Theor. Appl. Genet. 62, 97–102 (1982)

THEORETICAL AND APPLIED GENETICS

Genetic and Environmental Factors Affecting the Suitability of Dogs as Guide Dogs for the Blind

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Summary. Many dogs are found to be unsuitable for training as guide dogs for the blind. Consequently the Royal Guide Dogs for the Blind Association of Australia has embarked on a breeding program to produce a strain of labrador dogs which is suitable for guide dog training.

The most common reasons for rejecting dogs are fearfulness, dog distraction, excitability, health and physical reasons and hip dysplasia. The selection program seems to have been successful in improving the success rate mainly by lowering fearfulness, but there has not been a continuing improvement. This is probably due to continual introduction of dogs from other populations into the breeding program.

Males suffer from a higher rejection rate due to dog distraction and a lower rejection rate due to fearfulness and excitability than females, so that there is little sex difference in overall success rate.

The heritability of success (0.44) is high enough to predict further progress from selection, again mainly against fearfulness.

Variation in environment prior to 6 weeks of age, in age when dogs were placed into a private home and in age when males were castrated, had little effect on the success rate.

Key words: Guide dogs – Behaviour – Genetics

Introduction

The Royal Guide Dogs for the Blind Association of Australia provides and trains dogs as guides for blind people. Initially the Association relied on dogs donated as adults by the public but only a small proportion (approximately 20%) of these dogs proved suitable. For this reason the Association began a 'puppy walking scheme' in which pups are given to volunteers who raise them until they are old enough for training. These volunteers are supervised by the Association. The aim of the research reported here is to design a breeding program which will increase the porportion of dogs which qualify as guide dogs. Many guide dog centres around the world have breeding programs and some have claimed considerable success (Scott and Bielfelt 1976), but none of these breeding programs have fully utilized quantitative genetics.

The challenge in applying quantitative genetics to the breeding of guide dogs arises because the criteria for success involve the behaviour of the dogs. Work on the genetics of behaviour is not new and there have been many successful selection experiments for behavioural traits in laboratory animals (Ehrman and Parsons 1976). Practical breeders also have changed behaviour by selection, for example, sheep dogs, gundogs, hounds.

This paper analyses the records of dogs placed on the puppy walking scheme to determine the factors which affect the success rate of the dogs, the traits which are important, and the heritabilities of these traits.

Materials and Methods

The records of dogs born from 1963 to 1975 were used. These records describe 1,031 dogs of which 929 were labradors and 102 were of other breeds (mostly golden retrievers). The dogs were either donated (*P dogs*) or bred by the Association (*A dogs*). During this period A dogs were born in three different kennels. Both A and P dogs were placed on the puppy walking scheme between 6 and 12 weeks of age and returned to the training centre at 12 to 18 months of age. Male pups were castrated, usually between 5 and 7 months of age. An attempt was made to castrate each dog just before he reached sexual maturity.

The dogs used in the Association's breeding program were largely obtained from the general labrador population. An attempt was made to select only suitable dogs, the major criterion being lack of fearfulness. Dogs whose offspring proved satisfactory remained in the breeding program for many years while those whose offspring were unsatisfactory were culled. In

0040-5752/82/0062/0097/$ 1.20

recent years some dogs bred by the Association have also been selected as breeding stock.

The records contain information on the fate of each dog (qualified as a guide dog, used for breeding or rejected). If it was rejected the reason(s) for rejection is recorded. In this analysis success is defined as either being used for breeding or qualifying as a guide dog. The dependant variables are thus a series of all-or-none variables – success or rejection for several different reasons and overall success. The independent variables examined were breed, source (A or P), sex, year of birth, place of birth, age when placed on the puppy walking scheme, number of puppy walkers and age at castration in males. There is some difficulty in finding an ideal method of analysis for data which involves a discrete dependent variable and both discrete and continuous independent variables (Bishop et al. 1975). We have used least-squares analysis after coding success as 1 and rejection as 0 for the initial analysis. Where it was desirable and practical arcsine or logit transformations have been used.

