DEVELOPMENTS IN THE GENETIC EVALUATION OF PERFORMANCE TRAITS IN HORSES

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SUMMARY

A review of recent works is presented. As a measure of performance, transformations of earning are generally used now. New measures use directly ranks in each competition which makes it possible to take into account each result, non earnings horses and avoids to use subjective measure of the event. Interest of accounting for non earning and non starters is discussed. Complexity of the competitive life could be taken into account through traits as precocity (high correlation with mature performance but different results about heritability) and longevity (better heritability with a survival model than with count of starts). Description of aptitude is detailed in thoroughbred by different traits for different distances and in sport horses by null correlation between dressage and jumping, and various results about « amateur » and professional competition. Genetic models are improved by adding of inbreeding and long term response.

Keywords : Horse, performance, genetic evaluation

INTRODUCTION

These last years, traditional problems of genetic evaluation (how to record performances, BLUP animal model evaluation) were solved and generalized in most countries. Future developments deal with new questions about which traits to improve and how to model inheritance.

MEASURE OF THE PERFORMANCE

Earnings and points. Most of recent authors measure performances in sport and race horses by their earnings or points allocated to ranks in each event. As pointed out by Langlois (1975), a transformation is necessary in most cases. For the gambling or, even in sport horses, simply for the spirit of the exhibition, riders must have the will to win. So, earnings are distributed exponentially in function of the ranks in a course or an event : you really want to be the first only if the difference in prize is very important between the winner and the second. This raw performance scale is attractive for competition but inadequate for genetic evaluation. Transformations are now commonly used and give a reasonable normal distribution of the trait. Following are only the most recent references to see the generalization of this concept : in Ireland Foran *et al.* (1994) used $\log_{10}$ (cumulated points in one year) in show jumping ; in The Netherlands Huizingua and van der Mey (1987) used $\sqrt{\text{highest level during lifetime}}$ for jumping and dressage horses ; in France Langlois *et al.* (1996) used Log (annual earnings) for thoroughbred in flat races and races over the jumps ; in Poland, Sobczynska and Kownacki (1996) used Log (annual earnings) for Arab horses in races ; in Italy, Sivestrelli *et al.* (1995)

used log(annual earnings) for jumping, $\log_{10}$(annual earning+1/number of starts) for trotters and $\log_{10}$ (earning +1) for thoroughbred ; in Finland Saastamoinen and Nylander (1996) used (annual earnings)$^{1/4}$ for standardbred trotters ; in Norway ; Klemetsdal (1994) used (cumulated earnings)$^{0.20}$ standardized within birth year for trotters ; in Sweden, Arnason *et al.* (1982) used (life time earnings)$^{1/2}$, (life time earnings)$^{1/4}$, $\sqrt{(\text{earnings / No of starts})}$, $\text{Log}_{10}(\sqrt{(\text{earnings / No of starts}+1)})$; in Japan, Moritsu and Ichikawa (1995) used (annual earning)$^{1/2}$ (annual earning)$^{1/4}$ Log(annual earning) for thoroughbred and in Germany Meinardus and Bruns (1989) used Log(earning at each place) for jumping and dressage.

Racing time. For races, racing time is a natural choice to measure performances. But, the will to win is not the same thing that the will to run fast. In trotters, best racing time is often used and genetic progress is observed in most countries (Arnason *et al.* 1989). In thoroughbred, after the polemic about the lack of progress on times (Gafney and Cunningham, 1988, Hill, 1988), few authors focused on time, they prefer earnings or handicaps and timeform. Tolley *et al.*(1985) reported rather low heritability estimates on speed. In recent years, studies on racing time are limited to countries where this production is marginal. In Spain Chico (1994) found heritability near 0 in « Grand prix » (high level prized) races for racing time. Racing time in each race was also studied in Japan (Oki *et al* 1995). Depending on dirt and turf tracks and on distances (1000-2000m) heritability estimates were from 0.081 to 0.254. and repeatability from 0.432 to 0.700. Time per start (not available in all races) were also used for thoroughbred in Australia (Williamson and Beilharz, 1996) with heritability of 0.23 to 0.70 depending on method, age, tracks and distances. In these last two specific countries, heritability of this trait remains high.

