

Impact of the event effect in genetic evaluation for ranking traits in horses

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Abstract

In genetic evaluation of horses, the genetic trend does not correspond into a phenotypic trend when using ranking as a phenotype due to its uniform distribution, and some other effects might be absorbing that trend. From a founder population, a further four discrete generations of 100 individuals were simulated under random mating. Then, ten additional discrete generations were simulated by selecting the best 10% of the animals. Likewise, an underlying variable with heritability 0.1 or 0.2, affected by an event environmental influence, generation and permanent environment, was simulated to establish the ranking assignment of 10 random participants or according to the competitive level for each event, in 10 or 100 structured or unstructured events. The ranking trait genetic evaluation model was tested to include or exclude the event effect and the permanent environment effect, depending on the scenario. The results showed that the event effect fitted the different competitive level of each event, leading to a 5% to 23% of selection response improvement for structured competitions. Therefore, the event effect should be included in the genetic evaluation models of horses. The permanent environment fitted or simulated did not significantly improve the selection response. The event effect explained the competition genetic level, by compensating the genetic trend obtained by selection.

KEYWORDS

breeding programme, genetic response, phenotypic trend

1 | INTRODUCTION

Ranking is the traditional criterion to measure performance in horse competitions, as it is the criterion most often registered and easily available. This trait allows horses that participate in the same event to be compared with each other (García-Ballesteros et al., 2018; Ricard & Legarra, 2010; Tavernier, 1991). However, considering ranking as a performance indicator could give inadequate information of the true level of performance (Cervantes et al., 2020). In addition, a racehorse must be fast, adapted to each event and the event's own environmental

conditions (Tavernier, 1991). Thus, the final position is the sum of genetic effects and environment factors (Gómez et al., 2010) and also depends on the performance of the competitors.

Probably the most serious concern is the effect of the competitors' level during the same event when considering ranking traits in genetic evaluation of horses (Cervantes et al., 2020; Gómez et al., 2011). Additional difficulties in establishing a statistical model for a fixed number of participants are: (a) the mean of the qualifying positions is stable over the time leading to no phenotypic trend across time and (b) differences between positions do not directly

express the equivalent differences in a supposed underlying variable that would express the performance capacity. In fact, an assumption of normality is usually established whilst these differences between scores lead to uniformity in the distribution of the analysed trait. Finally, since a possible genetic trend is not translated into a corresponding phenotypic trend, there must be other effects, such as the event, the generation or year effect, absorbing that genetic trend in the genetic evaluation models.

Differences in the obtained rank by two animals are not a potential indicator of performance because it can be confused with the level of the competitors of the event if this is not fitted. In a competition, in which all the competitors are submitted to the same event, ranking scores finally depend on the competitive level of the rest of competitors (Gómez et al., 2011; Vicente et al., 2014). But horse performance does not depend on the performance of the other competitors, at least not more than the desire to win that makes a horse respond better in a competition with suitable rivals (Thiruvankadan et al., 2009). In ranking traits, the event effect has a different interpretation than that from the herd effect (Ricard & Touvais, 2007) traditionally used in genetic evaluation models in cattle. The event has no effect on the performance within it, which is only defined by the additive genetic and the other random effects in the model. Moreover, the event effect can be only estimated from the genetic relationship of the individuals that participate in the other races. However, competitors are really structured into categories according to their technical performance: the best competitor will go to the best event and will meet the best competitors from other studs, associating the genetic value and the event. Furthermore, owners tend to choose the event level according to their horse level to optimize its chances to obtain a better financially rewarding position (Gómez et al., 2011; Langlois & Blouin, 2007). Thus, when rank is the analysed trait, the common environmental influence of the event effect would have already been corrected, by only fitting the competitive level of the participants of that event.

In summary, by including the event effect in the genetic evaluation any differences would be corrected among the events such as the competition difficulties and the average level of the competitors (Cervantes et al., 2020; Gómez et al., 2011), because participation is not random among events. In this way, the event effect includes the level event difficulty and only depends on the competitors' level. This is an important factor in genetic evaluations, and the statistical models are designed to adjust adequately this effect and to obtain more accurate predicted breeding values for ranking traits (García-Ballesteros et al., 2018; Ricard, 1998; Ricard & Touvais, 2007).

The main objective of this study was to investigate through simulating the role of the event effect in the

genetic evaluation models for ranking traits in horses by compensating the genetic trend to accommodate the observable stable phenotypic one. Secondly, the aim of the study was also to assess whether the genetic trend achieved by selection is totally or partially compensated for by the trend in the permanent environment effect. The impact of fitting the event effect on the selection response for different competitions structure types, heritability scenarios and number of participations per animal was also quantified. Finally, the study included the consequences of using rank performance as selection criterion supposedly addressing an assumed underlying normal distribution, on the accuracy of the predicted breeding values in the genetic evaluation models.

2 | MATERIALS AND METHODS

2.1 | Data simulation

Data used for this research were generated by simulation. Discrete generations were considered in the simulation of 50 sires and 50 dams each. After the founder generation, four more generations were simulated under random mating conditions to create relationships among the animal candidates for selection. A further ten additional generations were simulated under selection following the procedure described below.

Founders additive genetics values (u_i) were randomly obtained from a normal distribution $u_i \sim N(0, \sigma_u^2)$ with σ_u^2 being the additive genetic variance. Additive genetic values for animals with known parents p and m were obtained by $u_i = \frac{1}{2}u_p + \frac{1}{2}u_m + \varphi_i$, with the Mendelian sampling obtained from a normal distribution $\varphi_i \sim N(0, \frac{1}{2}\sigma_u^2)$, thus ignoring the inbreeding coefficients in the parents.

The initial population for selection was established from the fifth generation. The events were simulated with exactly 10 competitors each and obtained randomly from among the candidates: some horses might have participated in more than one event and others might not have participated in any of the events. For each participation, an underlying value was simulated in the following model:

$$y_{ijkl} = \mu + g_i + c_{ij} + u_k + p_l + e_{ijkl}$$

where y_{ijkl} was the underlying value representing the animal performance of an individual k from the generation i in the competition j and the permanent environment l ; μ was the general mean with arbitrarily assigned value equal to 5.5 as the average ranking positions in an event with 10 participants, g_i was the simulated systematic effect of the generation i ; c_{ij} was the systematic effect of the event or competition

j nested within generation i ; u_k was the true genetic value of the animal k , p_l was the permanent environment effect and e_{ijkl} was the residual. The residuals and permanent effects were generated from respective normal distributions $e_{ijkl} \sim N(0, \sigma_e^2)$ and $p_l \sim N(0, \sigma_{pe}^2)$, with σ_e^2 being the residual variance and σ_{pe}^2 the permanent environmental variance. The phenotypic variance of the underlying variable was arbitrarily assigned a value equal to 1. The permanent environment effect was included or excluded in the simulation depending on the scenario. Systematic effects were simulated from uniform distributions arbitrarily ranged from -2 to 2 for generation and between -2.5 and 2.5 for the event. Note that generation and event effects will not influence the relative performance in the observable scale, but they are included to better match the theoretical assumptions of the threshold model.