In order to examine the effect of source and year, years have been grouped so that the number of dogs per cell was at least 11. The percent success was transformed to arcsines ($y = \arcsin \sqrt{x}$) and an analysis of variance carried out. The year SS has been divided into SS due to common regression and SS due to common deviations from regression. The interaction SS has been divided into SS due to differences in regression slopes and SS due to differences in deviations. The error variance has been calculated from the theoretical variance of arcsines, 820.4/n where n is the harmonic mean of the number of dogs per cell.

The effects of year, source and sex on the proportion of dogs rejected for each of the five most common reasons were assessed by transforming the porportions to logits and analysing them by least-squares weighted by the number of dogs per cell using the computer programm GLIM (Nelder 1975). GLIM calculates the deviance after fitting a linear model. For binomial data with logit transformation this deviance is distributed as a Chi-square and so can be used to test the goodness-of-fit of the model. The significance of each effect was tested by deleting it from the model and calculating the rise in the deviance. From this, analysis of variance tables were constructed. Non-significant terms were deleted from the model and the significant effects estimated. These effects were estimated from all the data but are expressed as the proportion of dogs expected to be successful in the most recent year (1975).

Heritabilities were estimated by least-squares analysis as suggested by Elston (1977), using the computer program LSMLGP (Harvey 1968). This program calculates the standard errors of the heritabilities by a modification of the method of Swiger et al. (1964) and Tallis (1959).

The model used was

$$r_{yklmn} = u + y_i + s_j + d_k + x_m + l_{ijkl} + e_{ijklmn}$$

where r is success or rejection coded as 1 or 0 respectively

y_i is the effect of the i^{th} year
s_j is the effect of the j^{th} sire
d_k is the effect of the k^{th} dam
x_m is the effect of the m^{th} sex
l_{ijkl} is the between-litter residual after fitting y, s and d
e_{ijklmn} is the within-litter (individual) error.

The same model was used for rejection for fearfulness, dog distraction, excitability, hip dysplasia and health again with success coded 1 and rejection coded 0.

Years, sires and dams are crossed rather than nested because the same sires and dams occur in several years and in different mating combinations. The residual between-litter variance will include the variance of litters within sire-dam-year classes and the interactions between sire, dam and year.

Results

Factors Affecting Success

The influence of the independent variables – breed, source, sex, year of birth, place of birth, age when placed on puppy walking scheme, number of puppy walkers and age at castration in males – on overall success was evaluated by least-squares analysis. Because data on some variables were very incomplete a series of analyses was done so that important effects could be estimated from as many records as possible. As an example the analysis based on year, sex, source and breed is given in Table 1. The interaction mean square is significantly less than the residual MS but this anomaly is probably due to the all or none nature of the data. Over all analyses, only source and year were significant. The least-squares means for % success were 38% for A dogs and 19% for P dogs.

Comparison of A and P Dogs

The dogs from the Association's breeding program can be viewed as the result of a selection 'experiment' in which donated puppies act as a control. This is not completely true because dogs from English and American

Table 1. Analysis of variance for overall success

Factor	df	MS	F
Year	9	0.535	2.65**
Breed	1	0.126	0.62
Source	1	4.635	22.92***
Sex	1	0.011	0.057
First order interactions	29	0.105	0.521
Residual	750	0.202	

** $p < 0.01$; *** $p < 0.001$

Table 2. Percentage success of A and P dogs

Year	A dogs		P dogs	
1963 – 1967	24	(37)[a]	26	(237)[a]
1968	50	(18)	29	(61)
1969	41	(22)	20	(59)
1970	47	(30)	10	(69)
1971	39	(91)	20	(45)
1972	19	(70)	9	(11)
1973 – 1975	40	(201)	24	(19)

[a] The number of dogs on which each percentage is based is shown in brackets

Table 3. Analysis of variance of success

	SS	df	MS	F
Source (S)	412	1	412	16.92***
Year (Y)	360	6	60	2.46*
Common regression	15.8	1	15.8	< 1
Common deviations	344.2	5	68.8	2.83*
SXY	190.4	6	31.7	1.30
Between regressions	24.4	1	24.4	< 1
Between deviations	166	5	33.2	1.36
Error			24.35	
$S^2_{\bar{y} \cdot x}$		10	51	

$S^2_{\bar{y} \cdot x}$ is the average variance of the deviations from regression
* $p < 0.05$; *** $p < 0.001$

breeding programs were introduced into the Australian A line, and there is the possibility that environmental differences before placement on the puppy walking schema may have been significant.