Scope under theses traits. To measure one performance in one event, the problem is to evaluate the level of the event and the level of one rank in this event. The level of the event is only the level of competitors because the only reason to be ranked at a given place is that you have been beaten by the horse ranked before you and you beat the horse ranked beside you. The level of a rank is the difference between your performance and those of the others. Some strategies based directly on ranks were tested. To appreciate the level inside an event, different transformation of the rank were used in order to more or less account for the number of starters. Some of these traits are linear function of the rank : the rank of coming (from 1 to the number of starters) for thoroughbred in Germany (Jaitner *et al.* 1994), [1-(Place-1)/Number of starters +constant for the level of the event] for jumping and dressage (Bruns 1981), (N° of starters - 2*finishing position +1)/(number of starters +0.5) for thoroughbreds (Williamson and Beilharz, 1996), some others try to give more differences between the first ranked and the others : $\sqrt{\text{place}}$ for jumping and dressage in Germany (Hassenstein *et al.* 1996), and the last ones try to give more differences for the first competitors and last ones, in contrast with the middle ones : the normalized rank score for jumping horses is equal to the expected value of being ranked at the given place when sampling from a normal distribution (Foran *et al.* 1995). To estimate the level of the event, some authors include a fixed effect for each race (Hassenstein C. *et al.* 1996) but it becomes difficult with a large number of event, in this last study only 1700 to

3400 events were analyzed and no estimation of heritability were made in the work of Jaitner *et al.* which include 24 000 races. So only the level of a group of events –assumed the same difficulty– is used in Foran *et al* (1995) or in Bruns (1981). The better way to measure the performance outlined by the rank is the normal score, as the number of starters affect the value of the rank : it is more difficult to be the first from 50 than from 10. So, you do not have to be linear with the rank and the effects of non linearity is the same for the first and the last ones. If you correct only for the first ones (as with $\sqrt{\text{place}}$ in Hassenstein *et al.*, 1996), you only mimic the distribution of earnings. But normalized ranks suppose that the levels of all competitors in one event are the same, wheras obviously they are not. The second problem is the level of the event The level of each event, even of the same « technical » difficulty is different and only depends on the level of competitors. So, to give only a group effect is to do the same thing than with earnings which suppose that all races with the same money prize are of the same level. All these methods only use the race as a fixed effect and so suppose good crossing over events to take into account genetic differences between events and do not take into account variance of competitors in one event. All these problems may be solved by the use of an appropriate interpretation of the rank. The ranks are the expression of the hierarchy of the underlying performance of each horse of the event. So if you suppose this underlying measure of performance and you calculate as likelihood of the data, the probability of the ranks of the horses, knowing the distribution of this underlying variable, you may built a correct model and then solves the problem of the mean level of each event and of variability of competitors. This has been done by Tavernier (1991). Heritability was, for example in jumping, 0.16 and repeatability 0.29 (Tavernier, 1994).

I believe that international agreement will be found to unify the models used to analyze such results in competition. Ranking methodology is probably the most rigorous approach but it has to be easier to use to be generally accepted.