Participants were ordered according to the underlying value, from lowest to highest, and the rankings were assigned according to their position in this order: lowest values correspond with the best performance, as done for the ranking trait during the competition.

Different scenarios were considered according to different factors:

- Competition structure. There were two types of competitions, unstructured and structured. In the unstructured competitions, any animal of the generation could participated in any event, independently of its genetic value. Participants per event were chosen randomly. A second scenario of structured competitions was simulated according to the horse-riding competitions in France (Ricard & Legarra, 2010). Three equal size groups of animals were established depending on the animal's genetic value (best, intermediate and bad) and three event categories for competitive ability from 1 to 3. Under this scenario, the animal participation probability depends on the competitive ability in that category according to the percentages presented in Table 1. In effect, there was a very low or no connection amongst the events.
- Average number of participations per horse. Each generation 10 or 100 events were simulated, so that one or ten average participations per horse were simulated.
- Fitting or not the event effect in the genetic evaluation. All scenarios were tested to include (E) or not the event (NE) as systematic effect in the genetic evaluation model.
- Heritability. Simulation was designed with two heritability values: 0.1 or 0.2.
- Permanent environment influence. Three different values of permanent environment variance were simulated according to its ratio (c^2) over the phenotypic variance: half the heritability (0.05 or 0.1), equal to the

TABLE 1 Structured competitions according to the competitive ability in three categories

Category	Competitive ability		
	1/3 Best	1/3 Intermediate	1/3 Bad
1	90%	8%	2%
2	8%	84%	8%
3	2%	8%	90%

Note: Ricard and Legarra (2010).

heritability (0.1 or 0.2) and twice the heritability (0.2 or 0.4).

- Fitting or not the permanent environmental effect in the simulation and/or in the genetic evaluation. A cross design was done by simulating or not this effect as well as fitting it or not in the genetic evaluation model. Then, four different scenarios were tested. The permanent environment effect was not fitted despite being simulated (PES) or it was fitted in the genetic evaluation but was not simulated (PEE). A third scenario included the effect in the genetic model when it was simulated (PESE). The fourth scenario excluded the effect in the genetic evaluation, and it was not simulated (No PE).

Issues like overlapping generations, number of participants, race lengths, ages and other effects were not simulated to avoid introducing a disequilibrium which would have made it difficult to disentangle the influence of the event effect from the genetic selection response. Furthermore, the inbreeding coefficient of the parents was ignored due to the high number of simulations needed to carry out in the study.

2.2 | Selection procedure

All the information accumulated at each generation was used to predict breeding values. The 10 best sires and the 10 best dams were randomly selected as parents to mate for the next generation. Even this balanced selection across sexes is not realistic, but it was done to avoid any additional statistical noise in the study.

Breeding values were predicted based on a mixed model with:

$$\mathbf{y} = \mathbf{Xb} + \mathbf{Zu} + \mathbf{Wp} + \mathbf{e}$$

$$\begin{pmatrix} \mathbf{u} \\ \mathbf{p} \\ \mathbf{e} \end{pmatrix} \sim N \left(\begin{bmatrix} 0 \\ 0 \\ 0 \end{bmatrix}, \begin{bmatrix} \mathbf{A}\sigma_u^2 & 0 & 0 \\ 0 & \mathbf{I}\sigma_{ep}^2 & 0 \\ 0 & 0 & \mathbf{I}\sigma_e^2 \end{bmatrix} \right)$$

where \mathbf{y} was the vector of raw rankings, \mathbf{b} the vector of systematic effects to be estimated, \mathbf{u} the vector of additive genetic effects, \mathbf{p} the vector of permanent environmental effects, \mathbf{e} the vector of residuals, \mathbf{X} the incidence matrix of systematic effects, \mathbf{Z} the incidence matrix of animal additive genetic effects and \mathbf{W} the incidence matrix of permanent environmental effects. The event effect was fitted or not depending on the scenario as systematic effect with the overall mean. The generation effect was simulated but not considered in the model as effect because the event effect was nested within generations. There were 10 or 100 events depending on the scenario per generation. The permanent environmental effect was fitted (PEE or PESE) or not (PES or No PE) as random effect also depending on the scenario. Variance components were assumed as known and were those used in the simulation of the underlying simulated variable.

2.3 | Genetic response, accuracy, and phenotypic trend

The true selection response per generation was monitored as the average additive genetic value of the underlying variable in the simulation. Accuracy in different scenarios was calculated in different ways: (a) the correlation between the true additive genetic value of the animals and the predicted breeding value obtained from the genetic evaluation for ranking trait (ρ_r); (b) accuracy obtained from the prediction error variance extracted directly from the corresponding element of the inverse of the coefficients matrix when the BLUP was solved (ρ_p); and (c) as a reference value, accuracy of the selection index based on the n (10 or 100) records of the animal (ρ_t):

$$\rho_t = \sqrt{\frac{nh^2}{1 + (n-1)(h^2 + c^2)}}$$

The phenotypic trend was visually decomposed by components to analyse the evolution of systematic and random effects. Additionally, association between predicted genetic and residual value pairs was visually analysed and correlated globally.

The mean and its standard error were calculated for all the described parameters from the values of 100 replicates in each scenario using the values of the last generation.

A specific code was developed in R language for this study.

3 | RESULTS

3.1 | Genetic response

Table 2 shows the selection response mean and standard error when fitting or not the event effect in the genetic

evaluation models in both unstructured and structured competitions. This assumes different heritabilities and events per horse without permanent environment, neither in the simulation nor in the genetic evaluation model. The same genetic selection responses in 10 generations with different heritability scenarios and participations per horse are given: in Figure 1 for scenarios of unstructured competitions and in Figure 2 for scenarios of structured competitions. Fitting or not the event effect did not affect the genetic response under unstructured competitions scenarios providing no significantly different responses in both cases. But there were significant increases in the response when the event was fitted in structured competitions scenarios from 5% ($h^2 = 0.1$ and one participation on average per candidate) to 23% ($h^2 = 0.2$ and ten participations on average per candidate). As mentioned already, fitting or not the event is also relevant despite there being no statistical power to show any significant differences in all scenarios of unstructured competitions, even though with 1 participation on average and $h^2 = 0.1$, the genetic response improved 3%. Thus, suggesting that with less information, there may be some events becoming randomly structured. Competition structuring always provides significantly worse responses than no structuring from 4% ($h^2 = 0.1$ and ten participations on average per candidate) to the worst situation of 36% ($h^2 = 0.2$ and one participation on average per candidate). The losses of the genetic response would become more evident if the event effect was not fitted. This result proves the influence of the event effect in structured competitions, which is clearer with greater heritability since the amount of information to estimate the event effect comes exclusively from the divergence between the expected and the observed resemblance between relatives.

