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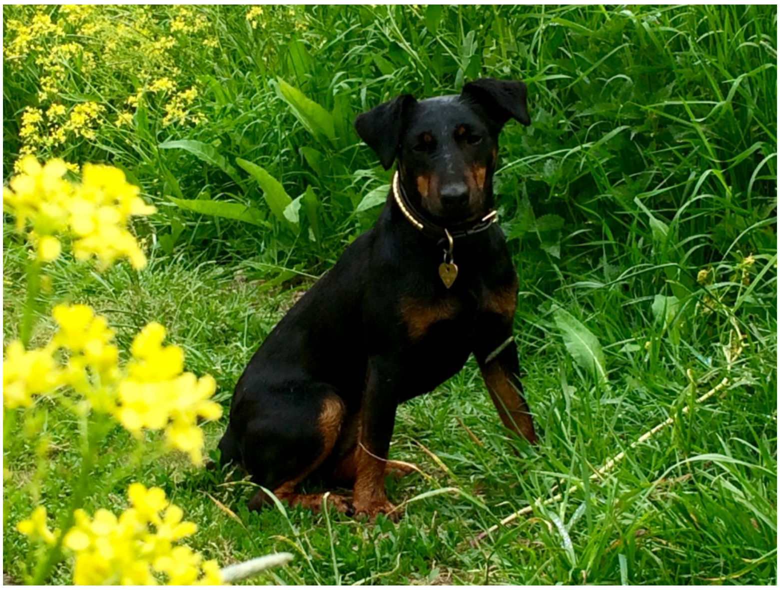
Department of Animal Breeding and Genetics

The inheritance of hunting traits in German Hunting Terriers

Amelie Werneyer



Department of Animal Breeding and Genetics
Examensarbete/SLU, Institutionen för husdjursgenetik
544
Uppsala, 2018

Degree Project in Animal Science, 30 hp
European Master of Animal Breeding and Genetics

The inheritance of hunting traits in German Hunting Terriers

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Credits: 30 ECTS
Level: Advanced
Course title: Degree Project in Animal Science, E30
Course code: EX0803
Course coordinating department: Dep. of Biomedical Science and Veterinary Public Health
Programme/education: Animal Science

Place of publication: Uppsala
Year of publication: 2018
Cover picture: Amelie Werneyer
Title of series: Examensarbete/SLU, Institutionen för husdjursgenetik
Part number: 544
Online publication: https://stud.epsilon.slu.se

Keywords: Heritability, Hunting Dogs, Terrier, Hunting Performance, Behavior

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Abstract

A convenient method for efficient and successful hunting – in accordance with the animal protection laws – is the service provided by hunting dogs. Approximately 12 000 – 18 000 years ago humans domesticated dogs for hunting purposes (Braastad & Bakken, 2002; Sablin & Khlopachev, 2002; Germonpré et al. 2008). During the time of breed creation dogs were selected for certain traits like for instance hunting (e.g. tracking or flushing), guidance, and protection (Naderi et al. 2001). Still today selection and other breeding measures help to improve the performance (Holloway et al. 2011) of hunting dogs (Ruusila & Pesonen, 2004).

The aim of this project was to estimate heritability parameters for hunting performance traits evaluated in breeding tests. Data from standardized, breed specific hunting ability tests for German Hunting Terrier (GHT), a versatile small hunting dog breed, was available for the present investigation. The data covered records from performance tests of the past twenty years and pedigree data that traced back to breed creation.

GHT dogs have to participate in aptitude tests in order to be certified as breeding animals and as a cornerstone for further contribution in more advanced performance tests. Furthermore, after successful testing the dog can be authorized for hunting on state grounds and for professional hunting. As a result a large number of GHT dogs are tested in the above mentioned breeding tests.

The data provided by the breed club consisted of two datasets. The performance dataset involved four conformation traits, twelve performance traits, the individual ID number of the dogs, total amount of points from the tests including rewarded price, test date and test location. The original performance dataset included more than 14 739 observations. The pedigree dataset contained a total of 101 250 individuals with information on birthdate and the identification of their dam and sire. After merging of the two datasets and data editing the joint, adjusted dataset consisted of 9457 test records, which were the basis for the estimation of variance components.

Heritability estimates of the present analysis varied between traits and were generally low. The highest heritability of 23 % was found for the hunting trait Water affinity, while the performance of Reaction to shot had almost no genetic contribution (h^2=0.01). The results from the genetic analysis were in line with findings of previous research, carried out for other types of hunting dogs, e.g., Liinamo (2004), Brenøe et al. (2002), Schmutz & Schmutz (1998) and Karjalainen et al. (1996). The conclusion behind the low heritability estimates is that different environmental effects (e.g., natural environment, age, system of testing and test evaluation or test location) strongly affect the performance in hunting aptitude tests. Reasons for the significant influences were discussed and some recommendations for improvement of hunting ability tests were made.

1 Introduction

The use of dogs for hunting brings many advantages; dogs can track down, point at, retrieve and give voice at scent or sight of game (Voges & Distl, 2008; Spady & Ostrander, 2008). Moreover, dogs provide hunters with a wide spectrum of information, which is not only useful for hunting, but also and more importantly helps to preserve wildlife. Examples are indication of game location, reaching into areas which are difficult to reach for humans and detection of for instance injured game.

To have dogs involved in all kinds of hunting, various hunting dog breeds were created for different purposes during the past centuries (Pedersen et al. 2012; Svartberg, 2005; Wilcox & Walkowicz, 1995). Refinement of performance in traits that are useful for different types of hunting was done by artificial selection (Van der Waaij et al. 2008). This resulted in different genetic predispositions for hunting traits across breeds (Brenøe et al. 2002; Duffy et al. 2008; Christiansen et al. 2001; Hart, 1975; Scott & Fuller, 1965).

Requirements for hunting dogs are complex and versatile, especially because hunting performance does not only depend on physical characteristics. Instinct and intelligence (e.g. the ability to solve tasks independently), traits like alertness, reactivity, ability to adapt and comprehend, as well as trainability, have to be well advanced. Furthermore, work ethics, or in other words, the willingness to please and cooperate with the handler, endurance and eagerness to hunt, play important roles for the performance of hunting dogs (Scott & Fuller, 1965).

Heritabilities are often investigated for production traits in farm animal species (e.g. Korsgaard et al. 1999; Le et al. 2015; Wasana et al. 2015). Heritability studies on subjective traits like behavior and performance are more difficult to pursue, however, some studies in canine research (amongst other Christiansen et al. 2001; Schmutz & Schmutz, 1998; Liimatainen et al. 2007; Scott & Fuller, 1965; Van Der Waaij et al. 2008; Voges & Distl, 2008; Brenøe et al. 2002) show that there is a common interest on research in this field.

The present study focuses on GHT, a breed which was created in the 1920s in Germany (FCI, 2015). GHTs are considered to be versatile hunting dogs, which show high steadiness of character and courage and which are driven hunters. Hunting performance and aptitude tests have been carried out by breed club officials from the time of breed creation to display, if there is a positive response to selection of breeding animals.

Still today specialized aptitude tests for GHTs are primarily carried out to trace the hunting performance, temperament and health of individual dogs and the population in general. Although the tests only provide phenotypic information, they are designed as a foundation for a genetic evaluation carried out by TG-Verlag Beuing GmbH – a data processing service center in Germany. Based on the test results continuous statistical reporting (e.g. estimation of breeding values) is implemented. Previous studies in other types of dogs have shown that differences in performance between sexes, age groups, seasons of birth and testing or based on the location occur (e.g. Liinamo et al. 1997 and Courreau et al. 2005).

The aim of this project was to estimate variance components for environmental and genetic influences and subsequently calculate heritability estimates for hunting traits in the breed GHT. Furthermore, the current test regulations and development in testing performance will be investigated. At last, an outlook on possible improvements in the current system of testing and the meaning of the estimated heritability for further breeding strategies will be given.

1.1 Literature Overview

Dogs – as readily accessible resource for research – have been studied intensely and profitably throughout the last centuries not only for gaining knowledge within animal science, but also with respect to human behavior and medical research. Hence, research in various fields has been realized and published. Amongst others, research in the field of canine genetics and breeding, on performance, personality and behavior traits was carried out in different hunting and working dogs. This research was used as a fundamental knowledge for this project.

Hunting ability tests, which are the focus of the present analysis, are usually carried out to mimic natural hunting conditions as close as possible (e.g. Schmutz & Schmutz, 1998; Karjalainen et al. 1996 and Liinamo et al. 1997). This means on the one hand that the performance of dogs was evaluated in realistic situations but on the other hand numerous environmental effects need to be considered as well, like the risk of non-objective evaluation of traits. The purpose of ability tests also across breeds and types of hunting dogs is to evaluate the performance or behavior presented in various test disciplines. Subsequently genetic parameters will be estimated to gain information for selection and breeding purposes. However, the test set-ups and methods of analysis vary between breeds and the various scientific studies. The system and test disciplines of hunting ability tests are in most cases different according to the type of hunting dog (e.g. Blood-Hound, Flushing Dog, Retriever or Terrier) and breed specific test disciplines occur. Nevertheless, often the disciplines are similar, or they are combined or overlap. This makes it hard to compare the research on diverse breeds and hunting tests. The same applies for studies on different types of working dogs. More detailed reasons for the variance between the earlier studies and this project will be discussed in Chapter 4.

1.1.1 Hunting dogs – Pointing dogs

Research on different pointing dog breeds and genetic analysis of hunting performance traits has been done (e.g. Arvelius & Klemetsdal, 2013; Brenøe et al. 2002; Schmutz & Schmutz, 1998; Vangen, 1990). Pointing dogs are very versatile and hence very common hunting dogs for small wild game and wildfowl areas. On command the pointing dog searches for game and at success stands still, i.e. points at the sight of game until the hunter gives a command to make it flush (fly), catches or shoots it. This demeanor during hunting gives the hunter the possibility first to notice game, to stalk towards the game and shoot it controlled in the air (Arvelius & Klemetsdal, 2013).

The results of the genetic analyses are shown in Tables 1 and 2 and show similar although slightly varying heritability estimates. Differences between the studies occur because of multiple reasons like different breeds, differences in test structure and traits, subjectivity of test evaluation, difference in number of tested individuals, different populations, or methods of analysis.

In Norway, hunting ability tests were executed from 1996 to 1999 for Pointers and from 1995 to 1999 for Brittany Spaniels (Bretons) through the Norwegian Kennel Club. The results were used by Brenøe et al. (2002) for estimation of genetic parameters and heritability of the Bird-Finder Index. This dataset on Norwegian pointing dogs included results from – depending on the test discipline – around 390 Short-Haired Pointers, 334 Wire-Haired Pointers and 264 Bretons. The test disciplines in the young dogs class and open class were evaluated according to a standardized, but mostly subjective evaluation system. The scale for evaluation in Brenøe et al. (2002) ranged from “1” to “6” with “4” being the optimal score for Seeking Width, Ability to Work in the Field and Cooperation. Results show, that traits which are related to social interaction tend to have lower heritability compared to pure hunting-related aptitude. The study reveals that heritability estimates analyzed for Bretons, Short- and Wire-Haired Pointers are typically low to moderate. Environmental factors in this study (e.g. sex, age, test year, ground) seem to have lower effects on the performance of Short-Haired Pointers compared to Wire-Haired Pointers and Breton. The Bird-Finder Index was found to have a heritability close to zero. The repeatability and heritability estimates were compared with Schmutz & Schmutz (1998) and Vangen (1990) in Table 1. In the discussion different effects like the dog handlers´ level of experience, handlers keeping genetically related individuals, influence of judge, overrepresentation of certain pedigrees in one test area, generations and breed were suggested as explanations for the low heritabilities.

Schmutz & Schmutz (1998) evaluated “young dog’s (16 months or younger) natural inclination to hunt”. The purpose of the investigation was to help breeders in finding fitting breeding mates and to guide dog buyers in finding a suitable dog according to its hunting ability. The study included 80 Short- and 99 Wire-Haired Pointers, 75 Griffons, 86 Large Munsterlanders and 144 Pudelpointers. The natural ability tests were hosted by the North American Versatile Hunting Dog Association (NAVHDA). Tests were carried out in northern America between 1977 and 1996 (Large Munsterlander) and 1983 to 1992 (the other four investigated breeds). For Large Munsterlander the population was evaluated over a fifteen year period, to estimate genetic variation. The tests were carried out by a team of three judges, who prior to being a judge had to undergo perennial education and constant schooling as well as they had to train and show dogs themselves. The evaluation of the seven traits was done on a narrow scale from “0” to “4”. Like in the previous study, heritability estimates were low to moderate. Exceptions were the disciplines Searching and Tracking in Short-Haired Pointers, which were highly heritable (>40%) for this breed. Furthermore Desire and Tracking, which showed no significant heritability in Short-Haired Pointers, Griffons, Large Munsterlanders and Pudelpointers, but was moderately heritable in Wire-Haired Pointers.
Schmutz & Schmutz (1998) also discussed the effect of the handler and training, the origin of traits like Pointing in different pointing dog breeds or Sound on track in hounds as well as the influence of breed differences and environment.

Table 1 Heritability estimates and repeatability for hunting traits in Short- and Wire-Haired Pointers, Bretons, Munsterlander and Pudelpointer according to Brenøe et al. (2002), Schmutz & Schmutz (1998) and Vangen (1990)

	Short-Haired		Short-Haired	Short-Haired	Wire-Haired		Wire-Haired	Wire-Haired	Breton		Griffon	Large Munster-lander	Pudelpointer
	Brenøe et al. (2002)		Schmutz & Schmutz (1998)	Vangen (1990)	Brenøe et al. (2002)		Schmutz & Schmutz (1998)	Vangen (1990)	Brenøe et al. (2002)		Schmutz & Schmutz (1998)	Schmutz & Schmutz (1998)	Schmutz & Schmutz (1998)
Traits	h^2	r	h^2	h^2	h^2	r	h^2	h^2	h^2	r	h^2	h^2	h^2
Hunting Eagerness/Desire	0.28	0.41	0.31	0.24	0.17	0.31	0.14	0.28	0.19	0.35	0.21	0.22	0.05
Speed	0.26	0.34		0.17	0.18	0.3		0.35	0.23	0.36			
Style	0.27	0.33			0.16	0.26			0.20	0.33			
Independence	0.14	0.29			0.21	0.48			0.06	0.29			
Seeking width	0.25	0.38			0.17	0.29			0.21	0.3			
Ability to work	0.25	0.36		0.20	0.18	0.24		0.23	0.20	0.30			
Cooperation	0.21	0.22	0.22	0.15	0.10	0.11	0.34	0.14	0.09	0.19	0.06	0.25	0.09
Bird-Finder Index	0.04	0.06			0.05	0.06			0	0.03			
Nose	[1]		0.35				0.32				0.33	0.19	0.19
Search/Quatering			0.48				0.31				0.18	0.19	0.12
Waterwork/Retrieve			0.13				0.32				0.30	0.24	0.31
Pointing			0.25				0.13				0.13	0.31	0.10
Tracking			0.48				0.14				0.13	0.80	0.17
Total Score			0.35				0.27				0.22	0.33	0.08

[1] Missing information means that individuals of the respective breeds were not tested for this specific test discipline, because the compared analyses focused on different traits.