The status of a Horse. What is preceding suggest that all horses have some available performances. In fact, there are two successive gates : some horses never come to a show jumping or on a hippodrome and some would never be ranked or earn some money. For the second case –the starters but non winner horses– different strategies have been used, depending on the trait. When Log(earning) is used (by year or event), the mainly usual choice is to discard starts without earnings (Langlois, 1975, Meinardus and Bruns, 1989). Some authors add 1 to calculate the Logarithm (Sivestrelli *et al.* 1995). Some others define a continuous trait from the first to the last (Foran *et al.* 1995). Cutting-off the data introduce selection and therefor cannot be recommended. Affecting the same value to non-winners horses, without any reference to the level of the race is also a mistake. The strategy of the new model based on ranks makes it possible to take into account horses with no places as they were beaten by the last placed horse. So, the value of non placed horses is modulated at each event by the value of horses which had participated to the event. This solves the problem of identical value. For the second case – horses which never came to a competition– no information are available about this loss of data : perhaps it is a very good horse which have been exported to another country or perhaps it is a very bad one which never jump any obstacle ! Klemetsdal (1992) simulated a population which would be pre-selected before entering on a trotter race on a hypothetical trait correlated with future earnings. He proved that genetic trend was underestimated when ignoring this fact and that affecting a zero on non starters is a better way than cut-off to estimate genetic trend. Arnason (1996) suggested a multiple trait approach with a variable defining the status of the horse (starter or not) and proved that it is an easy and good method to avoid biases in genetic progress and an aid to limit inbreeding.

THE COMPETITIVE LIFE OF A HORSE

New development is to consider not only the result of one event as the quality of a horse but its capacity to make a good career in his entire life. Different approach begin to analyze other traits related to performances : precocity, longevity and a better description of the discipline.

Precocity. Two versions of precocity are interesting : the possibility to make early performances and the relation between these performances and later performances.

Early performances. Age at first start in trotters was analyzed by Saastamoinen and Nylander (1996a-b). Heritability estimates for age at first qualifying start, passed qualifying start and first race for trotters in two breeds (domestic one and standardbred) are low (0.04 to 0.16) In lack of other results, these heritability estimates suggest that early start of a career mainly depends on environment.

Relation with mature performances. Relation between early performances and latter performances have been more studied. In France, in jumping horses (Tavernier, 1992) genetic correlation between log(earnings) 4 years old and later results is 0.67 with 10 years old, 0.76 with 6 years old and 0.92 with 5 years old, whereas phenotypic correlations are low (respectively 0.20, 0.30 and 0.42). This explains that the capacity to win in jumping is more or less related to precocity but is due to a large extend to change in environment rather than different genetic ability. Correlations were also computed for Dressage with the new criterion based on ranks in France (Ricard, 1996) and were found to be high (from 0.74 to 0.99) between all ages, with most of them higher than .85. Heritability estimates were higher in jumping at 4 and 5 years old (0.33, 0.28 versus 0.26 at 10 years old) and it was also true for Dressage not a 4 years but at 5 and 6 years old (0.36 and 0.32 versus 0.26 at 8 years old). In Netherlands, results of Huizinga and Van Der Meij (1989) are based on lifetime total, i.e. cumulated performances, so correlations between early performances and adult ones are subject to autocorrelation. Genetic correlations are 0.95 between 4 and 5 years, 0.89 between 4 and 6 years in Jumping and respectively 0.90 and 0.96 in Dressage. Phenotypic correlations are high : 0.68 between 4 and 5 and 0.65 between 4 and 6 in Jumping, 0.78 and 0.69 respectively in dressage. Heritability estimates are not shown for theses traits but are told to be consistent with heritability obtained at adult age (from 6 to 8 years) and are around 0.20 in jumping and 0.10 in Dressage. In Germany, Meinardus and Bruns (1989) found low heritability estimates for jumping and dressage with young horses, 0.04 and 0.09, respectively, versus 0.18 and 0.16 for adult horses. Their performance was earning at each placing. These very different results are surprising as the biological determinism of all these measures is likely to be the same. Competition for young horses are particular in France where they are reserved to a certain class of age (4-5-6 separately) and with special rules (no chronometer, good grounds and special track superintendant), this is a professional circuit and so with a good homogeneity of the level of riders. This may explain good heritability. The choice of the criteria is also important : for example in France in dressage, results are very consistent with the criteria based on ranks but correlations are lower with earnings which introduce more subjectivity in the true level of events and do not take into account horse with no earnings (48% of horses in Dressage each year). So the structure of competition and recording are important to correctly evaluate the same nature of performance.