Table 2 lists the success rate by source and year and the analysis of variance of these effects is given in Table 3. The A dogs had a higher success rate than the P dogs but there was no significant trend over years nor any difference between the regression slopes. The significant common deviations from regression indicate that parallel yearly fluctuations in success rate occurred in the two lines.

Reasons for Rejection

In the records a description of why a dog was rejected is given. Table 4 contains the proportion of dogs rejected for each reason. If a dog was rejected for more than one reason it is included under both reasons.

The most obvious difference between A and P dogs was in the proportion rejected for fearfulness but the numbers in Table 4 cannot be compared directly because they do not allow for differences betwen years and sexes which are partially confounded with the differences between sources. To make a direct comparison the proportion rejected for each reason for each year-source-sex combination must be analysed. This was done for the five most common reasons for rejection by transforming the proportions to logits and analysing them using the program GLIM (Nelder 1975). In each case the model with the three main effects provided a satisfactory fit.

Table 4. Reason for rejection. Percentages of dogs rejected for each reason

Reason	A dogs	P dogs
Fearfulness	26.8	43.9
Dog distraction	7.5	4.8
Excitability	6.4	9.9
Health or physical	12.4	16.8
Hip dysplasia	8.4	6.1
Lacks concentration	0.9	2.3
Aggressive	4.3	1.9
Over sensitive	3.2	2.3
Lacks initiative	2.1	1.5
Lacks willingness	1.5	0.8
Lacks body sensitivity	3.6	1.3
Other distractions	0.4	0.6
Other	0.9	2.7
Total number	466	524

For fearfulness, source, sex and year were all significant ($p < 0.05$). The % of success fitted by this model for 1975 are given in Table 5. More females than males and more P than A dogs were rejected for fearfulness. For excitability only sex was significant, the fitted % success for 1975 being females 80%, males 91%. Only year was significant for health. The % success fluctuated from year to year being 0.94 in 1975 and 0.88 in 1974, for example.

With dog distraction a further problem was encountered because of differences in the time at which different reasons for rejection occur. Rejections for fearfulness tended to occur before rejections for dog distraction. Since P dogs had a higher rejection rate for fearfulness than A dogs they tended to be rejected early, before they were assessed for dog distraction. This causes a bias in the A/P comparison. To overcome this, analysis was based on the number of dogs rejected for dog distraction of those not rejected for fearfulness. This analysis found significant effects due to sex and source and predicted success rates in 1975 are given in Table 5. For hip dysplasia only years were found to be significant. The success rate was very high in 1963, dropped to 0.75 in 1969 and 1972 and rose to 0.96 in 1975. This does not necessarily represent changes in the status of the dogs' hips but changes in attitude as to the grade of hip dysplasia that was acceptable.

Examination of the other independent variables – place born, age when placed on the puppy walking scheme, number of puppy walkers, breed, age when castrated – failed to find any significant effects on rejections for fearfulness, dog distraction, excitability, hip dysplasia or health.

Table 5. The effect of source and sex on the percentage of dogs successful with respect to fearfulness and dog distraction

Source	Fearfulness		Dog distraction	
	Female	Male	Female	Male
A	67	75	95	89
P	54	63	88	78

The figures are the percent success predicted by the GLIM model for 1975

Associations Between Reasons for Rejection

Four-way contingency tables classified by source, age and two reasons for rejection were analysed by log-linear least-squares analysis using GLIM. The only significant association between reasons was between excitability and dog distraction. Dogs which were rejected for excitability were also likely to be rejected for dog distraction. This can be explained by assuming that dogs' activity levels in many situations are correlated. Overactive dogs are difficult to control in many ways, including training to ignore other dogs.

Heritabilities

The information on 394 A dogs born between 1968 and 1975 were used to estimate heritabilities. The analysis of variance tables for overall success, rejection due to fearfulness, dog distraction, excitability, physical reasons and hip dysplasia are given in Table 6. This table shows that in no case was the between-litter residual variance significant; in fact in four cases the between-litter F was less than one. For dog distraction the effect of litter was almost significant ($p < 0.1$). The most likely cause of between-litter variation is the common environment members of the litter experience before being placed on the puppy walking scheme. One cause of this common environment is the number of pups in the litter. The simple correlation between success for dog distraction, coded as above, and the number of pups in the litter was -0.08, or -0.12 ($p < 0.05$) for dogs not rejected for fearfulness.