English Setters were investigated by Arvelius & Klemetsdal (2013) with the purpose to encourage a joint genetic evaluation between Sweden and Norway. The authors claimed that joint evaluation could increase the accuracy of the performance tests and subsequently lead to genetic improvement of the breed. Heritabilities of performance traits in English Setters are summarized in Table 2.

The English Setters were tested in six traits and genetic parameters were estimated on national and across-country level. The disciplines Speed, Style, Hunting drive, Independence, Search width, Quartering and Cooperation were used in both countries and in different test types. The test data were collected between 2003 and 2010 in Sweden and 1994 and 2011 in Norway; the Swedish and Norwegian Kennel Clubs provided the pedigree data for the analysis. 685 dogs from Sweden with 3 629 records and 7 175 individuals from Norway with 94 414 records were used for the study. A scale for the evaluation of traits between “1” and “6” (bad to excellent) was used.

In Sweden the results from heritability estimation were generally lower (h^2=0.07 to h^2=0.13 compared to h^2=0.08 to h^2=0.18 for Norway). Furthermore, Arvelius & Klemetsdal (2013) discussed several effects that influenced the performance of English Setters in hunting tests. One such effect was the lower number of dogs judged by one person in Norway and the joint evaluation. Also the accuracy of across-country parameter estimation was higher, especially for dogs that were tested in Sweden; here an average increase of 19% could be achieved. This led Arvelius & Klemetsdal (2013) to the conclusion that a joint evaluation and smaller group sizes would benefit populations with limited information like in Sweden. With more accurate information on the performance of individuals selection on certain traits could lead to faster genetic gain. For both Swedish and Norwegian breeders more detailed and standardized information on sires and dams would have the advantage to more easily find out about a good breeding mate also across countries. As a consequence the genepool would be enlarged and the inbreeding rate decreased.

Vangen & Klemetsdal (1988) analyzed Norwegian English Setters and Finnish Hounds. They applied 5 285 test records from 968 English Setters that participated in hunting ability tests in Norway. The five most important traits in the genetic analysis yielded in low heritability estimates and repeatability, as shown in Table 2.

Table 2 Heritability estimates and repeatability for hunting traits in English Setter, according to Vangen & Klemetsdal (1988) and Arvelius & Klemetsdal (2013)

	Vangen & Klemetsdal (1988)		SWE national Arvelius & Klemetsdal (2013)		SWE Joint Arvelius & Klemetsdal (2013)		NOR national Arvelius & Klemetsdal (2013)		NOR Joint Arvelius & Klemetsdal (2013)	
Traits	h^2	r	h^2	r	h^2	r	h^2	r	h^2	r
Hunting Eagerness/Desire	0.22	0.34	0.12	0.27	0.11	0.31	0.18	0.38	0.18	0.38
Speed	0.18	0.29	0.11	0.24	0.11	0.28	0.17	0.35	0.17	0.35
Style	0.18	0.29	0.13	0.19	0.13	0.22	0.15	0.3	0.15	0.3
Seeking Width	[2]		0.06	0.27	0.11	0.29	0.16	0.33	0.16	0.32
Ability to work	0.18	0.19								
Cooperation	0.09	0.17	0.07	0.18	0.08	0.22	0.07	0.18	0.07	0.18
Search/Quatering			0.08	0.16	0.12	0.18	0.13	0.3	0.14	0.3
Total Score	0.17	0.25								

[2] Missing information means that one of the respective breeds was not tested for this specific test discipline, because the compared analyses focused on different traits.

1.1.2 Hunting dogs – Blood Hounds, Flushing and Retrieving dogs

Blood Hounds, as well as Flushing and Retrieving Dogs all have different purposes in hunting. Hunting ability tests of these breeds involve different test disciplines which are based on the particular fields of application.

Blood Hounds

The group of Blood or Scent Hounds includes breeds which are "highly specialized and trained hunting dogs for searching trails or tracks of wounded game" (Voges & Distl, 2008). Blood Hounds are well-known for their fine noses and calmness while they are working. Due to low demand for specialist dogs, populations are usually small, compared to more versatile dog breeds. GHTs are also tested in scent-trailing in later tests (Deutscher Jagdterrier-Club eV., 2014), which is why the study by Voges & Distl (2008) is considered relevant for this project.

A German study by Voges & Distl (2008) focuses on the analysis of genetic diversity for the three different scent hound breeds Bavarian Mountain Hound (BMH), Hanoverian Hound (HH) and Tyrolean Hound (TH). Inbreeding rates were calculated by using pedigree information from the respective European wide scent-hound kennel clubs. For the analysis, dogs registered between 1992 and 2004 were used; the dataset contained pedigree information from 3 231 BMH, 1 371 HH and 1 167 TH. Average inbreeding coefficients of 4.5% for BMH, 6.8% for HH and 9.5% for TH were found. Accordingly the authors demanded a "need for careful breed management in these highly specialized hound breeds to maintain genetic diversity" (Voges & Distl, 2008) and suggested to establish joint stud books for these dog breeds to prevent further inbreeding.

Flushing Dogs

Flushing dogs have been used and bred in countries and especially for areas that are difficult to access for humans. Large coniferous forests like in Scandinavia, but also wet lowlands and thick brushwoods are the perfect hunting grounds for this type of hunting dogs. They can trail game over longer distances, either making it flush in the direction of the hunter or signalizing the hunter by giving voice where the game is located.

Research on hunting ability tests in Finland involving Finnish Hounds and Finnish Spitz by Liinamo (2004), Liinamo et al. (1997), Karjalainen et al. (1995) and Vangen & Klemetsdal (1988) give further insight into genetic analysis of flushing dogs. Schmutz & Schmutz (1998) refer to a research paper on flushing dogs by Kreiner et al. (1992) claiming low heritabilities for most traits related to tracking and flushing in Austrian Hounds. However, the researchers' weren´t able to find significant heritability estimates in a joint analysis. Thus, in for each breed separate investigations, low but significant results were found.

Liinamo (2004) did a follow-up study of Liinamo et al. (1997), based on the flushing dog breed Finnish Hounds. Results from this research are in line with results by Kreiner et al. (1992).The objective of Liinamo (2004) was to investigate possible genetic progress. Furthermore, the author reflected on what kind of information could be useful for measuring performance, selection purposes, calculation of genetic gain and breeding values. During 1987 and 2003 in total 92 164 observations from 13 641 Finnish Hounds were recorded for the follow-up study. The data on hunting ability was obtained from hare hunting trails which include test disciplines related to Search, Pursuit, Tongue and Ghost trailing.

Heritability estimates indicated that there was a very large influence of the environment, because the estimates were low, similarly to a previous study from Liinamo et al. (1997). One environmental effect discussed by Liinamo (2004) were the "wild" conditions under which the trials were carried out. These included the condition of the soil, snow cover, weather, local geography and number of game in the testing area. According to Liinamo (2004), the results showed that interest to breed for specific traits varied, because recorded genetic progress varied. Furthermore, low to moderate positive correlations were estimated between the four traits. The conclusion presented in the study is that genetic progress can be achieved by selection for behavioral traits in dog populations, if sufficient information for accurate selection of breeding mates is available.

Liinamo et al. (1997) studied the hunting performance of Finnish Hounds with the purpose to estimate heritabilities and repeatabilities. A minor goal of the project was to find the most informative traits for genetic development and to calculate genetic correlations among them. Two data sets, each from 2-day hare-hunting trials and so called heats performed in Finland between the years 1988 and 1992 were obtained for this study. The data sets contained 28 791and 82 064 records with each 5 666 participating individuals. The dogs were evaluated in 28 different test disciplines on two scales from "1 to 10" and "1 to 9". The evaluation was subjective, similarly to the previously mentioned publications. Fixed effects used in the model were e.g., age of dog, snow situation, and the interaction of testing area, testing year and testing month. No significant effect of sex was found for the Finnish Hounds; therefore sex was not included in the model.

As in the follow-up study from 2004, Liinamo et al. (1997) criticized that the evaluation was "held under "wild" conditions". Thereby, different environmental effects distort the results of the performance and genetic analysis. Similar to statements by e.g. Brenøe et al. (2002), Karjalainen et al. (1996) and Kreiner et al. (1992), Liinamo et al. (1997) claims that in hunting tests "objective measures cannot readily be found for field circumstances". The heritabilities were generally low. Hence, Liinamo et al. (1997) suggested introduction of classical evaluation of breeding values based on BLUP for four traits in order to improve selection in Finnish Hounds.

An earlier study by Karjalainen et al. (1996) was based on 11 751 test observations, which were obtained from 1 625 Finnish Spitz individuals between 1978 and 1992. The hunting aptitude tests for Finnish Spitz were carried out in order to gain information on performance and thereby improve the premise for selection and development of bird hunting skills. The heritability estimates were generally low for the measures of subjectively evaluated hunting performance. Again this was a consequence of large influence of random environmental effects, subjectivity in test evaluation, ambiguous evaluation system, vague test standards and regulations and lack of educated judges. The authors further reproduced a conclusion by Kreiner et al. (1992) from the previously mentioned study on Austrian Hounds which stated an "inadequacy of the tests to be completely standardized and objective". Additionally, low repeatability of test results indicated that the data quality should be improved. Another factor on data quality might have been that not more than 8.5% of the Finnish Spitz population were tested in the field trails.

Age of the dog, testing month, testing area and year, as well as the interaction of testing area and year all influenced the test performance significantly. An effect of sex was marginal but existed in Karjalainen et al. (1996). In disciplines that were more related to hunting skills like Barking and Frequency of barking, females showed a better performance. Males scored higher in speed-related measures like Searching. Large differences between young and old dogs were found for all traits. The weather conditions, most of all wind and humidity were found to have a large effect for all measures of hunting performance except for Frequency of barking. Calm wind and dry weather had a positive influence on various test scores.

In contrast to Karjalainen et al. (1996), Vangen & Klemetsdal (1988) observed low heritability estimates for Search, Tongue and Total score (Table 3). Vangen & Klemetsdal (1988) studied the Finnish Spitz population from 1978 to 1986. Their data was based on 4 864 hunting test observations from 736 individuals. Some traits were objectively measured, others were standardized (subjective) scores. Heritability estimates in this study were lower for Barking score and Searching, but Following, Total impression and Final score showed higher heritability. Also the repeatability was higher in Vangen &Klemetsdal (1988).

Table 3 Heritability and repeatability estimates for hunting traits in Finnish Hounds and Finnish Spitz by Liinamo et al. (1997), Liinamo (2004), Karjalainen et al. (1996), Vangen & Klemetsdal (1988)

	Finnish Hound		Finnish Hound		Finnish Spitz		Finnish Spitz	
	Liinamo et al. (1997)		Liinamo (2004)		Karjalainen et al. (1996)		Vangen & Klemetsdal (1988)	
Traits	h^2	r	h^2	r	h^2	r	h^2	r
Search score	0.05	0.08	0.07	0.09	0.14-0.15	0.3	0.07	0.31
Pursuit score	0.13	0.18	0.11	0.20	0.07-0.08	0.14-0.17	0.10	0.22
Bird-finding	[3]						0.11	0.14
Marking							0.04	0.16
Holding birds							0.18	0.23
General impression	0.09	0.16			0.06-0.07	0.14-0.18		
Tongue	0.13	0.36	0.16	0.33	0.07-0.08	0.18-0.20	0.02	0.28
Frequency	0.15	0.27			0.15-0.17	0.26-0.28		
Ghost trailing score	0.12	0.32	0.15	0.29				
Merit score	0.11	0.17			0.05-0.06	0.14-0.17		
Fault score	0.20	0.01						
Total score					0.04-0.06	0.15-0.19	0.11	0.19

1.1.3 Retrieving Dogs

Retrieving dogs are "traditionally used after the shot" (Lindberg et al. 2004). The dog waits for the hunter to shoot or flushes game birds on command; after the shot it retrieves the prey from the water or other areas which are difficult to reach for humans.

Therefore, hunting ability test for retrieving breeds like Golden, Labrador, or Flatcoated Retrievers include the evaluation of water affinity, grip while retrieving and retrieving over obstacles. Comparison of the heritability estimates by Lindberg et al. (2004), Van der Waaij et al. (2008) and Wilsson & Sundgren (1997b) are presented in Table 4 and show differences between the estimates.

Research on hunting traits was carried out by Lindberg et al. (2004) for Flatcoated Retrievers, while Van der Waaij et al. (2008) and Wilsson & Sundgren (1997a; 1997b) used Labrador Retrievers and German Shepherd Dogs. The estimation of genetic parameters for traits observed in a hunting behavior test was the objective of investigations by Lindberg et al. (2004), which was carried out in six separate subtests. Additionally, the existence of broader personality traits in Flatcoated Retrievers was investigated. The data set, which was recorded between 1992 and 2000, consisted of performance data from each 800 to 1 150 dogs which were tested for 10 traits.