The increase in response when counting with ten participations instead of one on average per candidate was significant in all cases, but more remarkable in structured competitions scenarios (103% more with $h^2 = 0.1$ and 105% more with $h^2 = 0.2$) than in unstructured competitions (64% with $h^2 = 0.1$ and 82% with $h^2 = 0.2$).

Since the structured competition is the most plausible scenario with significant differences in the selection response in all scenarios, only the results regarding these scenarios are given in rest of this results section.

3.2 | Accuracy

Figure 3 shows the theoretical accuracy, the accuracy as the correlation between real and predicted breeding value and the accuracy derived from the prediction error variance in all the considered structured scenarios. By fitting the event effect in the model, ρ_p was always lower in

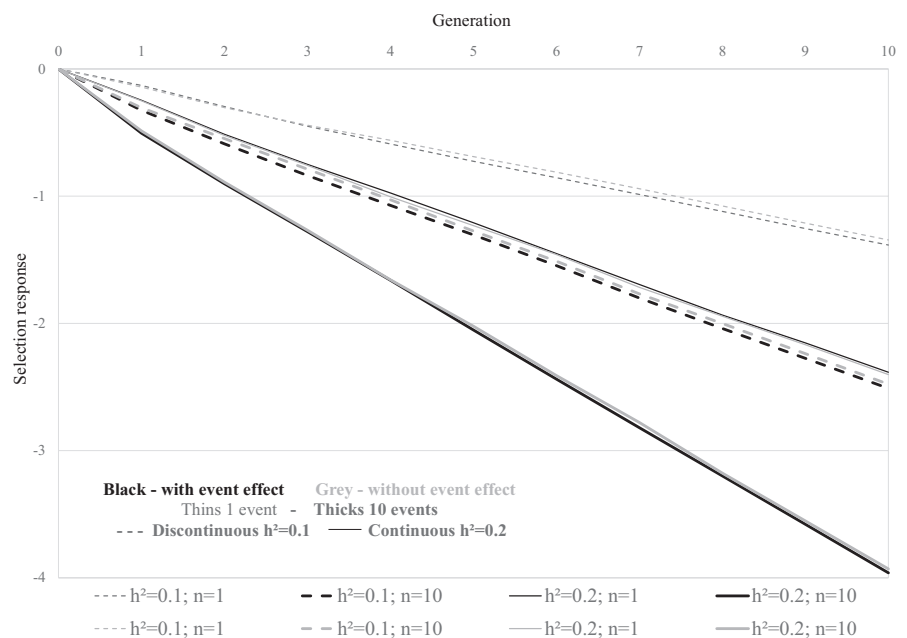
TABLE 2 Selection response mean and standard error fitting or not the event effect in the genetic evaluation models in unstructured and structured competitions assumed different heritabilities and events per horse

Average of number of events		Unstructured competitions		Structured competitions	
h^2	1	0.1	0.2	0.1	0.2
E		-1.505 ± 0.027^{ns}	-2.640 ± 0.037^{ns}	-1.289 ± 0.027^{ns}	-1.900 ± 0.033^a
NE		-1.459 ± 0.030^{ns}	-2.620 ± 0.034^{ns}	-1.224 ± 0.022^{ns}	-1.683 ± 0.028^b
(NE – E)/NE (%)		–3%	–1%	–5%	–13%
UC versus SC (E) (%)		0%	0%	–14%	–28%
UC versus SC (NE) (%)		0%	0%	–16%	–36%
h^2	10	0.1	0.2	0.1	0.2
E		-2.737 ± 0.021^{ns}	-4.339 ± 0.028^{ns}	-2.616 ± 0.016^a	-3.900 ± 0.023^a
NE		-2.703 ± 0.019^{ns}	-4.316 ± 0.028^{ns}	-2.305 ± 0.019^b	-3.169 ± 0.022^b
(NE – E)/NE (%)		–1%	–1%	–13%	–23%
UC versus SC (E) (%)		0%	0%	–4%	–10%
UC versus SC (NE) (%)		0%	0%	–15%	–27%
Difference per events mean number (%)		82%	64%	103%	105%

Note: Different significant responses ($p < .05$) within heritability value carry different letters.

Abbreviations: E, with event effect; NE, without event effect; SC, structured competition; UC, unstructured competitions.

FIGURE 1 Selection response in 10 selection generations in genetic evaluation models for the raw rank according to fitted or not the event effect in different scenarios in unstructured competitions



all scenarios in structured competitions, showing the loss of accuracy due to the need to estimate the event effect. This loss was between 50% and 100% in scenarios with one participation on average per animal and between 11% and 21% with 10 participations (Table 3). In fact, the lowest accuracy values were obtained in all scenarios with $h^2 = 0.1$ and one average participation (0.017 and 0.020 in structured and unstructured scenarios, respectively) (Table 3) comparing with values from ρ_r and ρ_t (Figure 3). If the event effect was not fitted, the accuracy

would have been lower in the less informative scenarios and especially with an average of a single participation per animal.

3.3 | Phenotypic trend decomposition

Figure 4 shows information about the results in one replicate with $h^2 = 0.2$ and 10 participations per horse in a structured scenario where the event effect was fitted as a