In trotters, correlation between ages were estimated in Sweden by Arnason *et al.* (1989). They were high for performances measured as earnings or earnings per start (0.76 to 1) between horses of 3, 4 and 5 years old. Heritability estimates decrease with age (from 0.38 at 3 years old to 0.18 for results before 13 years old) In Norway, for cumulated earnings, genetic correlation were very high (0.97 to 0.99) between 3 to 6 years old, partially due to some autocorrelation (Klemestdal, 1994). In contrast with the previous study, heritability increase with age (from 0.14 to 0.22). In Finland, Saastamoinen and Ojala, (1991) found higher heritability at an early age for all kind of performances : best time, number of starts, earnings$^{1/4}$ logit (first placing) logit (first to third placing), logit (disqualified races) with range for example from .38 to .19 for earnings at 3 to 5 years old. Generaly, early performances seem to be more heritable. Note that these estimates are from derived American standardbred which is already a precocious breed.

Longevity. Performance traits are sometimes recorded per event, per year or per life reflecting either the success of the horse, the capacity of the horse to repeat his success or to maintain it during a long time. To appreciate these different qualities, we may use a global trait as sum of performance over the life or distinguish different trait and analyze them separately.

A competitive career. With elementary record a « repeatability » model is often use for convenience, expecting a constant correlation between all records. Certainly a simple repeatability model is not the better one, specially when you use records in each event whatever the kind of record (Meinardus and Bruns, 1989, Tavernier 1991) : two events close to each other in time are likely to be more correlated than two distant events. In the future, a new model should be found to define the structure of an optimal career. In other productions, some authors evaluate traits as time series : lactation for Jamrozik and Schaeffer (1997) or application to growth curve for Meyer and Hill (1997). In our case, major difficulty is that no typical curve may be fit as for growth or lactation, different strategies of career over time may be found and each of them have to be identified and estimated.

Physical resistance. Two approaches have been studied recently : a study of diseases, mainly bone diseases and a study of longevity in competition. These two approaches complete each other : the longevity is the result of good health. Study about diseases is the subject of the paper of Philipsson in this present congress. So I only report one study (Winter *et al*. 1995) about relation between bone diseases and performances, which is the objective of good health. These first results are not on competition result but only on judgment in stationary performance trait for stallions. Genetic correlations seem to be moderate but negative biologically for rideability (from .006 for Sidebone to 0.41 for Osteochondrosis dissecans) with one exception for Arthropathia deformans which is favorable (-0.28). For jumping genetic correlation are near 0 except for osteochondrosis dissecans (0.53). Longevity be measured by the number of starts. In trotters heritability of such a trait is 0.02 to 0.12 in Sweden with annual measure depending on the age (Arnason *at al.* 1989), in Norway for the Norwegian trotter heritability were, for accumulated number of starts with the better power to normalized distributions : 0.02 to 0.10 from 3 to 6 years old (Klemestdal, 1989) and in Finland it was 0.13 for standardbred trotter for $\sqrt{\text{number of starts}}$ (Saastamoinen and Nylander, 1996). Genetic correlation of this trait with performances traits are low :-0.26 to 0.39 with earnings or earnings per start in Sweden, high in Norway : 0.70 to 0.95 and Finland 0.85 which is difficult to interpret but perhaps in relation with standard error due to low heritability. Very low heritability was also found in jumping by Foran *et al* (1994) : 0.04. Longevity has been studied with an appropriate model based on survival analysis and censored data in Jumping competition (Ricard and Fournet-Hanocq, 1997). Year of performance, age at first start, adjustment for level of performance and breed had significant influence. Heritability estimate was 0.18, so higher than for number of starts. Difference in half life of progeny of two extreme stallions is more than 2 years. The genetic correlation estimated from a multivariate analysis of longevity and Log(earnings) was favorable and reached -0.41, in spite of a phenotypic adjustment of longevity for performance level (Ricard and Chapuis, 1997).