According to Lindberg et al. (2004) the test regulations were "recently" extended by two additional traits, for which 190 observations have been recorded and used for the analysis. Similarly to the studies by Brenøe et al. (2002), Arvelius & Klemetsdal (2013) Karjalainen et al. (1996), Lindberg et

[3] Missing information means that one of the respective breeds was not tested for this specific test discipline, because the compared analyses focused on different traits (applies also to the following tables).

al. (2004) found a significant effect of test leader/judge for almost all traits. Furthermore the type of test object (dummy or game) and previous experience also had an effect on the performance, while age and sex were observed to have less influence. The heritability estimates for Flatcoated Retrievers varied between 0.1 and 0.4. Additionally the researchers observed broader personality traits, which they named: Excitement, Willingness to retrieve and Independence for which they found heritability estimates of 0.49, 0.28, and 0.16, respectively. Among the personality traits weak genetic correlations from −0.08 to 0.15 were estimated.
Van der Waaij et al. (2008) analyzed influences of systematic effects on behavior test results and estimated genetic parameters in 1 813 Labrador Retrievers and 2 757 German Shepherds. The data was from behavioral tests carried out between 1980 and 2003 by the Swedish Dog Training Centre (SDTC). Even though testing age varied from 0.5 to 7.5 years, most dogs participating in the test were between 1.5 and 2 years of age. Age was suggested to have an effect on the test performance and was therefore tested in three age groups (< 1 year, 1 – 1.9 years, > 1.9 years). The behavior test was not a specific hunting ability test, though the results from this study include hunting related test disciplines. Courage, Defense Drive, Rey Drive, Nerve Stability, Temperament, Cooperation, Affability and Gun Shyness were tested and evaluated on a non-consistent scale. The scale varied from “1 – 3” for Gun Shyness and Sharpness to “1 – 9” for Defense Drive, Temperament and Affability. So both a narrow and wide scale where used within the investigation. The authors discuss the influence of sex and age as most relevant for the behavior, furthermore seasons of birth and testing and litter size and composition.

In Labrador Retrievers Courage, Hardness, Nerve Stability and Affability showed no significant heritability. Environmental effects tested by Van der Waaij et al. (2008) were amongst others test age, sex, season of birth, season of testing, litter size, litter composition and number of males within the litter. Heritability estimates were low to moderate (0.13 to 0.58) for all significant traits.

The evaluation by Wilsson & Sundgren (1997a) was based on performance results collected from 1 310 German Shepherds and 797 Labrador Retrievers. The objective of this study was to check for variation between the breeds in behavior test results at the Swedish Dog Training Centre (SDTC). The second aim was to enhance the working performance by applying a structured breeding program. Wilsson & Sundgren (1997b) is a follow-up study, which had the aim to determine if variation of test results was heritable. The data was collected between 1983 and 1991 and includes test results from 1 002 German shepherds and 467 Labrador retrievers which were bred by the SDTC, furthermore 637 (308 German shepherds and 330 Labrador retrievers) individuals were “purchased from private breeders at the age of 8 weeks” (Wilsson & Sundgren, 1997b). A comparison of dogs bred by the SDTC and private breeders showed that except for the trait Sharpness the SDTC offspring scored significantly higher in all traits. Estimates for heritability were calculated from intra-class correlation and except for the trait Prey Drive in Labradors all traits differed significantly from zero. In general heritability estimates were low to moderate.

Table 4 Heritability estimates for hunting ability in Flatcoated Retrievers according to Lindberg et al. (2004)

Trait	Lindberg et al. (2004) h²	Van der Waaij et al. (2008) h²	Wilsson & Sundgren (1997b) h²
Reaction to shot	0.37	0.56	
Single marking test	0.13		
Reaction when throwing the game	0.41		
Interest in search	0.26		
Retrieving	0.34		
Delivery	0.15		
Grip	0.19		
Interest in water retrieving	0.23		
Cooperation	0.12	0.25	0.35
Waiting passively in a group	0.74		
Courage		0.13	0.28
Sharpness		0.13	0.11
Prey drive		0.32	0.05
Nerve stability		0.15	0.17
Hardness		0.16	0.20
Temperament		0.18	0.10
Personality Trait			
Excitement	0.49		
Willingness to retrieve	0.28		
Independence	0.16		

A publication by Liinamo et al. (2007) on the heritability of aggression traits in 325 Golden Retrievers used information from owner´s opinions and Canine Behavioral Assessment and Research Questionnaire (CBARQ). The data collection process took place between 1997 and 2005, dogs were chosen because of their aggressive behavior (n = 159) or their direct relation to an aggressive dog (n = 166). Aggressive behavior occurred more often in certain Golden Retriever family groups (Knol et al. 1997, cited in Liinamo et al. 2007) hence, it was supposed to be genetically manifested. The aim of the molecular genetic study was to find family based aggression traits in the Dutch Golden Retriever population, especially finding traits available from CBARQ with sufficient genetic variation, which could be useful as phenotypes for future molecular genetic studies in this field. Liinamo et al. (2007) tested for effects of age, the origin of the dog (e.g. shelter, breeder, private), and various effects related to the relationship of the owner with the dog (e.g. participation in obedience courses and ways to react to misbehavior of the dog). After tests for significance only age and reproductive status of the dogs were used in the model. Heritabilities were generally high for most of the traits, which led the researchers to the conclusion that the methods applied in this study were inadequate (small amount of test animals, preselection of test animals).

A recent study by Tavares et al. (2015) on water affinity in Labrador Retrievers did not give further insight on performance traits, but on behavioral traits like the genetic disposition to approach water, swim and retrieve game. The coat of a Labrador Retriever is described as thick and water resistant, also a distinctive otter-shaped tail and webbed toes are typical signs from selection. The aim of Tavares et al. (2015) was to find out about animal welfare traits like the importance for modern Labrador lineages of having access to water and the possibility to swim on a regular basis. This study is a first step and requires further research including more individuals and the ability to test for effects like age, sex, and earlier experiences. Results show that Labradors have a significant tendency to interact with water, before attending to humans or other dogs.

1.1.4 Non scientific literature on German Hunting Terriers

Apart from scientific research, there has been some research and also books have been published by German cynologists and researchers. This information is basically used as measure of guidance for dog breeders and owners and to capture knowledge on the breed.

Bierwirth & Merle (2011) published information on breed creation and standard, education and training of GHTs, preparation for ability and performance tests, breeding, health care and treatment of diseases and injuries. Contributors to the book are Gruenewald, who was one of the four breed creators, Beuing, who is an acknowledged animal scientist and in charge of the statistical analysis of the performance data and Lemmer, a veterinarian and cynologist.

A portrait of the breed by Schindl (1995) also covered the process of breed creation, but in larger detail. Furthermore information on the establishment and development of GHT breed clubs were given. The author described how the German and DDR breed club were founded and merged, and how the international breed club was created. Advice on how to purchase, educate and keep GHTs, as well as information on the performance tests, hunting related terminology, skills of GHTs and health care were given. The text book is based on the written legacy of Lackner, who is yet another of the four breed creators.

Vocke (1994) wrote another German reference book which again includes the historical background of the breed, information on breeding, rearing, keeping and appropriate education, performance testing and health care. However, this book also incorporated information on genetic research on behavioral, phenotypical and genetic faults, which can occur in this breed. Furthermore, Vocke (1994) presented heritability estimates for eight traits that were calculated and published by Beuing (1993) (Tables 5 and 17).

Table 5 Heritability estimates for GHTs calculated according to Beuing (1993)

Trait	n	h^2
Conformation	4397	0.12
Fur score	3917	0.25
Chest-circumference	1267	0.34
Height at withers	1280	0.55
Nose	4288	0.14
Voice on trail	4689	0.28
Hardness	2549	0.19
Water affinity	4264	0.31

1.1.5 Working dogs

Research on performance of working dogs has been done on a larger scale, especially in correlation with personality traits like boldness, aggression, cooperation with the handler, but also with regard to genetic analysis or performance improvement by breeding. The publications will just briefly be summarized, in order to show that even for working dogs research with similar purpose has been carried out.

Particularly important is the role of German or Belgian Shepherds for research on working dogs. Shepherds are often used for military or police services. Individuals originating from breeding programs or selected for these services have to undergo all kinds of behavioral and performance tests as e.g. Arvelius et al. (2014), Van der Waaij et al. (2008), Courreau et al. (2004), Ruefenacht et al. (2002), Svartberg et al. (2002) and Wilsson & Sundgren (1997a) describe in their papers. Other dog breeds which were used for scientific research on behavior and performance of working dogs were Border and Rough Collies, American and Californian Guide Dogs and Labrador Retrievers, however, these are not related to the present study and therefore not mentioned.

Arvelius et al. (2014) worked with German Shepherds from the Swedish Armed Forces training program. The objective of this study was to estimate heritabilities and genetic correlations, in order to select individuals for breeding and training. While correlations for most traits were high, heritability estimates were low to moderate. Furthermore, they found that the Swedish Armed Forces temperament tests are useful not only to select dogs for training, but also for breeding purposes. However, the test should be adapted in order to maximize its outcome; for instance introduce breeding values estimated with Best Linear Unbiased Prediction (BLUP), alter the scales and evaluation process and additionally considering genetic parameters could help.

Arvelius et al. (2013) analyzed differences of two different versions of Herding Trait Characterization, which were used to describe the herding performance for Border Collies. Observations from the tests have been used to calculate heritability estimates. Differences in calculated heritabilities occur, because two different systems of evaluation were used. Heritabilities in the first test version vary significantly from those in the second version; five results from the second test version are presented in Table 6. Conclusions on the reason of the difference between the test versions were amongst others the objectivity and structure of the first test version, yet this does not have further informational value here. According to the researchers using narrow and simple scales for evaluation, evaluating traits from neutral to desirable (having the optimum at one end of the scale) and defining the traits accurately and objective are key solutions to improve the quality of the results. Accurate results are beneficial for usage of the data for breeding and selection purposes. Arvelius et al. (2013) suggest using a linear mixed model in order to predict BLUP breeding values, which involves kinship information. This measure would, apart from being more expensive, accelerate genetic progress for herding traits.

Table 6 Heritability estimates for chosen hunting related traits in Border Collie by Arvelius et al. (2013)

Trait	h^2
Work ethic	0.14
Courage	0.11
Grip	0.13
Will to drive	0.06
Cooperation	0.04

In contrast to most dog breeds, the Alaskan Sled Dog has solely been selected for performance (Huson et al. 2010). Sled dogs are hybrids, which means that the genetic diversity within the breed is comparably large. Applying molecular methods, origins of specific performance-related behaviors could be traced back to constitutive breeds. Furthermore, after determination of the molecular signature, differences between dogs which had been bred for distance or sprint competitions were found. According to Huson et al. (2010) “Alaskan Malamute and Siberian Husky contributions are associated with enhanced endurance; Pointer and Saluki are associated with enhanced speed and the Anatolian Shepherd demonstrates a positive influence on work ethic”. These results are the basis for further research on finding more genes which can be associated with athletic attributes in Alaskan Sled Dogs.

Van der Waaij et al. (2008) studied effects on behavior test results in Labrador Retrievers and German Shepherds. Courage, Defense drive, Prey drive, Nerve stability, Temperament, Cooperation, Affability and Gun shyness were tested in 2 757 German Shepherds. Males showed more sharpness than bitches, as well as a significantly earlier successful performance in test situations. Season of birth affected Cooperation, Prey drive and Temperament in the working dogs.

Heritability, genetic correlations and the role of environmental factors for defense capacity traits in Belgian Shepherds were investigated by Courreau et al. (2004). Results showed that heritability estimates were low to moderate, repeatability relatively high and genetic correlations were moderate to high, except for the trait Jumping which seems to be independent from the other abilities. In general, male dogs scored better than the female dogs and an effect of breed variety was noticeable. Furthermore, age significantly influenced test performance. Courreau et al. (2004) agreed with e.g. Karjalainen et al. (1996) and Brenøe et al. (2002) that performance in competitions was strongly affected by the environment. But the authors also put the opinion into perspective that hunting competitions were more affected by environmental factors compared to defense competitions. They suggested possible reasons for low heritability estimates being difficult to get rid of environmental factors and reduced genetic variability due to genetic selection and bottlenecks because of breed creation.

Genetic and non-genetic effects on behavioral traits were examined by Ruefenacht et al. (2002) for test results from field behavior tests organized by the Swiss German Shepherd breeding club. Effects proven significant for this study were sex, age, judge and kennel. Judge and kennel effect were highly significant as was the difference in performance between dogs tested before 1989 and later, after a change of test regulations. Heritability estimates ranged between low to moderate, while genetic correlations between the behavioral traits were generally positive and moderate to high. Ruefenacht et al. (2002) discussed the results in context to preselection of dogs taking the tests, experience of dog handlers and training as well as set-up of tests and accurate and objective evaluation of traits. Furthermore, the judge effect was debated, which was significant in this study regardless of examined education, annual training and enduring education. Sex-specific social behavior and the fact that more males than females were used for actual working purposes were suggested as the reason for performance differences in males and females.

Ruefenacht et al. (2002) suggested firstly to increase selection intensities, secondly to increase the number of dogs that enter competitions, alter the scoring and evaluation in the tests, and at last to include both personal performance and kinship performance by applying estimated breeding values.
Results of the publications are presented and compared in Table 7.

Table 7 Heritability estimates for different working dogs traits from Arvelius et al. (2014), Van der Waaij et al. (2008), Ruefenacht et al. (2002), Wilsson & Sundgren (1997b)

	Arvelius et al. (2014)	Van der Waaij et al. (2008)	Ruefenacht et al. (2002)	Wilsson & Sundgren (1997b)
Trait	h^2	h^2	h^2	h^2
Affability	0.06	0.38	[4]	0.37
Hunting drive	0.19			
Courage	0.18	0.19		0.26
Nerve Stability	0.16	0.16	0.18	0.25
Hardness	0.09	0.14	0.14	0.15
Sharpness	0.11	0.19	0.09	0.13
Cooperation	0.12	0.17		0.28
Prey Drive	0.21	0.23		0.31
Gun-Shyness	0.00	0.22	0.23	
Defense Drive		0.14	0.10	0.20
Temperament		0.18	0.17	0.15
Self-Confidence			0.18	

A study by Svartberg et al. (2002) used data from working trials with 2 655 dogs of the two breeds German Shepherd dog and Belgian Tervuren. Apart from the working trials, 1 178 male and 1 041 female German Shepherds and 203 male and 233 female Belgian Tervuren individuals were tested in the Dog Mentality Assessment (DMA) between 1989 and 1997. The dogs were between 12 and 18 months old when they were examined in 23 different test disciplines. Svartberg et al. (2002) had the goal to find out if there is a correlation between personality and test performance. The results of this study represented the hypothesis and earlier results that there is a relationship between the ability to learn easily, score high in tests and a bold personality. German Shepherds, which were chosen because of their reputation for being bold and trainable, which was affirmed by the study, overall scored higher than the more shy Belgian Tervuren. These dogs are generally less bold, active and playful, which was concluded to lead to a lower ability "to learn more complex behaviour and perform well in situations requiring persistence". A conclusion for choosing an individual working dog is that bolder animals should be selected. Even though no heritability estimates were calculated in this study, an assumption was made that selection of bold individuals is possibly beneficial for selection of breeding mates as well.