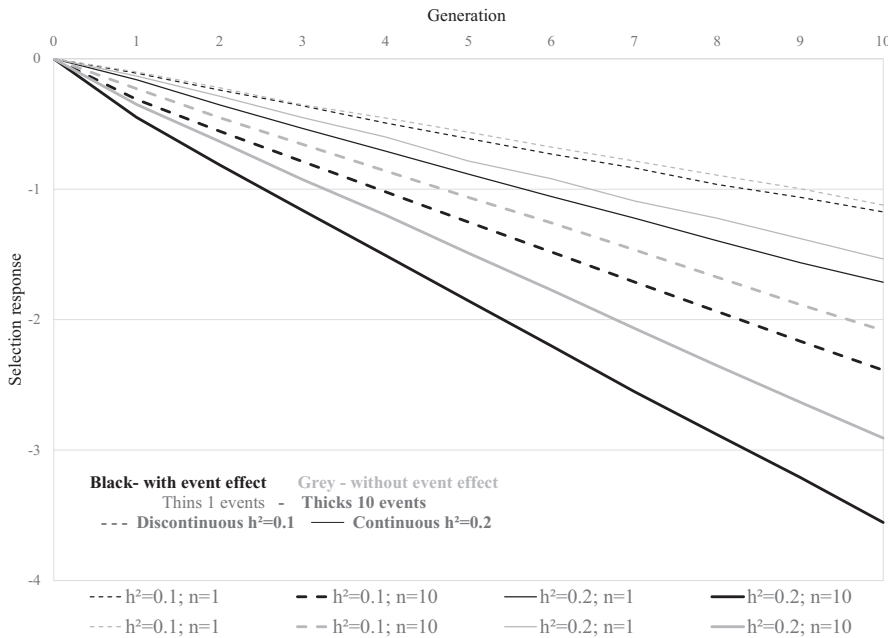


FIGURE 2 Selection response in 10 selection generations in genetic evaluation models for the raw rank according to fitted or not the event effect in different scenarios in structured competitions

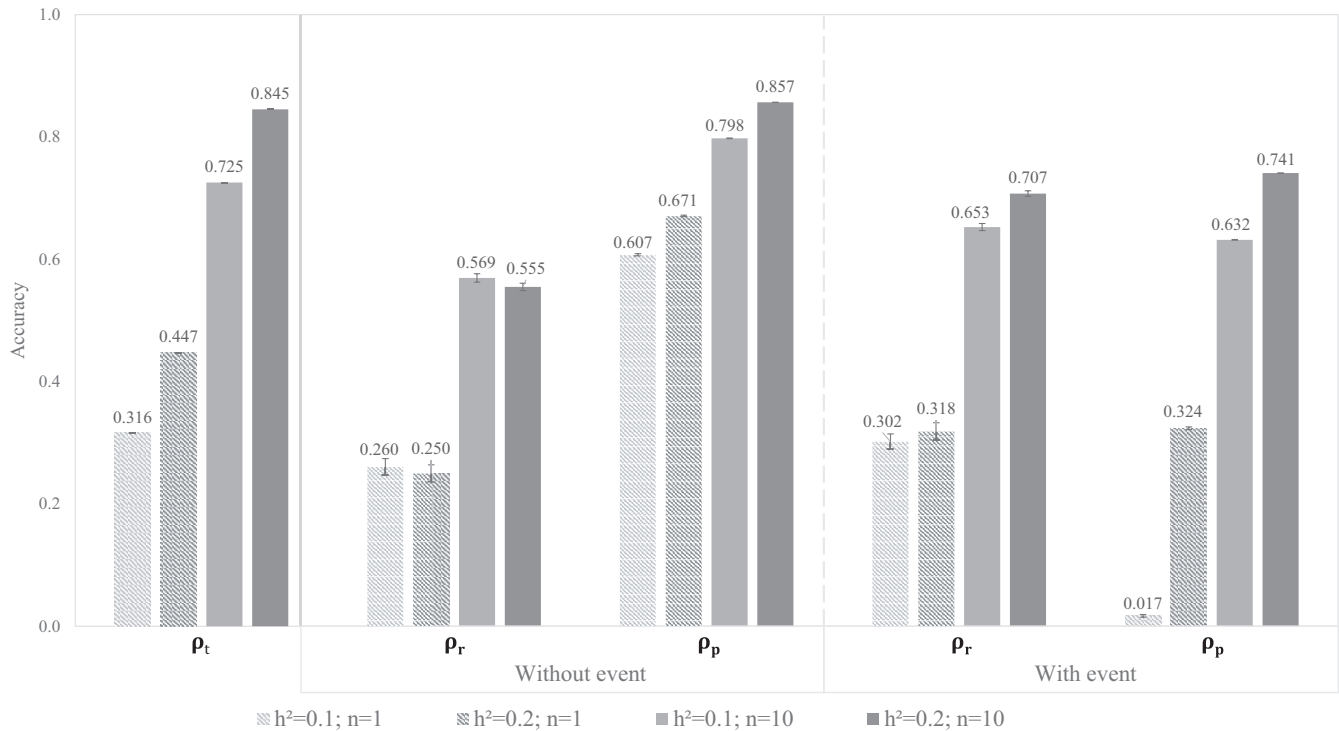


FIGURE 3 Theoretical accuracy (ρ_t), accuracy as the correlation between real and predicted value (ρ_r) and accuracy derived from the prediction error variance (ρ_p) fitting and not the event effect in different scenarios in structured competitions

systematic effect: a good example for similar scenarios with the same patterns. Figure 4a shows the observable genetic trend in predicted breeding values which corresponds to what is expected with a remarkable genetic response from the point where selection begins. Predicted residual value distribution is shown (Figure 4b) with absence of trend along generations. The evolution of the obtained estimates for the event effect is shown in Figure 4c. This

figure gives an inverse trend to the genetic trend showing how the event effect can account for the different competitive level. These different event levels evolve across generations as a consequence of the selection process with evident success observed in the genetic trend. Note that a model with only a generation effect instead of the event effect could have been fitted, but the different genetic level of the different categories according to competitiveness in

TABLE 3 Accuracy mean derived from the predictor error variance and standard error fitting or not the event effect in the genetic evaluation models in unstructured and structured competitions assumed different heritabilities and events per horse

Average of number of events		Unstructured competitions		Structured competitions	
h^2	1	0.1	0.2	0.1	0.2
E		0.020 ± 0.002	0.340 ± 0.003	0.017 ± 0.002	0.324 ± 0.002
NE		0.607 ± 0.002	0.682 ± 0.002	0.607 ± 0.002	0.671 ± 0.001
(NE – E)/NE (%)		100%	50%	100%	52%
h^2	10	0.1	0.2	0.1	0.2
E		0.654 ± 0.001	0.762 ± 0.000	0.632 ± 0.001	0.741 ± 0.000
NE		0.802 ± 0.001	0.858 ± 0.000	0.798 ± 0.000	0.857 ± 0.000
(NE – E)/NE (%)		18%	11%	21%	14%

Abbreviations: E, with event effect; NE, without event effect.

structured competitions would not be adjusted. In fact, it is possible to appreciate three rough lines according to the three simulated event categories. The inclusion of the event effect also affected the proportion of the selected horses for each competitive ability. In structured competitions and ten records on average, the inclusion of the event effect increased 19% and 27% ($h^2 = 0.1$ and $h^2 = 0.2$, respectively) the number of best horses simulated. Finally, the pairs \hat{e} with \hat{u} (Figure 4d) had a null (or low positive) correlation between these predicted values.

