta}\frac{\gamma^{\gamma}w_l^{\gamma-1}e^{-\gamma w_l}}{\Gamma(\gamma)} \qquad (6)$$

The introduction of the different fixed effects were tested by maximization of the logarithm of the likelihood alone. To estimate the parameter $\gamma$ we used an iterative procedure, maximizing $f(\gamma|Y,b=\hat{b},\alpha=\hat{\alpha})$

with $\hat{b}$, $\hat{\alpha}$ obtained from maximization of $f(b, \alpha, s|Y, \gamma = \hat{\gamma})$ with $\hat{\gamma}$ obtained from maximization of the previous density $f(\gamma|Y, b = \hat{b}, \alpha = \hat{\alpha})$. At convergence, the $\gamma$ value was expected to be close to that one which would maximize $f(\gamma|Y)$.

***Results***

The estimations of the parameters "α" (survivor in time intervals), of the "age" effect and of the "age at first start" effect are partially confounded. The true distribution of the length of life is a combination of these three effects. The survivor function, the density function and the hazard function may be computed from these estimations to illustrate the "average" stayability. The curves of survivor never overlaps : the probability to be still alive after any number of years in competition was always superior for a horse which started the competition as early as possible. However, this feature was not enough pronounced so that the probability to be still alive at a given age (so with different number of years in competition, according to the age at first start) would be higher for a horse which started earlier than another. The probability to be still present after 5 years in competition for horses which began at 4 years old was 59% (they were then 8 years old) against 53% for those which began at 5, 45% for those which began at 6 and 41% for those which began at 7 but the last were 11 years old. After the age of 10, the probability to be still present was 43% for the horses which began at 4, 44% for those which began at 5, 45% for those which began at 6 and 50% for those which began at 7. The half-lives (50% horses still alive) were decreasing with the age at first start from 6.1 for a horse which starts first at 4 to 3.5 for a horse which starts after 8 years old. The decrease was rapid : 0.8 year between a horse which starts first at 4 and 5 years and reduced then to 0.1 years between 8 and 9 years at first start.

The main particular effects are "number of starts" and "level of performance". The relative culling rate associated to the "number of starts" effect was always the highest for the horse with a small number of events. More than a cause, a high number of starts was likely to be an indication of good health and of the desire to continue jumping competition. After 6 years old, the influence of the level of performance was clear : the better was the horse, the smaller was his relative culling rate (Figure 2). Only the relative culling rate of horses with a performance rate higher than 130 was higher than that of horses between 120 and 130 but this difference was not significant. The horses which did not earn money had a distinctly higher relative culling rate. A horse without earning had 1.9 chance more of being culled than an average horse with performance rate between 90 and 100. This last horse had himself 1,6 chance more to be culled than a horse with a performance rate of 120 to 130. According to its large magnitude, it appeared to be essential to include this effect in the study of functional stayability.

***Sires effect***

The parameter $\gamma$ of the gamma function was estimated at 38.73. The expectation and variance of $w$=exp($s$) were 1 and 0.0258, respectively, and the expectation and variance of $s$ were -0.0130 and 0.0261. To provide a corresponding heritability, a phenotypic variance of the trait was needed. Well, this variance was difficult to measure because the design of the explanatory variables was also dependent on time. In order to give a scale of size, taking into account age and age at first start effects, the variance of Log(t) varied from 0.5511 to 0.6023 according to the age at first start. The corresponding heritability was near 0.18. For example, the deviation of the half life of offsprings from the best and the worst sire was greater than two years, if they started at 5 years old (respectively 6.9 years and 4.5 years). The genetic variability of the trait appeared to be really interesting. To give an idea of the genetic relationship between length of sport life and sport capacity, the correlation between breeding value estimates of sires for the two traits was computed. The sires breeding value for jumping capacity were obtained by an index based on the performances of the progeny. The correlation was -0.06, i.e. close to 0 or slightly favorable, between functional stayability, adjusted for level of performance, and jumping ability.

## VALIDITY OF MODELS

***Animal Model Applications***

Since a long time animal model applications are applied in most countries in genetic evaluation of horses from competitions (Germany, France) and races (for trotters in Sweden, France, Norwegian, Belgian). In France, routine evaluations are performed in jumping since 1987 and in trotters since 1989. It is today possible to validate these applications in comparing genetic evaluation of young horses with their latter performances in competitions. Regressions to predict performances from BLUP animal model evaluations had been fitted for logarithm of earnings corrected for fixed effects obtained in jumping at 4 to 8 years old and genetic evaluations from 1987 to 1991 of the 3 years old riding horses at the date of evaluation (Table 1)

Tables 1 Correlation between Animal model evaluations at 3 years old and performances at 4 to 8 years old

| Age at Performance | 4 | 5 | 6 | 7 | 8 |
|---|---|---|---|---|---|
| Number of Horses | 9301 | 10641 | 8060 | 4805 | 2154 |
| Regression parameter | 0.797 | 1.044 | 1.016 | 1.100 | 1.137 |
| $R^2$ | 0.130 | 0.146 | 0.104 | 0.098 | 0.094 |
| Mean of reliability of BLUP | 0.249 | 0.228 | 0.213 | 0.206 | 0.202 |

The slope of the linear regression is near 1 for horses older than 4 years, as expected. Genetic correlations between performances at 4 years and at mature age is near 0.70 (Tavernier, 1992), with a lower genetic variance at 4. So the regression coefficient between BLUP evaluations, based on a repeated trait with genetic correlations between age of 1, and performances at 4 is expected to be lower than 1. R-squares seem to be higher than 0.04 to 0.05 expected with and heritability of 0.20 and reliability between 0.20 and 0.25 of BLUP evaluations. First of all, coefficients of determination are variable from horses to horses (standard deviation near 0.08) and are correlated to the values of the estimation (the better is a stallion or a mare the most their relatives participates to competitions), this may explain a part of the importance of the correlation between BLUP and performance. Second, heritability (0.20) used in genetic evaluation seem to be lower than those estimated recently with an animal model and REML method on a large data set. The heritability at 4 and 5 is consequently higher : 0.33 and 0.28 and latter nearly higher : 0.22 at 6 and 0.26 at 10. So the "realized" heritability is higher than those expected. Finally, it is possible that good environmental conditions are coming together with good genetic evaluation before performances : a good rider will prefer to test in competition a horse with good genealogical references.