None of the other reasons for rejection correlated significantly with size of the litter except hip dysplasia (amongst dogs assessed for this character). The correlation between success for hip dysplasia and litter size was 0.10, perhaps due to the fact that pups in larger litters weigh less.

The effects of sex in these analyses were similar to those presented in previous sections.

In calculating the sire and dam variance components the within-litter and residual between-litter sum of squares have been pooled. Only for dog distraction will this raise the estimate as compared with estimates based on the unpooled variances. These components are expressed in Table 7 as the heritability estimates based on the sire or dam variance components using the formula

$$\frac{4\,\sigma_s^2 \text{ (or d)}}{\sigma_s^2 + \sigma_d^2 + \sigma_e^2}.$$

The dam variance includes the effect of maternal environment as well as genetic effects whereas the sire component is due to genetic effects only. Therefore comparison of sire and dam components indicates the

Table 6. Analysis of variance for the effects of sire and dam

Source of variation	df	Success MS	Fear MS	DD[a] MS	Excitability MS	Health MS	HD[b] MS
Year	7	0.616**	0.544***	0.105	0.0422	0.102	0.0307
Sire	10	0.556**	0.528***	0.060	0.0561	0.250*	0.0945
Dam	26	0.478***	0.269**	0.112	0.0804	0.136	0.1151*
Sex	1	0.361	0.562	0.202	0.1069	0.047	0.0548
Between litter residual	22	0.1940	0.082	0.101	0.0591	0.100	0.0442
Error	327	0.2027	0.150	0.067	0.0549	0.106	0.0762

Year, sire and dam effects have been tested against the pooled residual and error, except for DD where the residual is almost significant. Sex has been tested against the error MS

[a] Dog distraction; [b] Hip dysplasia

* $p<0.05$; ** $p<0.01$; *** $p<0.001$

Table 7. Heritability estimates

	Sire Variance		Dam Variance		Pooled Variance	
	h^2	(se)	h^2	(se)	h^2	(se)
Success	0.46	(0.19)	0.42	(0.18)	0.44	(0.13)
Fear	0.67	(0.22)	0.25	(0.15)	0.46	(0.13)
Dog distraction	−0.04	(0.08)	0.23	(0.14)	0.09	(0.08)
Excitability	0	(0.09)	0.17	(0.13)	0.09	(0.08)
Health	0.40	(0.17)	0.10	(0.12)	0.25	(0.10)
Hip dysplasia	0.08	(0.11)	0.20	(0.13)	0.14	(0.09)

importance of maternal environmental effects. The standard errors of the estimates of these heritabilities are large but in three cases the sire component of variance was larger and in four cases the dam component was larger. This suggests that the effects of maternal environment were small. The trait where the two components were most different is rejection for fearfulness and the sire component was larger. If this difference is real it would mean that effect of maternal environment is in the opposite direction to the direct genetic effect of a dam on her offspring.

Because maternal environment did no appear to be important the heritability estimates can be improved by calculating pooled estimates by

$$h^2 = \frac{2\,(\sigma_s^2 + \sigma_d^2)}{\sigma_s^2 + \sigma_d^2 + \sigma_e^2}.$$

There are also given in Table 7.

Discussion

Factors Affecting Success

The fact that only year and source significantly affected overall success rate does not prove that the other independent variables are of no importance.

Breed differences have been found in the U.K. (Guide Dogs for the Blind 1975) but here only a small number of dogs of breeds other than labrador and golden retriever were used. The non-significance of age when placed is in contrast to the San Rafael results (Pfaffenberger and Scott 1959) but nearly all dogs in Australia were placed before the age at which performance declines (13 weeks). Similarly, age at castration was deliberately constrained to what was regarded as the optimum period.

The absence of a sex difference is contrary to the traditional belief that females are more suitable as guide dogs. This could be due to the earlier castration of males in Australia in recent years than had been the practice here and overseas in earlier times.