A publication by Wilsson & Sundgren (1998) was based on 630 German Shepherd puppies from the Swedish Dog Training Centre. The goal of this project was to investigate if it is possible to predict adult behavior already at the age of eight weeks and to analyze heritability estimates for puppy behavior. The puppies were tested a second time at an age of 450 to 600 days according to the regulations of selection for service dogs. The results of the study showed moderately high to high heritabilities for behavior traits and an effect of sex, which was found for four out of ten traits. Basically female pups showed more independence and active behavior than males. Moreover, maternal effects from puppy test results were found. Despite the hypothesis by Wilsson & Sundgren (1998) that adult behavior can be predicted, performance in puppy tests was not in line with the behavioral traits at an adult age. Reasons for this were assumed by juvenile behavior being governed

[4] Missing information means that one of the respective breeds was not tested for this specific test discipline, because the compared analyses focused on different traits.

by different genes compared to behavior at later age, or that the test structure and evaluated traits vary too much. Consequently, these tests were not considered to be useful for predicting the aptitude to be a service dog.

1.2 German Hunting Terriers

The GHT is a small hunting dog breed, which was bred for versatile hunting purposes (FCI, 2015). Key hunting skills are underground work, tracking and flushing game in fields and forests and moreover, work in and around water. This breed is one of few breeds which are acknowledged to give voice on trail. This trait as well as the lack of gun-shyness is, amongst others, a prerequisite to register a GHT as a breeding animal (Deutscher Jagdterrier-Club eV., 2013; Deutscher Jagdterrier-Club eV., 2014).

The members of German Hunting Terrier Clubs in many countries and especially the officials of the originating breed club “Deutscher Jagdterrier Club e.V.” are highly motivated breeders. They started already at the beginning of breed creation to use all kinds of available technology to record traits such as test performance of breeding animals and offspring, examine conformation and health of individuals and calculate inbreeding coefficients. Furthermore, they educated their judges to guarantee standardized performance tests and consistent evaluation of traits (Deutscher Jagdterrier-Club eV., 2015).

1.2.1 Test types for German Hunting Terriers

There are several tests organized by the national German Hunting Terrier Clubs, which have been designed accurately for this breed and the prospective or possible field of hunting for these dogs (Deutscher Jagdterrier-Club eV., 2014; Bierwirth & Merle, 2011; Schindl, 1995; Vocke, 1994). The aptitude tests include test disciplines which substitute different fields of hunting in which GHTs are commonly used. The grading system is based on benchmarks which have been set and adapted by German cynologists and breed club officials ever since the breed has been created and testing of hunting skills has been carried out (Bierwirth & Merle, 2011; Schindl, 1995; Vocke, 1994). The test disciplines and grading system are briefly described in chapter 2.2.

The dogs are not only tested as young dogs, but at different ages, in different test disciplines and for various purposes. The tests are as close as possible to practical hunting situations and according to the developmental stage of the individuals. Hence young dogs are just tested in aptitude tests, in which test for conformation and fur traits are included and which are equivalent to the requirements of a breed show. Subsequently to the aptitude tests full-grown dogs have to prove their performance in more difficult tests. The latter tests target on verifying the aptitude – proven in tests as young dogs – to work underground, test the ability to track down wild-boars, retrieve and giving more precise information (e.g. on the dogs nature) to the national breed book authorities. The analyses in this project are based on the data gained from the breeding tests.

Breeding Tests 1 and 2

Both breeding tests have the purpose of testing the young dogs’ aptitude. The first breeding test (BT1) is performed in underground hunting. The second breeding test (BT2) is carried out on the fields and includes most of all tracking related test disciplines.

Regulations on when and how dogs can enter the different tests vary from country to country and can be found in national test regulations (e.g. Deutscher Jagdterrier-Club eV., 2014; SKK, 2017; Tysk Jagtterrier Klub, 2006). In general the tests are taken before the age of 36 months, in many cases the dogs are tested around or after the 15^{th} month, which is the relevant age for breeding maturity.

For the breed shows in Germany there is a minimum age of 15 months, in Sweden a dog has to be at least 9 months, or 12 month to take the underground test.

The tests take place amongst others in Austria, Croatia, Czech Republic, Denmark, Germany, Hungary, Italy, Luxembourg, Norway, Poland, Sweden, and Switzerland. Dogs which fulfill all prerequisites (e.g. age, pedigree, conformation according to breed regulations, depending on country if test docked tail or undocked tail) are accepted. It is recommended to prepare the young dogs by showing them the training and testing facilities and letting them do a test run, to ensure the young dog knows what it has to do in the test situation. The Deutscher Jagdterrier-Club eV., (2014) advises the breeders and puppy owners against training or hunting with a young dog on a larger scale before the test. Although training will influence the performance and falsify the result for the aptitude of hunting performance, it is enforcedly accepted.

- BT1 includes testing for hereditary predisposition in hunting underground in for instance fox dens
- BT1 comprises entering and searching an artificial den and showing the interaction with game
- BT2 involves the Field work, hunting at and in water and the evaluation of body measurements, Conformation, Fur and health traits, equal to the Breed Show.
- BT2 comprises trailing game, entering and searching game in water and a test of reaction to shot

Test disciplines and evaluation of these are mentioned in the following chapter.

Both breeding tests can be done the same day and are taken as two individual tests then. In this case Reaction to shot and Nature of the dogs will be evaluated just once as a total score.

Breeding Show

In order to pass the breeding tests, an examination of body measurements, Conformation, Fur score and health traits is required. This examination can either be done in the course of BT1 or BT2, or by participation in a Breeding Show.

The breed club collects all information on heritable traits for dogs which are supposed to be used in breeding. The purpose of these examinations is to make sure that no defects which influence the hunting ability or health occur or proliferate in the breed (Deutscher Jagdterrier-Club eV., 2015). The heritability of these traits is marginally shown in Chapter 3.2.

There are regional, also national and international breeding shows which are organized just for GHTs. Dogs which are competing in those special breeding shows will be evaluated according to outward appearance: Body-shape and measurement, Fur, Dentition, Health and Conformation (extremities, setting of ears and tail) are examined. Furthermore a determination of genetic defects (which could lead to exclusion from breeding) and gaits will be carried out. At last during the whole test the nature and behavior will be assessed.

1.2.2 Aim of testing hunting aptitude

The breeding tests are primarily carried out as a measure for the breed club to keep control on the conformation, performance and health of the breed (Deutscher Jagdterrier-Club eV., 2014; Deutscher Jagdterrier-Club eV., 2015; Bierwirth & Merle, 2011; Schindl, 1995; Vocke, 1994). Subsequently, the recorded phenotypic data is used for the estimation of breeding values which can be used as guidance for breeders on finding beneficial breeding mates. Another major reason for testing young dogs, which is more important to the handlers, is to check that the individual wouldn’t bringing itself into danger during practical hunting (Bierwirth & Merle, 2011; Schindl, 1995; Vocke, 1994). Especially in underground (aptitude test, GP Hunting Ability Test, Key-Performance proof) and later in wild-boar hunting (field test) this is a key motivator.

2 Material & Methods

2.1 Data

The data for this project was provided by the Deutscher Jagdterrier Club e.V. as owners of the data and by TG-Verlag Beuing GmbH in Gießen which is the official data processing service center holding the data. Two files were obtained, one contained the pedigree information of all registered GHTs in Germany and the other performance data. This information has been recorded since the creation of the breed and thereby provides pedigrees of in particular cases more than 50 generations. The pedigree file lists 101 250 individuals, while the performance dataset consisted of test results (phenotypic information) from different countries (Austria, Denmark, Croatia, Luxembourg, Sweden, and Switzerland) and different types of tests with a total of 14 738 records.

For this project only data from young dog tests – so called aptitude tests – were used in order to minimize influences of training, experiences and also leader effect (Schmutz & Schmutz 1998). These tests are noncompetitive; the performance of the individuals is compared and evaluated with regards to an approved standard (Schmutz & Schmutz 1998). The tests are conducted by the breed club using educated and experienced judges and one audit manager (head judge). Every test group consisted of a maximum of six dogs and their handlers, which were evaluated by three judges, the most experienced of them will be picked by the audit manager to umpire the group of judges.

In Germany there is no minimum age limit for the aptitude tests, but for breeding shows the dogs should be at least 15 months old. Hence, most dogs are tested at the age of 15 months or slightly later. Maximum age for the young dog tests is 36 months of age. In breeding test 1 and 2 the dogs should just show their aptitude in different traits; training and experiences in hunting are considered to not being beneficial.

The time-span for the analysis of the last 20 years was chosen because the two German breed clubs (Deutscher Jagdterrier Club e.V. and the Deutscher Jagdterrier-Club e.V. der DDR (of the former DDR)) merged in 1990. Because of the merge new breed regulations were put into charge and the focus of the club and performance testing was more on aligning the tests. To make sure that influences from the merge are minimized, the analysis involves data from tests between 1996 and 2016.

In the performance dataset some missing values occur because some dogs were just tested in one test type and each test type (BT1 and BT2) includes just one half of all test disciplines; so to receive all values the dogs would need to participate in both tests.

The lowest number of observations has been recorded for Sound at sight, which is just tested on request if an individual is known to make no Sound on track. Because of these few observations this trait was not used in further analyses.

2.2 Description of Traits and Score Sheets for Breeding Tests

The Breeding Tests 1 and 2 are noncompetitive; the evaluation is based on an approved standard to which the dogs' test performance is compared. This approved standard is published and described in the national testing regulations (Deutscher Jagdterrier-Club eV., 2014). These regulations are adapted recurrently during official breed club conferences.

Table 8 shows what test disciplines are tested in BT1, which is the underground aptitude test. The individuals can score from "0 to 4" (no performance to excellent performance) in all test disciplines. For all traits, except Bolting the fox (which has the maximal score of "4.5"), the score "4h" (outstanding performance) is the maximal score. In this project "4h" is displayed as score "5"; it can be only be handed out on reasoned submission of the judges. In the investigated dataset "5" was assessed in the traits Nose work aptitude, Sound on trail, Obedience and Water affinity, as well as for Conformation and Fur score.

To give one example, a score of "0" for Sound on trail will be given if a dog does not give voice while trailing a hare. If an individual just barks once or twice but otherwise remains silent a "1", for more frequent but still insufficient sound a "2" can be given. Dogs which give sufficient but not consistent voice over longer distances will score "3"; while a consistent sound on long distances will be rewarded with "4". An outstanding performance ("4h"/"5") is shown if the sound remains completely persistent also in difficult environmental conditions, like trailing over obstacles, different vegetation and soil, remaining on the right trail plus making sound, even if other possibly fresher trails were passed. Table 9 shows the test disciplines of Breeding Test 2, the scores and the system of grading is the same as for BT1.

In both tests there are weights on the various disciplines. The highest weight is put on Bolting the fox, the second highest is Nose work aptitude, which is evaluated in BT2 and the lowest weights are on Reaction to shot and Sound at sight of game. The latter is because this trait is just a compensatory trait for Sound on trail and thus should not be of high value. Apart from naming the test disciplines, Tables 8 and 9 show how the points for each discipline (e.g. Bolting the fox: Score "4" multiplied with weight equals 32 points) and resulting from this the Total points are evaluated. The column Maximum amount of points, Points required for Price 1 to 3 provide information on how many points a dog needs to be rewarded with one of the three prices. 72 points for BT1 and 100 points for BT2 are the maximum amount of points a dog can be rewarded with. After the Breeding Test the dog handler receives a test certificate and a transcript of records with the dogs' performance. This performance will be recorded and edited by the statistical data processing center TG-Verlag Beuing GmbH. Consequently, the test results will be used for the prediction of breeding values (BLUP), which also include pedigree information of the individual and performance information of relatives.

Table 8 Evaluation chart for Breeding Test 1 (BT1, Underground aptitude test) including system of calculating points for evaluation of Total Points and Price

Test discipline	Weight	Maximum amount of Points	Points required for: 1. Price		2. Price		3. Price	
			Score	Points	Score	Points	Score	Points
Bolting the fox	8	("4" * 8 =) 32	4	32	3	24	2.5	20
Passion underground	3	12	3	9	2	6	1	3
Sound during underground work	3	12	3	9	2	6	1	3
Search during underground work	4	16	3	12	2	8	1	4
Accomplishable Points BT1		72						
Demanded Points BT1				62		52		41

Table 9 Evaluation chart for Breeding Test 2 (BT2, Field work) including system of calculating points and evaluation of Total Points and Price

Test discipline	Weight	Maximum amount of Points	Points required for: 1. Price		2. Price		3. Price	
			Score	Points	Score	Points	Score	Points
Nose work aptitude	6	("4" * 6 =) 24	3	18	2	12	2	12
Trail reliability	3	12	3	9	2	6	1	3
Trail volition	3	12	3	9	2	6	1	3
Giving voice on trail	4	16	3	12	2	8	1	4
Giving voice when game at sight	1	4			4	4	2	2
Water affinity	4	16	3	12	2	8	1	4
Obedience	4	16	3	12	2	8	1	4
Reaction to shot	1	4	4	4	4	4	4	4
Accomplishable Points BT2		100						
Demanded Points BT2				80		70		60

2.3 Traits evaluated in Breeding Tests

The specialized breeding tests aim at providing a maximum of information about the tested individual. Therefore, eleven test disciplines for hunting performance, four conformation traits and also evaluation of the dogs' nature and character are recorded. The evaluation of nature and character are not described in further depth, because these traits were not included in this project. However, differences between the terms are described in the Annex. The description of the traits is based on the non-scientific literature by Bierwirth & Merle (2011), Schindl (1995) and Vocke (1994) and the German testing regulations (Deutscher Jagdterrier-Club eV., 2014).

Bolting the fox

Underground work used to be the main task for which Terriers were bred and is also today one of their key skills (Bierwirth & Merle, 2011; Schindl, 1995; Vocke, 1994). Dogs used for underground hunts need to be able to scare small predators like foxes out of their den. In order to be successful these dogs need to appear dominant and superior, the louder and more aggressive their sound is, the more effective the dogs are. The test is taken in an artificial den (fox) and the dog scores with a maximum score of "4.5" for bolting the fox out of the den.

Endurance/Passion

During the whole underground test, the dog should show noticeable determination to fulfill the exercise and not stop until the handler calls the dog. How fast and determined the GHT embraces the artificial den, how keen it is to find the fox inside, and for how long it makes a sound and tries to make the fox bolt are the key points for the evaluation.