Figure 5 shows the results in the same scenario as Figure 4 but when the event effect was not fitted in the model as the only difference. The genetic trend (Figure 5a) reveals that in this case, although there was a rough soft genetic trend, this evolution was hardly noticeable. Predicted residual values (Figure 5b) did not show any type of evolution throughout the generations, as happened in the previous example when the event effect was fitted in the model. Finally, the pairs \hat{e} with \hat{u} (Figure 5c) show the grouped values into lines corresponding to the animals of each generation: an extreme negative correlation within each generation is shown, but when calculated globally with the individuals of all generations, the result is a null or positive correlation value.

3.4 | Permanent environment

Table 4 shows different scenarios of selection response in 10 generations accounting for or not the permanent environmental effect in both the simulation and genetic evaluation models even for anyone of them. The scenarios are given for structured competitions all fitting the event systematically effect and with an average of ten records per animal.

There were no significant differences when fitting or not the permanent effect in the model when this effect

was included in the simulation model (PESE vs. PES). However, higher responses were obtained when the permanent environmental effect was fitted in the model without having been simulated (PEE vs. No PE). Specifically, responses from 3% (heritability 0.1 and c^2 0.1) to 7% (heritability 0.1 and c^2 0.1) with the latter were being the best response. The 7% was the maximum improvement achieved among all the scenarios essayed regarding this random effect. There were no significant differences in responses when the magnitude of the permanent environmental variance was half the genetic additive variance ($c^2 = \frac{1}{2}h^2$), independently of the heritability value.

For the structured scenario with $h^2 = 0.2$, $c^2 = 0.4$ and ten participations per horse, Figure 6 gives information about solutions for a replicate where event and permanent environment effects were fitted as systematic and random effect, respectively (PESE). All other scenarios with event and permanent environmental effect led to almost identical patterns. Predicted breeding and residual values showed the same trend as described in Figure 4a,b when permanent environmental effect was not accounted for. This effect showed a flat trend across generations. Finally, estimated event effect and pairs \hat{e} with \hat{u} (Figure 6e) showed similar patterns than when permanent effect influence was not studied (Figure 4d).

4 | DISCUSSION

The aim of this study was to assess and quantify the role of the event fixed effect in the genetic evaluation model used in breeding programmes dealing with ranking trait as a selection criterion. The ranking obtained by the participants is considered a traditional phenotype in the genetic evaluation of horses after sorting the animals in order of arrival at the finish line, by gains or by scores (Ricard &

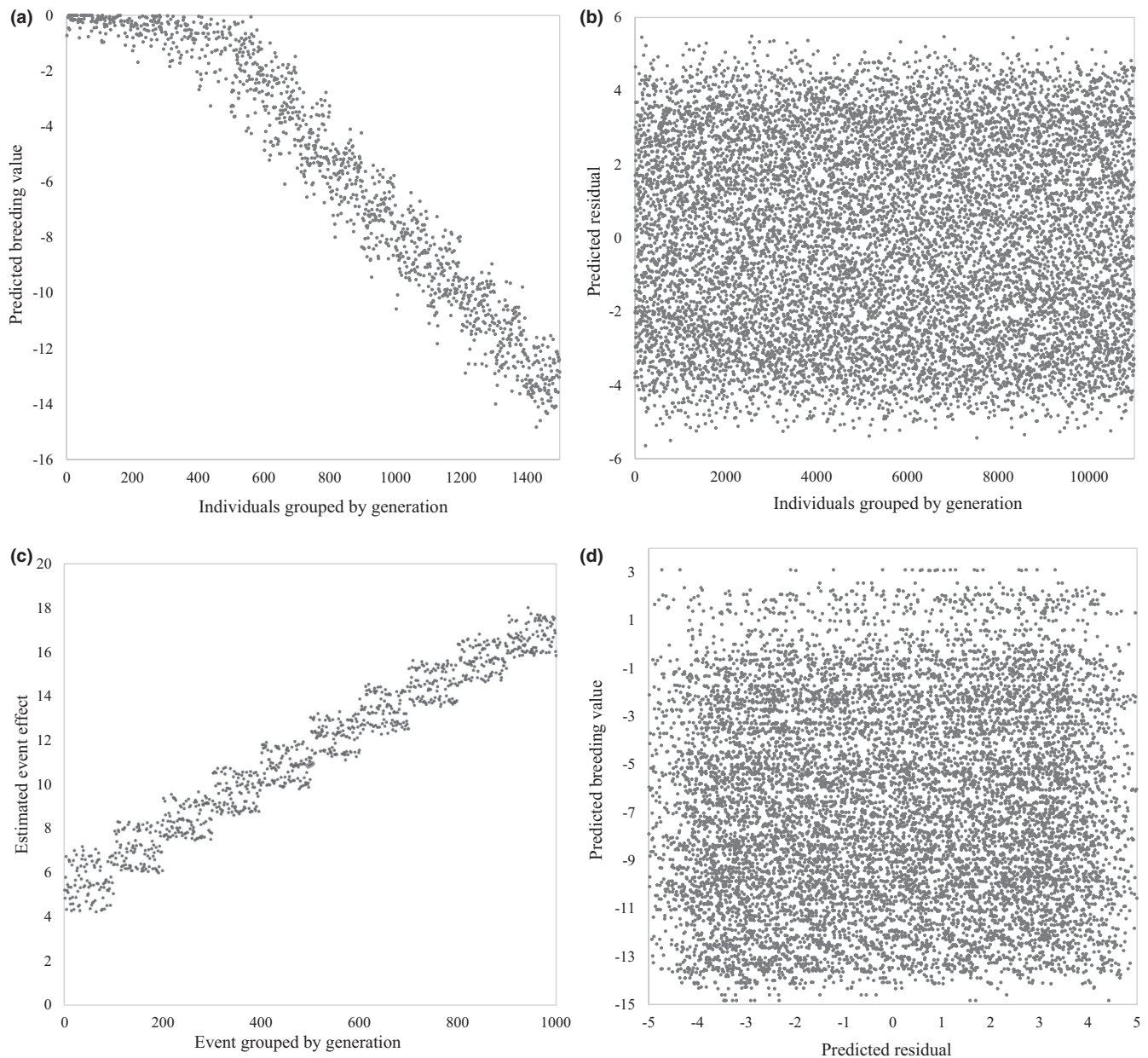


FIGURE 4 Evolution of the predicted genetic (a) and residual value (b), event effect estimations (c) and predicted genetic and residual pairs (d) in genetic evaluation of the raw rank with event effect fitted with heritability value of 0.2 and 10 participations per horse in structured competitions

Legarra, 2010; Tavernier, 1994). The methodology designed to work with Gaussian traits, on a trait presenting discrete or categorical uniform distribution as the ranking, would reduce the efficiency of these genetic evaluations and, therefore, worth examining. Furthermore, the uniform distribution is assumed to be the observable expression of a Gaussian underlying variable. Some procedures based on the Thurstonian approach (Gianola & Simianer, 2006; Ricard & Legarra, 2010) were developed to deal with this.