Comparison of A and P Dogs

The A dogs had a higher success rate than the P dogs, suggesting that the selection program had been successful, but their advantage did not increase with time. It appears as if the selection program made an initial immediate advance but no further gain.

There are at least two possible reasons for this.

(1) The difference between A and P dogs may be environmental, probably due to their different environment from 0–6 weeks. This cannot be excluded but two facts argue against it. Firstly, the environments appeared similar and if anything one would expect the P pups to get more handling which should have made them better not worse than the A dogs. Secondly, the difference between the three places where A dogs were reared from 0–6 weeks was found to be non-significant suggesting that within this range of conditions, place of rearing is not very important.

(2) The selection program for most of this period consisted of obtaining breeding stock from the outside population, then either keeping them for several litters or culling them on the basis of the performance of their offspring. Only a few of the brood stock were bred from selected stock so that the advantage of the A dogs largely represents a one-generation gain.

Slower than expected genetic improvement due to constant introduction of animals from outside the breeding program has also been found in dairy cattle (Badham 1975) and is perhaps a common flaw in the implementation of breeding programs.

The other significant effect in Table 3 is that between years due to common deviations. Therefore there were factors which affected the A and P dogs similarly, causing the large fluctuations from year to year. These were presumably environmental factors perhaps connected with the puppy walking scheme, the supply and demand for dogs or changes in training staff.

No strictly comparable data on guide dogs have been published. Figure 3.1 of Scott and Bielfert (1976) compares the success rate of dogs from a breeding program and dogs donated as adults. From 1950 on the difference between these groups increased suggesting genetic improvement but improvement in the puppy rearing program could also be the cause. As in our data the year to year fluctuations of the two groups were very similar, demonstrating the importance of factors other than the quality of the dogs.

Reasons for Rejection

Comparisons of Table 4 with results from England (Baillie 1972; Guide Dogs for the Blind 1975) and USA (Scott and Bielfelt 1976) show that the pattern of reasons for rejection is similar in all three places. Fearfulness, distraction and aggression are amongst the most important reasons everywhere although their relative importance varies slightly. Differences between strains and sexes are not available from elsewhere.

Heritabilities

The absence of between-litter residual variation is surprising and in contrast to other published results. Scott and Bielfelt (1976) found the average composition of variance on 13 behavioural tests on guide dog puppies aged 7–12 weeks to be: – between matings 9%, between litters within matings 14% and within litters 76%. Scott and Fuller (1965) present similar statistics for 44 physical and behavioural traits: – 12% between matings and 12% between litters. However, there are two important differences between these studies and our own. Firstly, in both of the other cases the dogs were still being kept as litters when the tests were run, whereas in the present study they were only maintained as litters until 6–12 weeks. Secondly, neither of the past studies removed year effects in their analysis.

This contrast in findings suggests that the importance of between-litter within-mating variation should decrease with time after the litter is dispersed and some evidence in favour of this hypothesis has been found in other data (Goddard 1979).

The lack of significant maternal environment effects is largely in agreement with the two past studies. Scott and Fuller (1965) concluded that there was good evidence for this effect only in traits where the dam had an obvious opportunity to affect the behaviour of her pups in the test situation. Scott and Bielfelt (1976) found average between-sire variance to be 5% compared with 18% between dams but this is largely explained by the fact that in their analysis the between-dam variance included the between-litter variation. Murphree and Newton (1971) crossed a 'nervous' and a 'stable' strain of pointers and found no difference between the reciprocal crosses, confirming the conclusion that maternal environment effects are not important.

The results show that fearfulness is the most important and heritable component of success. This is consistent with the finding that the difference between the A and P dogs is largely due to differences in fearfulness and the fact that it is fearfulness that has been the main selection criterion in the breeding program. This is also in keeping with the successful selection for fearfulness in pointers by Murphee and Dykman (1965).

The low heritability of rejection for dog distraction at first appears inconsistent with the superiority of the A dogs on this trait. However, because the incidence of this trait is low the low heritability tells us little about the effect of selection based on a continuous measure of the trait.

Acknowledgement

This work was support by a grant from the Uncle Bens Company in Australia and overseas. The authors are most grateful for the cooperation of the Royal Guide Dogs for the Blind Association of Australia.

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Received December 2, 1981
Communicated by
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