Sound during underground work

For underground work it is at least as important for dogs to give voice as it is for the tests on the field. A loud, ongoing and persistent sound from the GHT is desired to master this test. The best performance show dogs, that enter the artificial den already with a harsh and forceful sound and which keep this tone until they reach the fox and during the next minutes in front of the cage.
Dogs which reach the fox but remain silent are of no use for practical underground hunting. The risk, that one is unable to find these dogs deep down in dens or burrows is high.

Search during underground task

Here the strategical approach is rated, how does the dog search inside the artificial den? Does it search in every direction and how fast can the dog find the fox? Experienced dogs are not supposed to enter and search dens that are not used by game. A combination of the characteristics Nose work, Passion, Tactical searching ability and Volition to find the fox is necessary to pass in this part of the underground test.

Nose work

To evaluate the aptitude to do Nose work, the dog should be examined and evaluated during all possible situations (on field and underground) over the whole day of testing. Dogs can be assessed with a "4" or even outstanding if they find the scent directly and follow on the trail. An outstanding performance is shown when the dog reliably searches different types of soil, vegetation and over obstacles. The dogs should show determination for trailing, also over longer distances.

Trail reliability

This test discipline (together with Trail volition and Giving voice traits) is evaluated according to the trail work on a field. In the small breeding test groups, the judges and participants search field for hare; the dog is set on a trail (without having seen the hare) and supposed to trail precisely with every turn and double. "The demeanor of the dog in search, and whether it uses its nose to guide the search or simply runs aimlessly" (Schmutz & Schmutz, 1998), influences the grading. A dog working on the trail should show that it is able to trail fast working, without crossing, overrunning (running away from the trail), running parallel, losing the trail or searching uncoordinatedly – which is considered to be either over-eagerness or poor nose work.

Trail volition

Trail volition is supposed to rate the tenacity with which the GHT is following a trail. So even if the conditions for trailing are difficult (amongst others wind, rain, obstacles, changeovers from one field to another, crossing trails), the dog should not stop searching for the right trail. If it searches until it is called back or at least searched on a distance of around 400 meters it is considered to have shown excellent volition.

Giving Voice on trail

The GHT needs to make a complete persistent and ongoing sound (short breaks are allowed for passing) to master this test. Individuals which make no sound are unwanted as this trait is a prerequisite for breeding and for passing the aptitude tests. Voice on trail is considered to be a basic skill GHTs have, also compared to other Terrier breeds like Parson Russel Terriers, Westphalia Terriers and others, for which this test discipline is not obligatory.

Sound when game at sight

GHTs need to make sound for game in order to pass the aptitude test. Even though it is supposed to be manifested in GHTs, not all dogs give Voice on trail. Dogs which are known to not give Voice on trail can be tested in Sound at sight on request. The sound is then triggered by vision of volatile game, which is a higher stimulus for a dog to bark. Dogs which give voice at sight of game pass the aptitude test, but are not allowed in breeding, because it is defined and preassigned that only Voice on trail is good enough. Dogs which pass with Sound at sight benefit by being allowed to hunt on state grounds. This measure should ensure that this fault in character is not passed on.

Water affinity

To prove Water affinity, the dog needs to enter the water (without current) twice with a low or no incentive and swim a wider distance before it returns. Incentives like throwing a stone or a swimming obstacle are allowed but result in a lower grading the more they are used. Dogs which do not take up the water on their own will fail the test.

Obedience

The grade for this discipline is a total score, based on situations from the whole test day. Such can be the leashing process, the dogs’ behavior during the gun-shyness test or during the examination of fur/dentition/body shape, if and how the dog comes to its leader when called and basically every situation which can reveal the relationship between dog and its leader. The judges want to see if the dog wants to obey (is willing to please), understands its leader/owner and performs the tasks given to him.

Reaction to shot

To test for the reaction to a shot the handlers have to walk their leashed dogs in a circle. The teams are supposed to have a little distance between each other and walk about 30 m away from someone who shoots into the air with a shotgun. The reactions of the dogs are observed. Interested looks and also in German called “Schusshitze”, which designates the reaction of dogs after the shot, if the dog wants to hunt down game immediately without being obedient to his handler, will not bring a deterioration in the rating. Yet, jumping away, fleeing from and hiding behind the handler are undesired behaviors. In general, two shots will be fired, to make sure that every dog was looked at.

Conformation

In order to receive information about size, type of fur, the built of the dogs, health and congenital phenotypic defects all dogs are examined during a Breed Show. As mentioned in Chapter 1.2.1, this Breed Show can be in conjunction with BT1 or BT2 or an independent event. Height at withers and chest circumference are measured and recorded in cm.

The fur has to be dense and hard, depending on the fur type plain or rough. All regulations concerning the traits in this topic can be found in the breed standard in the annex.

2.4 Editing of data

Data editing and implementation of descriptive statistics and tests for significance was done in SAS (2002-2012). First steps in data editing were to delete records which lacked the individual´s ID, birth or test date and contained obvious recording mistakes. Such mistakes were for instance impossible scores, like a "7" on a scale of "5" scores, dogs which were born earlier than their parental generation, or tested before their own birth. Thereafter, instead of 101 250 observations the pedigree file consisted of 98 936 individuals and the performance dataset was decreased from 14 738 to 10 919 observations. The merged dataset consisted of 10 812 entries, because not all dogs from the pedigree dataset could be matched with performance data and not every test observation could be matched with a record in the pedigree. Therefore some of the data is lost at this point.

The merged dataset was subsequently adjusted for duplicate records; records of dogs which did one of the aptitude tests more than once were deleted and only the first test observation was kept. This was supposed to preclude the influence of training – as a non-genetic factor – on the test result. Dogs which participated in different test types were not considered to have duplicate records. Hence, because of three different test types, each individual can have up to three records in the dataset. From the merged dataset 715 duplicate test observations were deleted, which left 10 061 unique records. Out of these, 7 615 observations belonged to individual dogs.

IDs of individuals originating from different countries were brought into a uniform system because in the original dataset the IDs contained different country prefixes, some characters or birthdates within the ID. All IDs were replaced by individual codes in the same format. Test locations, which in the raw data set had been recorded in an inconsistent way, were revised, corrected in consultation with the breed club and the toponyms were replaced by codes.

None of the original datasets contained information on the sex of the dogs. Out of the 10 061 observations the sex for 12.7% of the bitches and 5.7% of the males was known, because they had been used in breeding. It was not possible to find out sex of dogs which had not been used in breeding. Therefore, the class sex contained 9 457 dogs, of which 546 are males, 1 201 females and 7 710 individuals were of unknown sex.

Breeding and test season were defined as groups of six months respectively (January-June and July-December). The tests are carried out perennially, organized in spring and autumn for GHTs, which is identical for most kinds of hunting dog breeds (Deutscher Jagdterrier-Club e.V., 2014).

The age at test was calculated in months by using birth and test date. Subsequently, age was classified in groups of six months each. In the performance dataset some dogs younger than 6 months had been recorded. It was considered to be improbable that dogs younger than six months participated successfully in the tests, these records were regarded as faulty records and deleted. Some dogs were recorded to older than 36 months at the test day. The German test regulations preclude dogs older than 36 months of age, which is why an upper age limit was defined as well. The limit was set for 54 months because the amount of dogs recorded in ability tests was still informative. Records of dogs older than 54 months were purged. In between the lower and upper age limit six age classes were kept and used for the investigation of an age effect.

Variables for the interaction of test year and season, location and test year were calculated, inserted in the dataset and tested for significance in order to check for further environmental effects and minimize the residual variance.

Before the year 1996 only a few dogs were recorded, this would have resulted in non-sufficient meaningfulness of results for these years. Thus, test observations recorded between 1989 and 1993 were deleted. After the deletion processes the merged dataset ultimately consisted of 9 457 observations, which were used for SAS and DMU analysis.

2.5 Statistical analyses

2.5.1 Building the model

Before the decision on a model for the analysis of variance components, different models with various combinations of effects were tested. Only effects with p-values below 0.05 were included in the final model analyzed with PROC GLM in SAS.

The factors Sex, Age (in groups or in months), Birth year, Birth season, Test year, Test season, Location, interaction of Test year times Test season, and interaction of Location, Test year and Test season, and lastly Size and Shape were tested for significant variations in the model. In Table 10 the significance of the factors is shown and categorized into four levels of significance.

Even though differences in performance between the sexes were significant, Sex was not applied in the model. The discrepancy in amount of dogs with known and unknown sex was large. Because Sex was only known for dogs used in breeding, using Sex in the model, would have affected the estimation of genetic variance. Size and Shape were found to have no statistical significant effects, which is why neither effect was used for further analysis. Test type just had an influence on Passion to hunt underground, Search demeanor underground and a low significance for Sound on trail, subsequently it was disregarded in the models for the field test and conformation. Birth season was only significant for the performance trait Water affinity and conformation traits Fur score, Height of withers and Chest-circumference. Therefore, Birth season was only included in the model for the conformation traits. Location was significant for all effects but Reaction to shot.

The traits Sound at sight of game, Obedience and Reaction to shot had distributional problems. Sound at sight of game had too few observations (278) to make significant assertions on the genetic background of the trait. Obedience and Reaction scores were extremely skewed, and almost all were equal to the maximum score. Nevertheless, heritability estimates for these traits were calculated for the sake of completeness.

Ultimately three models were used, all of them were applied twice, first time using Location as fixed and second as random effect. Location includes random environmental effects (like e.g. weather, judge, type of soil), but could also be considered as fixed. Heritability estimates (calculated as additive genetic variance divided by the sum of additive and residual variances) did not differ substantially between the two types of models. The highest difference between the results was calculated for Bolting the fox and Obedience (difference of 0.02). A similar approach was chosen by Karjalainen et al. (1996) who chose a subclass of the effect of weather for the investigation.

The model for Underground Test (model 1):

$$y_{\mathrm{ijklmn}} = \mu + age_i + test\ year_j + test\ type_k + test\ year\ x\ test\ season_l + test\ location_m + a_n + e_{\mathrm{ijklmn}}$$

The components of the model are defined as:

- y_{ijklmn} = score of performance of a trial element of an individual dog in an event
- μ = the overall mean
- age_i = the fixed effect of age group (in 6-month classes (8 levels))
- $test\ year_j$ = the fixed effect of test year (20 levels from 1996 to 2016)
- $test\ type_k$ = fixed effect of the type of test (1 = breeding test 1 and 2, 2 = BT 1, underground hunting aptitude, 3 = BT 2, field work aptitude
- $test\ year\ x\ test\ season_l$ = the fixed effect of the interaction between test year and test season (41 levels, 2 seasons for years 1996 to 2015, 2016 only spring season)
- $test\ location_m$ = the fixed or random effect of location (91 levels in Europe, mostly Germany)
- a_n = the random additive effect of the animal $n \sim ND\ (0, A\sigma_a^2)$, where σ_a^2 is the additive genetic variance and A is the relationship matrix
- e_{ijklmn} = the random residual effect which is not explained by the model with $e_{\mathrm{ijklmn}} \sim IND\ (0, \sigma_e^2)$, where σ_e^2 is the residual variance

The model for the field test (model 2) consisted of:

$$y_{\mathrm{ijklmno}} = \mu + age_i + test\ year + test\ season_k + birth\ year_l + test\ year\ x\ test\ season_m + test\ location_n + a_o + e_{\mathrm{ijklmno}}$$

The components of this model are defined as in model 1 except:

- $test\ season_k$ = fixed effect of the season at test (January to June or July to December)
- $birth\ year_l$ = the fixed effect of year of birth (26 levels from 1989 to 2015)

The model used for the conformation traits (model 3) was

$$y_{\mathrm{ijklmn}} = \mu + age_i + birth\ year_j + birth\ season_k + test\ year\ x\ season_l + location_m + a_n + e_{\mathrm{ijklmn}}$$

The components of the model are defined as in model 1 and 2 except:

- $birth\ season_k$ = fixed effect of birth season (January to June and July to December)

Table 10 Levels of significance for different environmental effects calculated with SAS GLM

Trait	n	Sex	Age group	Test year	Location	Birth year	Test type	Test Year season	Test season	Birth season
Underground Test										
Bolt the fox	8249	****	*	****	****	NS	*	**	NS	NS
Passion	6221	****	**	NS	****	**	****	****	NS	NS
Sound underground	6235	***	**	*	****	NS	NS	NS	NS	NS
Search	6222	****	**	NS	****	****	****	****	NS	NS
Field Test										
Nose aptitude	8450	****	**	****	****	**	NS	****	****	NS
Trail reliability	6287	****	*	****	****	***	NS	****	****	NS
Trail volition	6286	****	**	****	****	**	NS	****	***	NS
Sound on trail	8364	****	****	****	****	***	*	****	****	*
Sound at sight	278	NS	NS	NS	**	NS	NS	NS	NS	NS
Water affinity	8384	****	****	****	****	*	NS	****	****	****
Obedience	6287	****	NS	*	****	NS	NS	NS	NS	NS
Reaction to shot	6381	NS	NS	*	NS	NS	NS	NS	NS	NS
Conformation Traits										
Conformation	4949	****	NS	****	*	NS	NS	*	NS	NS
Fur score	4874	****	NS	NS	****	NS	NS	NS	NS	****
Height at withers	7935	****	****	**	****	***	NS	***	NS	****
Chest-circumference	7935	****	****	NS	****	****	NS	****	**	****

With * for $\alpha = 0.05$, $1 - \alpha = 95\%$: weak significance, ** for $\alpha = 0.01$, $1 - \alpha = 99\%$: significant, *** for $\alpha = 0.001$, $1 - \alpha = 99.9\%$: highly significant, **** for $\alpha = 0.0001$, $1 - \alpha = 99.99\%$: extremely significant, NS for insignificant

2.5.2 Analysis of genetic parameters

The AI-REML (average information-restricted maximum likelihood) algorithm within the software package DMU (Madsen & Jensen, 2013) was used to estimate the variance components for hunting ability and conformation traits.

3. Results

3.1. Descriptive Statistics

The characteristics of the data have been summarized in Table 11. The minimum and maximum scores represent the actual evaluated scores, because generally the scale ranges from “0 to 5”. The performance of most traits in the breeding tests is recorded to be relatively close to the optimal or maximum score. The traits with the lowest corrected means compared to the top score are Sound on trail (-1.57 points) and aptitude for Nose work (- 1.44 points).

The standard deviation gives information about the distribution of the observations. The lower value of the SD is, the less variation among individuals can be found. In animal breeding a larger genetic variation is desired; so genetically a high SD is desirable, while statistically a low SD is favored because it increases the representativity. Due to a low frequency of dogs which performed in this test discipline, the highest SD in Table 11 has been calculated for Sound at sight, while Reaction to shot (Gun shyness) has the lowest SD. Moreover Table 11 shows the actually assessed lowest and highest score and the possible range of scores. For all traits except for Bolting the fox (maximum = “4.5”) the observed range was five scores.