The simulation was designed in the usual heritability ranges in ranking traits, usually between 0.07 and

0.15 (Bugislaus et al., 2005; Cervantes et al., 2020; Ekiz & Kocak, 2005). In horse competitions, heritabilities are neither high when the trait is not the rank, for example: the estimated 0.27 in different studies for annual earnings (Gómez et al., 2010); 0.23 in race time or 0.28 in speed (Ekiz & Kocak, 2005; Ricard & Touvais, 2007); or 0.06 or 0.15 for placing trait (Cervantes, et al., 2020; Ricard & Touvais, 2007). Despite the variance components in the underlying and observed scale can be very different due to the departures from the Gaussian distribution, in rank trait, García-Ballesteros et al. (2018) showed that differences in genetic parameters in the underlying and the observable

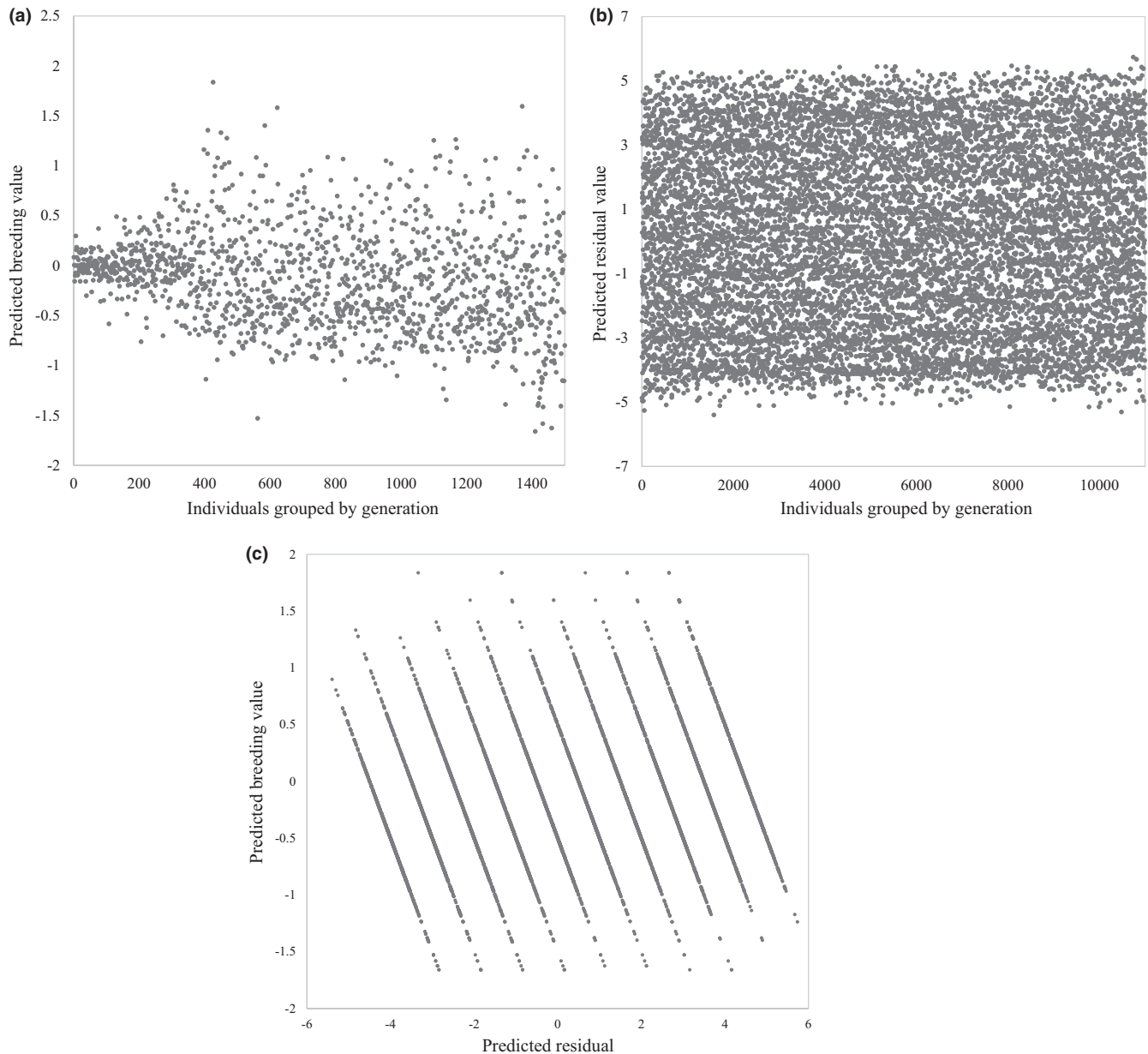


FIGURE 5 The predictor trends of the genetic (a) and residual value (b) and predicted genetic and residual pairs (c) in genetic evaluation of the raw rank without fitting event effect with heritability value of 0.2 and 10 participations per horse in structured competitions

scale were not significantly different when there were multiple categories which were mostly balanced.

Initially, a comparison was carried out between the realistic scenario of structured competitions and the unstructured competitions. This showed that the global genetic responses might be improved by organizing and promoting horse participation with different competitive levels in some events. Thus, creating the connection amongst events that would in turn lead up to 13% higher population genetic responses to selection. However, this is unrealistic in the current cultural scenario despite breeder associations organize some performance controls at an early stage to try to fix this problem.