More details in the description of the trait. In the beginning of horses study we only distinguish race performances and sport performances. Now, in this separate quality we also want to distinguish different aptitude.

Distances. In races distance is traditionally a specialty of different horses. Distances are often use as environmental effect on racing time, which is obviously the fact but may be analyzed as a different trait, even correlated with others. No work on genetic correlation have been made, only heritability have been calculated on different files. In the work of Oki *et al.* (1995), heritability seems to decrease with the distance : 0.25 to 0.08 for racing time from 1000m to 2000m on turf track. And in the work of Williamson and Beilharz (1996) heritability seems higher for short races (<1250m) and long races (>2100m) but their estimates are capricious and often outside the parameter space.

Sport horses. In sport, an important difference has been found between jumping and dressage, which is quite proved now (Huizingua and van der Meij, 1989 ; Bruns *et al.*, 1985 ; Schade *et al.*, 1994), and more recently works have been done about difference between « amateur » and professional horses in relation with the talent of riders. In Germany and in France, competitions are divided in 4 major different levels. Is it the same quality of horse which is expressed in these levels ? In contrary, is the quality of horses for bad riders the same as for good riders ? Very different results are obtained in the two countries. In Germany, genetic correlations were obtained in a file of competitions from 1990 to 1994 (Hassenstein *et al.*). The trait considered was $\sqrt{\text{place}}$. The model corrects performance for event and class of rider and number of starters. Four levels were distinguished. Heritability estimates vary from 0.071 (for the lowest level) to 0.129 (for the highest level). In jumping, genetic correlations were low between all levels (from 0.43 for the two lowest levels to 0.071 between the highest and the lowest) except for the two middle levels were the correlation was 0.782. In dressage lower genetic correlations were found with the larger between the two middle level (0.440) and the smaller negative one : -0.104 between the highest and the middle lower level. In contrast, in France these correlations were very high. In Dressage (Ricard, 1996) they were calculated from a simplified approach of the method based on ranks described in the first paragraph. Results between 1990 and 1995 were used. Two categorical levels were distinguished. Genetic correlation estimate was 0.81 (±0.11). In jumping, similar study was made for only one year (1987) with 332143 starts and 23592 horses. The genetic correlation estimate with the same distinction of two levels was 0.76 (±0.03). Perhaps the difference in methodology is not the only explanation, the organization of the competition is different, and so the same trait may be measured in France, but not in Germany

NEW DEVELOPMENTS IN GENETIC MODELS.

In other species, special interest is focused on molecular genetic. No advance has been done in this matter in Horses, perhaps as genetic maps for horses have not been completed so much. But genetic models were investigated for the effect of inbreeding, effect of long term selection and validity of the additive model in specific cases but which may have applications in other breeds. Inbreeding is a traditional subject of horse breeding but its true influence on performances was sparsely analyzed. The Norwegian Coldblooded trotter is a breed of choice to analyze this as inbreeding is nowadays close to 6% (Klemetsdal, 1993). Klemestsdal (1996) found a significant inbreeding depression of 21.1% of phenotypic variance (equivalent to 48.0% of a genetic standard deviation) of his performance trait for 10% of inbreeding. No influence of mare inbreeding was found. This suggest at least that a non zero dominance variance exists that has to be taken into account in the evaluations as well as for matings. In horses, however, few data are available to estimate dominance variance. The second consequence is that perhaps selection must take into account the increasing of inbreeding and try to limit it to preserve genetic variance. A work has been done by Arnason (1996) in order to change the selection criterion of BLUP animal model on a function of EBV and relationship among the male candidates for selection as suggested by Wray and Goddard (1994). This simulation concluded that such a criterion could be used in small populations and leads to a preservation of future genetic variance with small loss (2-3%) in the short term (which is long in time in horse population !). In another sight, Arnason (1994) tried to simulate the influence of a non-linear genetic model on genetic trend and heritability. This simple problem of scale induces a partial explanation of an apparent loss of progress, although the favorable alleles are not fixed.

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