Table 11 Number of tested individuals per test discipline (n), means, standard deviation, minimum, maximum and observed range of scores/points

Trait	n	Mean	Std. Dev.	Minimum	Maximum	Obs. Range
Height at withers (in cm)	7935	36.69	1.97	29	44	
Chest circumference (in cm)	7935	47.85	2.85	34	84	
Conformation	4949	3.68	0.91	1	5	5
Fur score	4974	4.16	0.54	1	5	5
Bolting the fox	8249	3.81	0.45	1	4.5	4.5
Passion underground	6221	3.73	0.69	0	4	5
Sound underground	6222	3.74	0.65	0	4	5
Search demeanor underground	6235	3.87	0.52	0	4	5
Nose hunting aptitude	8450	3.56	0.73	0	5	5
Track reliability	6287	3.49	0.77	0	4	5
Track volition	6286	3.76	0.60	0	4	5
Sound on trail	8364	3.43	0.96	0	5	5
Sound at sight of game	278	3.36	1.14	0	4	5
Water affinity	8385	4.06	1.00	0	5	5
Obedience	6287	3.84	0.46	0	5	5
Reaction to shot	6318	3.99	0.15	0	4	5
Total points	9421	141.74	37.38	0	172	172
Price	9411	1.41	0.77	0	4	4

3.2. Phenotypic results

3.2.1 Sex

Differences between sexes have been calculated using SAS PROC GLM (*lsmeans* option) and are statistically significant for all traits except Reaction to shot. As it can be seen in Table 12 generally female dogs show less performance in the aptitude tests compared to males. The only exception is the score for Sound on trail which is + 0.07 points better for females; the largest difference between the sexes was recorded for Water affinity where males score 0.17 higher than bitches. Table 12 also shows the average mean of individuals for which the sex is known, because they are registered breeding animals. This makes comparisons for pre-selected breeding animals and pure hunting dogs – which are represented in the group of unknown sex – possible.

Table 12 Corrected means for the effect of sex calculated with GLM (and *lsmeans*)

Trait	Male	Female	Difference between sexes	Breeding animals	Unknown sex
Underground Test					
Bolt the fox	3.91	3.82	-0.09	3.87	3.77
Passion	3.80	3.70	-0.10	3.75	3.65
Sound underground	3.87	3.79	-0.08	3.83	3.72
Search	3.92	3.89	-0.03	3.91	3.83
Field Test					
Nose aptitude	3.75	3.72	-0.03	3.74	3.47
Trail reliability	3.62	3.57	-0.05	3.60	3.31
Trail volition	3.79	3.77	-0.02	3.78	3.61
Sound on trail	3.66	3.73	0.07	3.70	3.34
Sound at sight	3.62	3.60	-0.02	3.61	3.32
Water affinity	4.33	4.16	-0.17	4.25	3.98
Obedience	3.90	3.90	0.00	3.90	3.81
Reaction to shot	3.99	4.00	0.01	4.00	3.99
Conformation traits					
Conformation	4.01	3.96	-0.05	3.99	3.61
Fur score	4.30	4.23	-0.07	4.27	4.15
Height at withers	37.89	36.00	-1.89	36.95	37.12
Chest-circumference	49.60	47.09	-2.51	48.35	48.46

3.2.2. Age

In Table 13 it can be seen that for most traits there is not a clear trend, more a performance depression throughout the middle aged dogs. With a probability of 0.95 and 0.99 Age was significant for various traits as presented in Table 11. Exceptions are Sound on trail and Water affinity which show extremely high levels of significance and the conformation traits which are not significant.

Table 13 Means for the effect of Age calculated with GLM (and *lsmeans*)

	Age group (in months)							
Trait	6 - 12	12 -18	18 - 24	24 - 30	30 - 36	36 - 42	42 - 48	48 - 54
Underground Test								
Bolt the fox	3.86	3.82	3.8	3.84	3.81	3.8	3.87	3.86
Passion	3.76	3.74	3.68	3.69	3.61	3.69	3.75	3.8
Sound underground	3.83	3.77	3.77	3.72	3.74	3.77	3.88	3.89
Search	3.91	3.89	3.87	3.83	3.82	3.84	3.95	3.93
Field Test								
Nose work	3.71	3.68	3.66	3.62	3.68	3.54	3.56	3.72
Trail reliability	3.58	3.52	3.5	3.49	3.5	3.37	3.45	3.58
Trail volition	3.79	3.74	3.72	3.69	3.71	3.67	3.65	3.82
Sound on trail	3.68	3.61	3.55	3.49	3.59	3.55	3.49	3.65
Sound at sight	3.66	3.52	3.48	3.54	4	3.74	2.65	3.5
Water affinity	4.19	4.24	4.14	4.05	4.04	4.15	4.26	4.18
Obedience	3.88	3.88	3.89	3.89	3.85	3.9	3.78	3.88
Reaction to shot	4	4	3.99	3.99	3.98	4	4	4
Conformation Traits								
Conformation	3.86	3.88	3.89	3.87	3.91	3.82	3.97	3.66
Fur score	4.23	4.23	4.22	4.25	4.19	4.17	4.2	4.31
Height at withers	36.7	36.73	36.54	36.82	37.03	37.32	37.43	37.47
Chest-circumference	47.52	47.92	47.97	48.53	48.7	48.85	48.59	49

3.2.3. Test Type

The factor test type includes different disciplines; Test Type 1 includes all traits, Test Type 2 includes the traits which are components of the Underground Test (BT1) plus conformation traits and Test Type 3 involves Field Test (BT2) traits plus conformation traits. Table 14 shows the variance between the mean scores in the different tests, where higher performance for Underground Hunting in Test Type 2 can be seen.

Table 14 Means for the effect of Test type and Test season calculated with SAS GLM (and lsmeans)

Trait	Test type 1	Test type2	Test type 3
Underground Test			
Bolt the fox	3.81	4.01	[5]
Passion	3.57	4.07	
Sound underground	3.71	4.07	
Search	3.71	4.37	
Field Test		[6]	
Nose work	3.58		3.47
Trail reliability	3.31		3.1
Trail volition	3.58		3.46
Sound on trail	3.49		3.15
Sound at sight	NS[7]	NS	NS
Water affinity	4.1		4.09
Obedience	3.84		3.94
Reaction to shot	3.99		3.98
Conformation Traits			
Conformation	3.7	3.63	3.68
Fur score	4.16	3.92	3.89
Height at withers	36.61	36.98	37.1
Chest-circumference	47.74	47.77	48.33

3.3. Heritability of traits in GHT

The genetic variance components estimated in the DMU software, carried out with AI-REML analysis, were generally low for the performance traits. The lowest heritabilities presented in Table 15, were estimated for Reaction to shot (h^2=0.01) and Obedience (h^2=0.02). Search underground (h^2=0.12) and Water affinity (h^2=0.23) showed the highest values in this genetic analysis. As discussed in Chapter 4, the low heritability indicates that the tests are highly influenced by random environmental factors. The estimates for the conformation traits are much higher with 57% for Height at withers and 40% for Chest-circumference. Standard Errors varied between 0.01 and 0.34.

[5] Test Type 3 just contains performance information on field hunting skills and conformation, missing values have not been recorded

[6] Test Type 2 just contains performance inform on underground hunting skills and conformation, missing values have not been recorded

[7] For Sound at sight only not significant results were obtained

Table 15 Heritability estimates of hunting traits in GHT with location being regarded as a fixed factor, calculated with DMU

Trait	h^2	SE
Underground Test		
Bolt the fox	0.07	0.02
Passion	0.08	0.02
Sound underground	0.06	0.02
Search	0.12	0.02
Field Test		
Nose work	0.04	0.01
Trail reliability	0.06	0.02
Trail volition	0.05	0.02
Sound on trail	0.09	0.02
Sound at sight	0.73	0.34
Water affinity	0.23	0.02
Obedience	0.02	0.01
Reaction to shot	0.01	0.01
Conformation Traits		
Conformation	0.08	0.02
Fur score	0.19	0.03
Height at withers	0.57	0.03
Chest-circumference	0.40	0.03

Table 16 Variance estimates for hunting traits in GHTs with location being regarded as a random factor, calculated with DMU

Trait	h^2	$\sigma^2_{location}$	σ^2_a	σ^2_e
Underground Test				
Bolt the fox	0.05	0.01	0.01	0.18
Passion	0.08	0.01	0.04	0.43
Sound underground	0.07	0.01	0.02	0.24
Search	0.12	0.01	0.05	0.36
Field Test				
Nose work	0.04	0.02	0.02	0.48
Trail reliability	0.07	0.02	0.04	0.53
Trail volition	0.05	0.01	0.02	0.33
Sound on trail	0.10	0.01	0.09	0.80
Sound at sight	0.51	0.34	0.53	0.49
Water affinity	0.23	0.01	0.23	0.77
Obedience	0.04	0.00	0.01	0.20
Reaction to shot	0.00	0.00	0.00	0.02

4. Discussion

The data used for this study had weaknesses in several points, mostly from a statistical point of view. The comparison with publications on other dog breeds was problematic because these studies differ in choice of breed, type and system of competition, as well as in methods used to calculate heritability and other genetic parameters (Courreau et al. 2004).

4.1. Comparison with previous studies

Beuing (1993) also estimated heritabilities for GHTs, however, it is neither known which methods the author used for the analysis, nor if the results of his study have been scientifically proven. As a matter of fact, the comparison between the heritability estimates has to be handled with caution. Nevertheless, a comparison of the current project and Beuing (1993) has been done, because no other analysis of heritability estimates in any other Hunting Terrier breed has been found. A table with the full comparison is presented in the Annex (Table 17).

Generally, it appears that the estimated values by Beuing (1993) are higher. For Conformation the heritability of the present project shows a 0.04 lower estimate, for Fur score 0.06 lower, but the trait Chest-circumference seems to have less environmental influence today, with 0.06 higher heritability. In the present project the estimate for Height at withers was also higher compared to Beuing (1993) with + 0.02, whereas less genetic variance was found for the traits Nose work (– 0.1), Sound on trail (– 0.19) and Water affinity (– 0.08).

4.2. Quality of data

In the dataset used for this project, values of observations were not randomly distributed. Moreover the traits Reaction to shot and Obedience had to be disregarded because they were too heavily skewed to have informational value. Furthermore, e.g., the lack of testing repeatability and in general high SD values diminished the quality of the data (Hradecká et al. 2015). This issue of low representativity occurred because dogs are not repeating the tests after they passed it and secondly, because in the majority of cases different judges evaluate the dogs if the tests are repeated.

Obvious errors in the dataset were for instance cases in which the individual was recorded to be born before its sire or dam. In other cases impossible scores like a "7" on a scale from "0 to 5" were recorded. Apart from these obvious errors, in many cases not all results for a test round were recorded, if the individual was tested twice or more often. So for example if the dog was valued with a "2" in the first test and it received the same assessment in the following test, the score was often not written down for the second test. A blank was left, which afterwards made it impossible to know if this particular test discipline hasn't been tested again and therefore the score is missing, or if the score was not recorded. When looking at the total score it often becomes obvious that the score wasn't recorded again, because the score is included in the sum of the calculation. For the analysis it was impossible to use this knowledge though and consequently many observations are lost during the deletion of duplicate test rounds.

As a conclusion, improvement of the quality of data would be beneficial for statistical analyses. A suggestion would be that recording of data should be done more accurately. Integrity can by increased by training people who are involved in data collection and editing (judges and helpers), by writing down every score and also making sure to record the right score. The entry of results and editing of performance and pedigree data should be done carefully and checked for correctness to prevent mistakes. Further steps are for instance extension of the data for more clearly defined environmental factors (completeness and objectivity) and performance of repeated tests (reliability) to enhance the data quality.

4.3. Availability of data

The amount of individuals and recorded observations play an important role in order to make significant and reliable statements on the analysis. The size of a test population is for instance addressed by Liinamo et al. (2007). The authors suggested that scientific quantitative genetic research requires test populations of at least between 500 to 1 000 dogs. In the current dataset, this number is highly exceeded with between 4 949 and 9 421 dogs per trait. Even though GHTs have to be presented at breeding tests before they can take part in hunting on state forest grounds and in order to be used for breeding, not all dogs are presented in aptitude tests. So the number of dogs participating in the breeding tests could be increased.

Another point for availability is that it is conceivable that breed clubs prevent handing out all existing data on a breed. There is no proof for this allegation, anyway it is possible that data which could put a breed or officials of a breed club into unfavorable light could be kept secret. Nevertheless, such conduct would be unwise and will probably be penalized by further deepening depressions in breed performance.

4.4. Influence of natural environment

Results of the present analysis show high influence of environmental factors on the performance in hunting ability tests. In previous research by e.g. Liinamo (2004) and Liinamo et al. (1997) the influences of soil condition, snow cover and the random appearance of various game species in the test area was discussed. Also Karjalainen et al. (1996) mentions, that environmental influences like the weather and particularly wind and precipitation influence on the one hand the evaluation of the performance due to the sentiment of the judge, but also the performance itself. Wind and rain can accelerate fading of scent, which makes it harder for the dog to pursue a trail. Liinamo et al. (1997) also states that “standardization of environment during field trials is not realistic”. Because of the high influence of environmental factor the authors suggest to collect more detailed information on these factors and record them in the dataset. After these enhancements of the data there could be more accurate correction for environmental factors in the model. Future research would benefit in receiving more precise results for heritability estimates.

In the present data there was no information on this matter. At least some measures like for example weather, size of test group, and appearance of (disturbing) game in the testing area should be recorded in the future. Also type of soil, vegetation and cover would be interesting, but might be more elaborate.

4.5. Influence of evaluation systems

Karjalainen et al. (1996) and Wilsson & Sundgren (1997b) agree, that in their respective studies the evaluation systems of the ability tests were determined too subjectively and vague. The evaluation system for GHTs has been adjusted several times (Bierwirth & Merle, 2011; Schindl, 1995) and the test disciplines are defined in much detail. For the GHT aptitude tests a narrow scale was chosen. This type of scale, combined with detailed instructions on the evaluation of performance should facilitate the process of scoring and prevent misjudgment or different assessment within the team of judges (Deutscher Jagdterrier-Club eV., 2014; Deutscher Jagdterrier-Club eV., 2015; Bierwirth & Merle, 2011; Schindl, 1995 and Vocke, 1994). Narrow scales have also been chosen by Schmutz & Schmutz (1998) and Karjalainen et al. (1996) argues that redefining the scores from a wide to a narrow scale would be more efficient. On the other hand in other breeds like Finnish Hounds and Flatcoated Retrievers wide scales with even varying ranges are used (Liinamo et al. 1997; Lindberg et al. 2004). In tests for English Setters (Arvelius et al. 2012) and in the paper by Brenøe et al. (2002) partly a different system of scoring is used. The range of scores generally is between “1 and 6”, for some of the disciplines the optimal score was not the maximum score. For those traits an exaggeration of the performance is taken into account. This system is more complex and should prevent breeding for too extreme performance in those traits (Brenøe et al. (2002).