An initial global inspection showed that the selection response on the underlying scale depends on the heritability. Nevertheless, it was not proportional regarding heritability as theoretically expected when a variable presents a normal distribution in all scenarios because this case depends on h^2 and on the genetic correlation between the criteria and the breeding value in the underlying scale. This is because the measured trait was not a direct translation of a variable with continuous distribution causing differences in responses due to the type of structuring of the competitions and the average number of participations per horse. Inbreeding might also be playing a role as it was assumed null in the parents during the simulation,

TABLE 4 Mean of selection response and standard error of the true genetic value always fitting the event effect and fitting or not the permanent environmental effect, in structured competitions assuming different heritabilities and permanent environmental variance with ten average participations per horse

h^2	0.1			0.2		
c^2	0.05	0.1	0.2	0.1	0.2	0.4
PES	-2.62 ± 0.02^a	-2.61 ± 0.02^a	-2.67 ± 0.02^{ab}	-3.96 ± 0.02^{ab}	-3.99 ± 0.02^b	-4.09 ± 0.02^b
PESE	-2.68 ± 0.02^a	-2.67 ± 0.02^{ab}	-2.72 ± 0.02^b	-4.00 ± 0.03^b	-4.03 ± 0.02^b	-4.18 ± 0.02^b
Difference (%)	2%	2%	2%	1%	1%	2%
PEE	-2.65 ± 0.02^a	-2.70 ± 0.02^b	-2.72 ± 0.02^b	-3.93 ± 0.02^{ab}	-4.00 ± 0.02^b	-4.19 ± 0.02^b
No PE	-2.62 ± 0.02^a			-3.90 ± 0.02^a		
Difference (%)	-1%	-3%	-4%	-1%	-3%	-7%

Note: Different significant responses ($p < .05$) within heritability value carry different letters.

Abbreviations: No PE, without fitting the permanent environment effect; PEE, permanent environment evaluated; PES, permanent environment simulated; PESE, permanent environment simulated and evaluated.

and there was a strong intensity of selection practised in the last 10 generations.

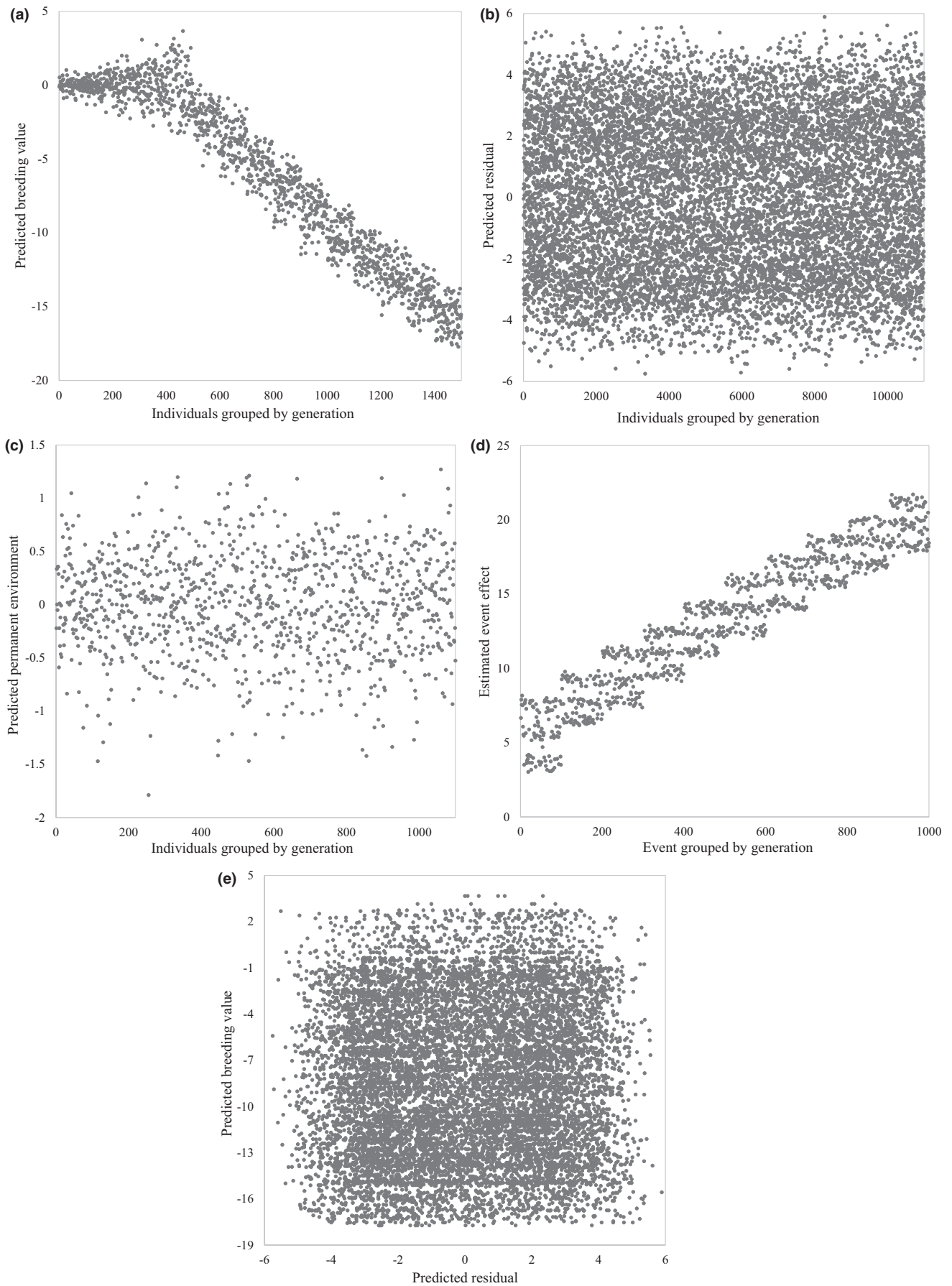
The genetic response of the underlying variable was used as a measure of the performance of genetic evaluation models for ranking traits. Thus, it was irrelevant whether to fit the event effect in the model for unstructured competitions, since the environmental influence of the comparison group was defined by the event already fitted. There were also irrelevant differences in the average competitive ability for each event. Although unstructured competitions are interesting from a theoretical point of view, they do not represent the real scenario in practice. Horse competitions are usually organized according to the competitive ability of the participants; the probability of animals with different competitive level participating in the same event is very low. Therefore, as expected, the event effect did not fit the environmental influence, but in the differences in competitive ability of participants. This was evident when competitors were randomly assigned in unstructured competitions without differences amongst them but providing identical responses to scenarios with or without the event effect. However, even though fitting the event effect in the model did not affect the response, including it was not completely innocuous in practice. This was because it had a negative influence in the predictor error variance (Figure 3) which might have impacted an animal from having been considered tested or untested.