***Validity of "rank" model***

The objective of this paper is to verify the ad equation of particular solutions to genetic evaluation of horses. The model proposed to explain ranking may be validate in an original way : in calculating the probability of each race, after evaluation of horses from the same file. This kind of work was done on phenotypic evaluation of trotters on results of one year. The data include 9228 races performed in 1989 by 13065 different horses which represent 129379 starts. 6 to 7 horses were recorded as "placed" in each races (so more than the number of horses with money in the race), the number of horses per race has mean 14 . The model for the underlying variable was the following :

$$y_{ijklm} = a_i + b_j + u_k + e_{ijkl}$$

$a_i$ : sex-age effect : female, males, geldings crossed with age : 2,3,4,5,6,7, 8 and more.
$b_j$ : distance of backing of the horse effect : 0, -25 meters, -50 meters.
$u_k$ : horse effect, $e_{ijkl}$ : residual

Estimate of repeatability was 0.26, with the same method than on jumping data. Probability of each race (with the same number of placed and non placed horses than in the file) was calculated from estimations of horses and fixed effects using taylor's series expansion to approximate integrals. The probability of races was multiplied per 11 in average compared to probability of each possible combinations when all horses are equal. Only 1% of race are unexpected : the probability of the ranking calculated from estimations is smaller than the probability when equal horses. More than 12% of races have their equal probability multiplied by 20. Elementary results for match between two horses are easy to compute as $P(y_1>y_2)=\Phi((\mu_1-\mu_2)/\sqrt{2})$ with $\mu_1$ the some of effects attached to the horse which win. So a horse estimated at 1 standard deviation of the distribution of evaluations on this file has a probability of 74% to win against a horse estimated at minus 1 standard deviation. Between the better and the worst horse, the probability that the first one wins is 99%.

***A trainer Effect***

The influence of trainers, riders, jockeys or driver is clear for the horse man. Their evaluation is, on the other hand, quite difficult. First of all, in sport competition, as this occupation represents often a spare time, one horse is riding by only one rider and the two effects are difficult to distinguish. For example, in France, 45% of identifiable riders ride only one horse during 4 years (from 1985 to 1989). Second, this kind of effect is changing in every event, so it could be taken into account only with elementary performance and not with aggregate trait as yearly performances. And third, this effect is often correlated with the genetic level of the horse, so a model with a random variable is not suitable, as it would be according to the number of horses by riders. Few authors tried to use such effect. Meinardus (1988) used group of riders as fixed effects in an animal model for competitions results. But theses riders were grouped from previous results with their horses. With the new model for ranking, we tested a trainer effect on trotters. In trotters, the deal is more professional and then, a trainer may have a larger number of horses than in jumping or dressage. The number of trainers is also lower than the number of drivers, and so they are easier to estimate as there is more records by trainer and easier to manipulate in equations (the matrix of fixed effects may be inverted). So this effect was added to the model presented in the previous paragraph. Trainers with 1 to 3 horses are grouped in a same classes and trainers with 4 to 9 horses in an other. All others trainers are identified themselves. Effects number is 529.

The first results is that, instead of the reduction of variance in the estimation of horse's effects, the model seems to be more adequate. To test its validity we calculated *a posteriori* probability of each race, as in the previous section, and the probability with equal horses was multiplied by 17 instead of 11. The value of each horses in the race is taken as his value added to the estimation of fixed effects of trainer and other fixed effects. Correlation between estimations from the two models are as follows:

Table 2 Correlation between horse and trainer effects in model with and without trainer

| With trainers | Without trainer Horse | With trainer Horse |
|---|---|---|
| Horse | 0.88 | |
| Trainer | 0.38 | -0.05 |

As expected from the model, correlation between horse effect and trainer effect is near 0. The association between horse and trainer which seems the better explanatory model is highly correlated to the horse effect without trainer effect but the little difference give nevertheless a better explication of the probability of ranking. Correlation between horse effect without trainer effect and trainer give a measure of the error made by neglecting the trainer effect. More had to be down on models to take into account the correlation between environmental and genetic influence. Correlation between estimations of horses in the two model is high but not near 1 and indicates a redistribution of the hierarchy.

## CONCLUSION

This patchwork of measures and models for performance in horses show the variability of the solutions proposed. During last years, the search of a biological scale for the performance gave several answers : from transformation of earnings as normal distribution to the adaptation of an underlying variable for each elementary rank. The confusion between capacity and stayability may be avoided by separate survival analysis. Validity and improvement of models is in good way, with regard to efficacy of the past routine evaluations and possibility to add trainer or rider effects, according to computer developments and new statistical tools. Emphasis will be made on two problems which had not been treated here : the preselection of the data available from competitions (Klemetsdal, 1992) and the multiplicity of objectives and measures (Arnason, 1987, 1989) which will be the subject of the following paper.

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