Irrespective of which scale was chosen for the hunting tests, the system of evaluation should recurrently be scrutinized and possible improvements of the evaluation system should be initiated in case new findings are generated. Additionally, assessing less complex instead more simple and clearly defined traits and involving objective measures to the system of evaluation would help to make the evaluation less ambiguous and subjective. Objective evaluation of traits could for instance include timespans during which a dog needs to trail, or bark, or it could be the estimated distance of a trail which has been search by a GHT. Bolting the fox does already include time spans during which the individual has to find the fox and a minimum time span during which the dog has to put pressure on the fox.

4.6. Influence of Judges

The dataset for the current project did not include information on judges. Therefore, no influence of judges could be estimated. According to several studies (e.g. Karjalainen et al. 1996; Liinamo et al. 1997; Brenøe et al. 2002; Arvelius & Klemetsdal, 2013) in some cases even well trained judges might give significantly different evaluations for the same performance, due to personal preferences. This could be one reason for lower heritability estimates (Arvelius et al. 2012; Liinamo et al. 1997; Karjalainen et al. 1996; Kreiner et al. 1992). Interference of the factor judge on the performance of dogs is consequently suggested. Strategies for inclusion of this factor into the model are presented by Brenøe et al. (2002) who suggested joint evaluation (e.g. cross-national cooperation, cross-breed judging) during the performance tests. Results in these two studies showed significant differences in scores. Also retaining a team of judges generally could improve objectivity (Wilsson & Sundgren, 1997b). Arvelius & Klemetsdal (2013) discussed substantial genetic gain in hunting traits of English Setters. They argue that the prevalence of higher scores either, but less likely occurs due to “true reflection of the dogs´ performance” – maybe under the effect of pre-selection as mentioned below –, or because the judges tend to give scores which are close to the desired performance, in other words adjust the scores upwards if the general performance is lower than expected.

Judges of “Deutscher Jagdterrier-Club eV.” have to fulfill a list of criteria before they can apply as candidates and subsequently receive a comprehensive education. They have to take a practical and theoretical examination and have to train, hunt and take tests with a GHT themselves (Deutscher Jagdterrier-Club eV., 2015). These measures should lower the risk of subjectivity in the evaluation of dogs. Nevertheless it is difficult to evaluate the hunting performance objectively (Liinamo, 1997) as similar measures, which were carried out in above mentioned studies show.

4.7. Influence of Sex

The effect of sex has been proven several times in recent studies for other dog breeds. In Table 12 it is clearly visible from the corrected mean scores, that also GHTs perform significantly different according to their sex. Results from that Table 12 show that generally male dogs seem to perform better in the aptitude tests. A problem with the dataset for the analysis was that sex was not recorded. It was possible to find out about the sex, at least for a small amount of dogs which in the past have been used for breeding. This information was however not used for the analysis. If this information would have been used as a factor in the model, it would have included a preselection process for breeding animals. Furthermore, the class sizes were significantly unbalanced which would have led to an underestimation of genetic factors.

For all traits the breeding animals seem to have higher average scores, superior over the large group of pure hunting dogs. The higher means could indicate a positive response to breeding measures, like success of selection of breeding animals in GHT, or genetic development as a result of breeding programs.

In previous research by e.g. Van der Waaij et al. (2008) sex had been recorded for all individuals. They found significant effects of sex specific behavior and performance in Labrador Retrievers and German Shepherds. Arvelius & Klemetsdal (2013), Liinamo, et al. (2007) and Karjalainen et al. (1996) also estimated and discussed the influence of sex, which varied from study to study and breed to breed. Hence, recording of sex is recommended also for GHTs with regards to further genetic improvement of the breed and enhanced scientific investigations on hunting performance traits.

4.8. Influence of training and experience

One more aspect which has just marginally been investigated in this project is the impact of training and experience level when the dogs enter the aptitude test. In the current analysis these effects were indicated by investigation of performance in different age groups. Previous publications (e.g. Liinamo et al. 1997; Karjalainen et al. 1996) also related the effect of age to training and experience, yet the level of training and experience in this project can only be presumed from the effect of age. However, proof for the assumption regarding these effects could easily have been provided by insertion of handler provided information or logbooks for training. In a study carried out by Arvelius et al. (2012) on behavior in English Setters and for Flatcoated Retrievers in Lindberg et al. (2004) scores for experience traits which were given by the handler and considered to be “valuable information” in order to adjust the test performance for influence of training and practical experience.

The possibility that older dogs did receive more training and have experience from practical hunting is the reason for scheduling aptitude test for GHTs at young age. Also Lindberg et al. (2004) mention that taking the tests at an earlier age or altering the test design would minimize the effect of training and experience. In other hunting dog breeds, similar approaches have been followed and more sophisticated tests follow at higher age (Schmutz & Schmutz, 1998).

In working dogs, training and experience is not regarded as negative for the validity of ability in performance traits. Training is even encouraged for less self-confident dogs or in order to succeed with the tests (Arvelius et al. 2014; Van der Waaij et al. 2008; Courreau et al. 2005).

Table 13 shows the corrected means of the eight age groups and it is noticeable that the overall difference between younger and older GHTs is negligible. Nevertheless a clear performance depression during middle ages (two to three and a half years) is visible. In most previous studies (e.g. Arvelius et al. 2014; Liinamo et al. 1997; Karjalainen et al. 1996) the effect of training is mentioned to be beneficial. Wilsson & Sundgren (1997b) on the contrary discuss a negligible effect of age on the performance. For hunting ability tests the dogs like the GHT preferably have little experience from training or practical hunting (Bierwirth & Merle, 2011; Schmutz & Schmutz 1998). A suggestion would be to include information on training and experience in the performance data. This information could involve number of training days in trainings dens or trails which have been worked on. For experience the number of hunts in the field or forest could be recorded, or number of bolted foxes. This knowledge could be used to improve the accuracy of the heritability estimates in further research by correction for this effect.

4.9. Impact of test location

The effect of test location was proven (displayed in Table 10) to significantly influence all performance traits. In GHTs test location is the only information regarding natural and geographical influences. It is therefore suspected that test location implies further factors like local geography, judge, weather, size of testing group and overrepresentation of certain pedigrees in one area. Consequently test location was used as a fixed as well as a random factor in the model of the present analysis. The same was done for the effect of veterinarian in a Master project (Zanders, 2014) on patella luxation. The effect of using it as a fixed or random factor was negligible though.

Test location did not have significant effects on the conformation traits, which is regarded to be reasonable because no logical or biological reason could be found why location would influence the conformation.

4.10. Further influences on hunting performance

One aspect for hunting performance is the handler. Cooperation of dog and handler, experience, attitude and authority of the handler are factors which influence not only the performance in ability tests, also in practical hunting. These factors can influence positively and negatively and can include more aspects which are impossible to know. Handlers experience has also been included in the analysis of Schmutz & Schmutz (1998). Handlers were classified according to the amount of dogs which they had presented (first -, third -, tenth time handlers) in ability tests before. They did not receive significant results, though a slightly positive trend. It would be recommended to include handlers experience in GHT performance data. The most simple options would be to classify handlers according to the amount of presented dogs like Schmutz & Schmutz (1998) did.

Natural environmental effects are hidden in the effects of test year and season. Test year possibly incorporates the effect of weather not only on the day of the ability test, but during the last months before the test. As weather can have an influence on the development and health, training or personality of a dog.

The season of testing was assumed to have an influence on some traits like Water affinity. In springtime the water temperature is expected to be lower, which is a reason to diminish the affinity for water. Furthermore, Test season also includes the influence of weather prior to and at the test, particularly temperature and rainfall have to be named. As shown in Table 11, in the analysis test season was found to be relevant for the traits Water affinity, Search underground, the field work traits Nose work, Trail reliability, Trail volition and also Sound on trail. Test season also shows statistical significance for the Conformation, Height of withers and Chest-circumference. Anyway, biologically an influence of test season is questionable for the condition of fur, conformation and size of dogs. Van der Waaij et al. (2008) investigated the effect of season of testing and claims that the reasons for differences in performance could be the hours of daylight and the hormone-cycle of the dog.

Moreover, Van der Waaij et al. (2008) discussed the factor Birth season, arguing that it had an significant effect on Cooperation, Prey drive, and temperament of German Shepherds and for Cooperation, Courage and Defense drive of Labrador Retrievers in their investigation. Many dog owners and breeders seem to prefer to buy puppies which are born in spring. Suggesting that imprinting and basic dog training (obedience training) is more successfully carried out during and before summer. Anyhow, results from this study show that there is no significant variation in performance of dogs according to the different birth months or seasons.

5. Conclusion

Breeding tests for GHTs are comparable to other breeding or ability tests for dogs of different breeds. The results from the current analysis, but also previous research, suggest that hunting ability is just to a limited extent heritable. The inverse conclusion confirms strong influence of environmental factors. The dataset used for this project did not contain much information on the environment, which led to high values of residual variance and low heritability estimates.

Some measures for accurate testing of performance have early been taken in account or were introduced over time (Deutscher Jagdterrier-Club eV., 2014), like perennial education and consistent schooling of judges, advancement of testing standard and regulations, implementation of breeding values with BLUP, breeding plans for health traits and genetic defects. For these various efforts of having a good standard in the testing scheme the breed club should be given credit for, but no lasting comfort should be taken from that. More objective, accurately defined factors should be included in the evaluation of hunting aptitude. Inclusion of measures for distances, time spans and intervals on which the evaluation can be based, recording of environmental factors like the weather and cover of soil (e.g. type of vegetation or snow) would improve the objectivity. Moreover, adding information on the level of experience of handlers and dogs, group sizes, judges and sexes would be beneficial for the breed club, the statistical data processing center and subsequently the breeders and dog owners. With these enhancements it would be possible to adjust more precisely for environmental factors in the model and thereby improve the accuracy and reliability of the variance components. This would be highly valuable for further analysis on performance in hunting ability tests and in order to make significant comments on the performance of GHTs. So development of the breeding test could not only increase heritability estimates, it would have an effect for prediction of breeding values and enable a faster genetic gain.

On basis of the underlying data it is not possible to give meaningful advice for breeding purposes. From the low heritabilities it can only be concluded, that genetic improvement of hunting performance traits is a tedious, yet possible process. Increasing the heritabilities and realizing significant genetic gain would require more accurate performance tests in the future. Subsequent analyses require further development of test and evaluation regulations, but with the suggested improvements it will be possible to draw better conclusions on the current status of performance in GHT.

6. Acknowledgements

During my studies and especially while doing my Master project, I had many people with me, who constantly encouraged and supported me, in order to succeed with this educational experience. I am sincerely grateful to each and every one who was by my side during this time.

First I would like to thank my main supervisor Katja Nilsson, for letting me find my own way through the project, her endless patience in answering questions, guidance in learning and improving skills for SAS, DMU and scientific writing; also for sharing her knowledge and experiences with me. I furthermore thank my co-supervisor Gabor Meszaros for his opinion and guidance.

Special thanks also go to Per Madsen for his incredible help in getting started with DMU and giving further insight into his research and statistical programming.

I would also like to thank people from the Department of Animal Breeding and Genetics and SLU in general for their kindness and readiness to help and answer my questions. Not failing to mention my fellow students from SLU and EMABG, furthermore friends in Uppsala who helped me with endless discussions and encouragement.

I am also very infinitely grateful for the chance to work with the data on German Hunting Terriers, provided by the TG-Verlag Beuing GmbH in Gießen. Especially Gabriele Schiller (Head Director of TG-Verlag Beuing GmbH) and Josef Andritzky (Breeding Director of Deutscher Jagdterrier-Club eV.) deserve words of thanks for letting me use the data and Heinz Tietz (Judge for GHT aptitude tests) and his fellow judges for letting me join and giving me insight into the breeding tests.

I would last but not least like to give invaluable thanks to my family and friends, who have given me unwavering support, unconditional love and great encouragement each day.

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7. Annex

7.1. Further Test-Types

7.1.1. GP Hunting Ability Test

This test is adapted to the age-based ability to hunt underground and trailing on fields or in the woods; it builds on the aptitude tests at young age. Test disciplines, which are designed to test if the dog is actually of valuable help in practical hunting are:

- Ability to work in dens and pulling out perished small predators
- Work on blood tracks while being leashed
- Retrieving hare or wild-fowl after trailing either in the forest or on field
- Search and retrieve lost game birds
- Flushing
- Flushing and retrieving in the water
- Nose work
- And obedience, which includes the evaluation of behavior while being leashed, down with shooting, general obedience

Most of the test disciplines are very demanding which is why the execution of the disciplines has to be spread over two test days. The only prerequisite for the ability test is the positive participation of at least one aptitude test.

7.1.2. Key Hunting Performance proof

During hunting or in training dogs can be rewarded with a proof of key hunting performance. To receive the proof supervision of at least one certified judge or experienced hunters, who confirm the performance is required. At least one proof of key hunting performance is required from the age of 4 years to keep the dog as a breeding dog. Proofs can be rewarded for wild boar hunting, underground hunting and tracking.

7.2. Description for different character terms

In this project the term character is defined as the full spectrum of behavior which is typical for an individual. It is an acquired and very inconsistent trait as it is highly influenced by experience, education and social interaction. It is not built from instinct which is congenital but from volition to react to a situation.

Temperament is also defined as a behavioral trait, though it is congenital and less influenceable compared to the character. Anyhow it can vary especially due to social interaction and changes of the environment.

The expression of our character, temperament and intelligence is defined as personality. Individuals do not express every characteristic in every situation or environment. Personality is also an inconsistent trait. Hence by reacting to a situation, the combination of character, temperament and intelligence determines the personality.

Nature is the term for the full spectrum of congenital characteristics. It is a consistent trait which is not affected by environmental influences.

The term heat in this project does not stand for estrous; it means a group of dogs which are flushing on command in a certain area.