Under the more real structured competitions scenario (Ricard & Legarra, 2010), participation of each animal is strongly restricted to events organized according to the animal's competitive ability. This reduces the connection

between events, which in turn requires more information to evaluate precisely each animal. This study was done using a methodology that assumes a normal distribution of genetic values, residuals and performances, although it was used in uniformly distributed performances. This violation of the normality assumption is expected to cause a loss of accuracy which would be interesting to quantify; nevertheless, some insight can be obtained by the accuracy drawn from this study. Figure 3 includes the true accuracy obtained in all scenarios together with those used in breeding year books. These are derived from the coefficient inverse matrix and the theoretical accuracy which should provide a selection index for repeated measures. The loss of accuracy of ρ_p compared with ρ_r was confirmed, because a phenotype with a uniform distribution was initially assumed to be otherwise. If no transformation is performed (Cervantes et al., 2020), the change of distribution affects the distance between the extreme positions (the first or the last), which is relatively much smaller in a uniform distribution than that assumed under a normal distribution. Fitting the event effect showed a reduction in the dispersion of the genetic values, but also reduced the accuracy. In effect confirming what Bugislaus et al. (2005) observed for the square root final rank character, concluding that the event effect must be considered in statistical models to avoid possible biases in the estimation of parameters and breeding values.

Figure 3 shows the competition structure impact on the information amount to correctly evaluate performance when it comes from ranking traits. This highlights the need to include the event effect in the models to fit the

FIGURE 6 The predictor evolution of the genetic (a), residual (b), and permanent value (c), event effect estimations (d) and predicted genetic and residual pairs (e) in genetic evaluation of the raw rank without fitting event effect with heritability value of 0.2, permanent environment variance of 0.4 and 10 participations per horse in structured competitions



competitive ability of each competition. Thus, when the event effect was not fitted, the same position in two events of different competitive levels would explain an identical performance, but fitting it allows accounted for mean genetic differences between events (Gómez et al., 2011; Ricard, 1998). Note that, as in unstructured scenarios, by including the event effect in the model it reduces the accuracy from the genetic evaluation but increases the accuracy obtained from the correlation between real and predicted breeding values compared to when not fitted. These differences in accuracies become alarming in the case of heritability 0.1 with only one participation on average per animal ($\rho_p = 0.017$ vs. $\rho_r = 0.324$). Fortunately, this study was focussed on the results obtained with higher number of participations per animal and for structured competitions making it more adjusted to real situations. Genetic breeding programmes include publishing a breeding year book of animals with genetic values to promote the use of the best animals as parents of future generations. Genetic values are usually published jointly with their accuracies that attempt to represent the correlation coefficient between the true and predicted breeding value. In reality, the true genetic value is always unknown, so this correlation is normally derived from the prediction error variance of each individual that is found in the coefficient inverse matrix of the BLUP resolution equations (ρ_p). Scenarios with less information per animal in principle do not require detailed discussion of the results obtained for ρ_p , which are strongly affected by the need to estimate the systematic effects. When the event effect was not fitted, the greater number of participations compensated for the lack of accuracy. However, accuracy was overestimated when there was not enough information. In any case, as expected, this analysis highlights the need to have a robust structure with systematic effects, not only to increase the genetic values accuracy, but also to guarantee the assessment of this accuracy.

The relevance of the event effect was demonstrated in the genetic evaluation model of ranking trait to obtain higher genetic response in structured competitions. Traditionally, horses participate in several different events, accumulating many records for the animal. Thus, additional random effects are commonly fitted in real genetic models to evaluate horse competitions (Cervantes et al., 2020; Ekiz & Kocak, 2005; García-Ballesteros et al., 2018; Ricard & Legarra, 2010). Analyses regarding an additional random effect, such as a permanent environmental effect, were carried out to simulate a more realistic scenario, and whether these effects would help accommodate the discrepancy between the stable phenotype and the non-flat genetic trends. Regardless, there were significant differences in scenarios for permanent environment, although they were lowly relevant (Table 4) compared with those

shown in Table 2 for fitting or not the event effect. In general, the best responses were obtained when the permanent environment effect was fitted in the model (PEE or PESE), irrespective of whether this effect was or not included in the simulation. Surprisingly, improvements from 1% to 7% were obtained when the permanent environmental effect was fitted but was not considered in the simulation. The transformation from an underlying simulated trait with normal distribution to the observable ranks with uniform distribution implies a loss of information, but fitting the event and permanent environmental effects in the evaluation models seems to partially recover this loss. It could be that the permanent environmental effects capture part of the variability at the phenotypic level of the events on the underlying scale. This improvement was not observed in the unstructured competitions (results not shown). The inclusion of a second random effect in the model might increase the response to selection even in scenarios when such effect was not a real part of the underlying variable defining the observed performance.

One of the motivations for this study was to disentangle how the effects of the model would compensate the flat phenotypic trend of the ranking trait by its uniform nature. Thus, for an established fixed number of competitors per event, the mean value of the qualifying position remains constant across generations. A favourable genetic trend was demonstrated when assessed by the evolution of the mean genetic value of an underlying variable (Figures 1 and 2). This genetic trend was obtained by selecting animals using a predicted breeding value from the observable ranking trait as criterion. Since the genetic trend was favourable whilst the phenotypic trend was plane, other effects solution of the genetic evaluation model had to compensate to meet the model equation.

Figures 4-6 provide information about the effects compensating for the genetic trend assessed by averaging predicted breeding values (BLUP genetic trend), thus showing that the event effect was influencing the results when present. The role of the event effect was also assumed to account for the growing competitive level appearing as a consequence of the selection process when fitting the competitive level within generation. This role would also be important in the case of an unstructured competitions scenario. However, when this effect was absent in the model, the BLUP genetic trend became almost imperceptible even when the real genetic trend was identical in both cases. Figure 5c shows how the model accommodates a negative correlation between predicted additive genetic values and residuals within generation in such a way that considering all the generations together that correlation becomes negligible. Even though trend patterns were different with and without event effect in the model, the real genetic trend was indistinguishable between them.

Figure 6 confirms the role of the event effect as the only effect keeping the function of compensating the successful genetic trend. This figure also shows the information on the evolution of the predicted permanent effects this becomes stable even when the permanent environmental levels were each associated with each individual, thus improving their genetic value across generations.

This study has shed light on the role played by the event effect in the genetic evaluation for ranking traits. The inclusion of the event effect has two clear advantages: (a) to capture the potential genetic trend and, (b) to correct the difference in the genetic (or non-genetic) level of the events within each generation. The reason for the second advantage is that without the introduction of the event effect, the horses of the worst competitions are as likely to be selected as the horses from the best competitions in structured competitions. Moreover, by needlessly including the event effect a loss in accuracy was produced. On the other hand, we observed that this unstructured scenario would provide a higher genetic response to selection. Therefore, it is advisable to organize and promote events with the participation of animals of a different competitive level and properly connected as some breeding programmes do when organizing young horse performance tests.

CONFLICT OF INTEREST

The authors declare no conflict of interest.

DATA AVAILABILITY STATEMENT

The simulations generated and/or analysed during the current study are available from the corresponding author upon reasonable request.

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