7.3. List of heritability estimates from used literature

Table 17 List of heritability estimates from used literature

Trait	Breed	h^2	Reference
Ability to work	Short-Haired Pointer	0.25	Brenøe et al. (2002)
Ability to work	Short-Haired Pointer	0.2	Vangen (1990)
Ability to work	Wire-Haired Pointer	0.18	Brenøe et al. (2002)
Ability to work	Wire-Haired Pointer	0.23	Vangen (1990)
Ability to work	Brittany Spaniel	0.2	Brenøe et al. (2002)
Ability to work	English Setter	0.18	Vangen & Klemetsdal (1988)
Affability	German Shepherd	0.06	Arvelius et al. (2014)
Affability	German Shepherd	0.38	Van der Waaij et al. (2008)
Affability	German Shepherd	0.37	Wilsson & Sundgren (1997b)
Bird-finder index	Short-Haired Pointer	0.04	Brenøe et al. (2002)
Bird-finder index	Wire-Haired Pointer	0.05	Brenøe et al. (2002)
Bird-finder index	Brittany Spaniel	0	Brenøe et al. (2002)
Bird-finding	Finnish Spitz	0.11	Vangen & Klemetsdal (1988)
Chest-circumference	German Hunting Terrier	0.34	Beuing (1993)
Conformation	German Hunting Terrier	0.12	Beuing (1993)
Cooperation	Short-Haired Pointer	0.21	Brenøe et al. (2002)
Cooperation	Short-Haired Pointer	0.22	Schmutz & Schmutz (1998)
Cooperation	Short-Haired Pointer	0.15	Vangen (1990)
Cooperation	Wire-Haired Pointer	0.1	Brenøe et al. (2002)
Cooperation	Wire-Haired Pointer	0.34	Schmutz & Schmutz (1998)
Cooperation	Wire-Haired Pointer	0.14	Vangen (1990)
Cooperation	Brittany Spaniel	0.09	Brenøe et al. (2002)
Cooperation	Griffon	0.06	Schmutz & Schmutz (1998)
Cooperation	Large Munsterlander	0.25	Schmutz & Schmutz (1998)
Cooperation	Pudelpointer	0.09	Schmutz & Schmutz (1998)
Cooperation	English Setter	0.09	Vangen & Klemetsdal (1988)
Cooperation	English Setter	0.07	Arvelius & Klemetsdal (SWE national, 2013)
Cooperation	English Setter	0.08	Arvelius & Klemetsdal (SWE joint, 2013)
Cooperation	English Setter	0.07	Arvelius & Klemetsdal (NOR national, 2013)
Cooperation	English Setter	0.07	Arvelius & Klemetsdal (NOR joint, 2013)
Cooperation	Flatcoated Retriever	0.12	Lindberg et al. (2004)
Cooperation	Flatcoated Retriever	0.25	Van der Waaij et al. (2008)
Cooperation	Labrador Retriever	0.35	Wilsson & Sundgren (1997b)
Cooperation	German Shepherd	0.12	Arvelius et al. (2014)
Cooperation	German Shepherd	0.17	Van der Waaij et al. (2008)

Cooperation	German Shepherd	0.28	Wilsson & Sundgren (1997b)
Cooperation	Border Collie	0.04	Arvelius et al. (2013)
Courage	Flatcoated Retriever	0.13	Van der Waaij et al. (2008)
Courage	Labrador Retriever	0.28	Wilsson& Sundgren (1997b)
Courage	German Shepherd	0.18	Arvelius et al. (2014)
Courage	German Shepherd	0.19	Van der Waaij et al. (2008)
Courage	German Shepherd	0.26	Wilsson & Sundgren (1997b)
Courage	Border Collie	0.11	Arvelius et al. (2013)
Defense drive	German Shepherd	0.14	Van der Waaij et al. (2008)
Defense drive	German Shepherd	0.1	Ruefenacht et al. (2002)
Defense drive	German Shepherd	0.2	Wilsson & Sundgren (1997b)
Delivery	Flatcoated Retriever	0.15	Lindberg et al. (2004)
Excitement	Flatcoated Retriever	0.49	Lindberg et al. (2004)
Fault Score	Finnish Hound	0.2	Liinamo et al. (1997)
Frequency of barking	Finnish Hound	0.15	Liinamo et al. (1997)
Frequency of barking	Finnish Spitz	0.15-0.17	Karjalainen et al. (1996)
Fur Score	German Hunting Terrier	0.25	Beuing (1993)
General impression	Finnish Hound	0.09	Liinamo et al. (1997)
General impression	Finnish Spitz	0.06-0.07	Karjalainen et al. (1996)
Ghost trailing score	Finnish Hound	0.12	Liinamo et al. (1997)
Ghost trailing score	Finnish Hound	0.15	Liinamo (2004)
Grip	Border Collie	0.13	Arvelius et al. (2013)
Grip	Flatcoated Retriever	0.19	Lindberg et al. (2004)
Grip/Holding birds	Finnish Spitz	0.18	Vangen & Klemetsdal (1988)
Gun-Shy	German Shepherd	0.22	Van der Waaij et al. (2008)
Gun-Shy	German Shepherd	0.23	Ruefenacht et al. (2002)
Hardness	Flatcoated Retriever	0.16	Van der Waaij et al. (2008)
Hardness	Labrador Retriever	0.2	Wilsson& Sundgren (1997b)
Hardness	German Shepherd	0.09	Arvelius et al. (2014)
Hardness	German Shepherd	0.14	Van der Waaij et al. (2008)
Hardness	German Shepherd	0.14	Ruefenacht et al. (2002)
Hardness	German Shepherd	0.15	Wilsson & Sundgren (1997b)
Hardness	German Hunting Terrier	0.19	Beuing (1993)
Height at withers	German Hunting Terrier	0.55	Beuing (1993)
Hunting eagerness/desire	German Shepherd	0.19	Arvelius et al. (2014)
Hunting eagerness/desire	Short-Haired Pointer	0.28	Brenøe et al. (2002)
Hunting eagerness/desire	Short-Haired Pointer	0.31	Schmutz & Schmutz (1998)
Hunting eagerness/desire	Short-Haired Pointer	0.24	Vangen (1990)
Hunting eagerness/desire	Wire-Haired Pointer	0.17	Brenøe et al. (2002)
Hunting eagerness/desire	Wire-Haired Pointer	0.14	Schmutz & Schmutz (1998)
Hunting eagerness/desire	Wire-Haired Pointer	0.28	Vangen (1990)
Hunting eagerness/desire	Brittany Spaniel	0.19	Brenøe et al. (2002)
Hunting eagerness/desire	Griffon	0.21	Schmutz & Schmutz (1998)
Hunting eagerness/desire	Large Munsterlander	0.22	Schmutz & Schmutz (1998)
Hunting eagerness/desire	Pudelpointer	0.05	Schmutz & Schmutz (1998)

Hunting eagerness/desire	English Setter	0.22	Vangen & Klemetsdal (1988)
Hunting eagerness/desire	English Setter	0.12	Arvelius & Klemetsdal (SWE national, 2013)
Hunting eagerness/desire	English Setter	0.11	Arvelius & Klemetsdal (SWE joint, 2013)
Hunting eagerness/desire	English Setter	0.18	Arvelius & Klemetsdal (NOR national, 2013)
Hunting eagerness/desire	English Setter	0.18	Arvelius & Klemetsdal (NOR joint, 2013)
Independence	Short-Haired Pointer	0.14	Brenøe et al. (2002)
Independence	Short-Haired Pointer	0.17	Vangen (1990)
Independence	Wire-Haired Pointer	0.21	Brenøe et al. (2002)
Independence	Brittany Spaniel	0.06	Brenøe et al. (2002)
Independence	Flatcoated Retriever	0.16	Lindberg et al. 2003
Interest in search	Flatcoated Retriever	0.26	Lindberg et al. (2004)
Interest in water retrieving	Flatcoated Retriever	0.23	Lindberg et al. (2004)
Marking	Finnish Spitz	0.04	Vangen & Klemetsdal (1988)
Marking	Flatcoated Retriever	0.13	Lindberg et al. (2004)
Merit score	Finnish Hound	0.11	Liinamo et al. (1997)
Merit score	Finnish Spitz	0.05-0.06	Karjalainen et al. (1996)
Nerve stability	Flatcoated Retriever	0.15	Van der Waaij et al. (2008)
Nerve stability	Labrador Retriever	0.17	Wilsson & Sundgren (1997b)
Nerve stability	German Shepherd	0.16	Arvelius et al. (2014)
Nerve stability	German Shepherd	0.16	Van der Waaij et al. (2008)
Nerve stability	German Shepherd	0.18	Ruefenacht et al. (2002)
Nerve stability	German Shepherd	0.25	Wilsson & Sundgren (1997b)
Nose	Short-Haired Pointer	0.35	Schmutz & Schmutz (1998)
Nose	Wire-Haired Pointer	0.32	Schmutz & Schmutz (1998)
Nose	Griffon	0.33	Schmutz & Schmutz (1998)
Nose	Large Munsterlander	0.19	Schmutz & Schmutz (1998)
Nose	Pudelpointer	0.19	Schmutz & Schmutz (1998)
Nose	German Hunting Terrier	0.14	Beuing (1993)
Persuit score	Finnish Hound	0.13	Liinamo et al. (1997)
Persuit score	Finnish Hound	0.11	Liinamo (2004)
Persuit score	Finnish Spitz	0.07-0.08	Karjalainen et al. (1996)
Persuit score	Finnish Spitz	0.1	Vangen & Klemetsdal (1988)
Pointing	Wire-Haired Pointer	0.13	Schmutz & Schmutz (1998)
Pointing	Griffon	0.13	Schmutz & Schmutz (1998)
Pointing	Large Munsterlander	0.31	Schmutz & Schmutz (1998)
Pointing	Pudelpointer	0.1	Schmutz & Schmutz (1998)
Pointing	Short-Haired Pointer	0.25	Schmutz & Schmutz (1998)
Prey drive	Flatcoated Retriever	0.32	Van der Waaij et al. (2008)
Prey drive	Labrador Retriever	0.05	Wilsson & Sundgren (1997b)
Prey drive	German Shepherd	0.21	Arvelius et al. (2014)
Prey drive	German Shepherd	0.23	Van der Waaij et al. (2008)
Prey drive	German Shepherd	0.31	Wilsson & Sundgren (1997b)
Reaction to shot	Flatcoated Retriever	0.37	Lindberg et al. (2004)
Reaction to shot	Flatcoated Retriever	0.56	Van der Waaij et al. (2008)
Reaction when throwing game	Flatcoated Retriever	0.41	Lindberg et al. (2004)

Retrieving	Flatcoated Retriever	0.34	Lindberg et al. (2004)
Search score	Finnish Hound	0.05	Liinamo et al. (1997)
Search score	Finnish Hound	0.07	Liinamo (2004)
Search score	Finnish Spitz	0.14-0.15	Karjalainen et al. (1996)
Search score	Finnish Spitz	0.07	Vangen & Klemetsdal (1988)
Search/Quartering	Short-Haired Pointer	0.48	Schmutz & Schmutz (1998)
Search/Quartering	Wire-Haired Pointer	0.31	Schmutz & Schmutz (1998)
Search/Quartering	Griffon	0.18	Schmutz & Schmutz (1998)
Search/Quartering	Large Munsterlander	0.19	Schmutz & Schmutz (1998)
Search/Quartering	Pudelpointer	0.12	Schmutz & Schmutz (1998)
Search/Quartering	English Setter	0.08	Arvelius & Klemetsdal (SWE national, 2013)
Search/Quartering	English Setter	0.12	Arvelius & Klemetsdal (SWE joint, 2013)
Search/Quartering	English Setter	0.13	Arvelius & Klemetsdal (NOR national, 2013)
Search/Quartering	English Setter	0.14	Arvelius & Klemetsdal (NOR joint, 2013)
Seeking width	Short-Haired Pointer	0.25	Brenøe et al. (2002)
Seeking width	Wire-Haired Pointer	0.17	Brenøe et al. (2002)
Seeking width	Brittany Spaniel	0.21	Brenøe et al. (2002)
Seeking width	English Setter	0.06	Arvelius & Klemetsdal (SWE national, 2013)
Seeking width	English Setter	0.11	Arvelius & Klemetsdal (SWE joint, 2013)
Seeking width	English Setter	0.16	Arvelius & Klemetsdal (NOR national, 2013)
Seeking width	English Setter	0.16	Arvelius & Klemetsdal (NOR joint, 2013)
Self-confidence	German Shepherd	0.18	Ruefenacht et al. (2002)
Sharpness	Flatcoated Retriever	0.13	Van der Waaij et al. (2008)
Sharpness	Labrador Retriever	0.11	Wilsson & Sundgren (1997b)
Sharpness	German Shepherd	0.11	Arvelius et al. (2014)
Sharpness	German Shepherd	0.19	Van der Waaij et al. (2008)
Sharpness	German Shepherd	0.09	Ruefenacht et al. (2002)
Sharpness	German Shepherd	0.13	Wilsson & Sundgren (1997b)
Speed	Short-Haired Pointer	0.26	Brenøe et al. (2002)
Speed	Short-Haired Pointer	0.17	Vangen (1990)
Speed	Wire-Haired Pointer	0.18	Brenøe et al. (2002)
Speed	Wire-Haired Pointer	0.35	Vangen (1990)
Speed	Brittany Spaniel	0.23	Brenøe et al. (2002)
Speed	English Setter	0.18	Vangen & Klemetsdal (1988)
Speed	English Setter	0.11	Arvelius & Klemetsdal (SWE national, 2013)
Speed	English Setter	0.11	Arvelius & Klemetsdal (SWE joint, 2013)
Speed	English Setter	0.17	Arvelius & Klemetsdal (NOR national, 2013)
Speed	English Setter	0.17	Arvelius & Klemetsdal (NOR joint, 2013)
Style	Short-Haired Pointer	0.27	Brenøe et al. (2002)
Style	Wire-Haired Pointer	0.16	Brenøe et al. (2002)
Style	Brittany Spaniel	0.2	Brenøe et al. (2002)
Style	English Setter	0.18	Vangen & Klemetsdal (1988)
Style	English Setter	0.13	Arvelius & Klemetsdal (SWE national, 2013)
Style	English Setter	0.13	Arvelius & Klemetsdal (SWE joint, 2013)
Style	English Setter	0.15	Arvelius & Klemetsdal (NOR national, 2013)

Style	English Setter	0.15	Arvelius & Klemetsdal (NOR joint, 2013)
Temperament	Flatcoated Retriever	0.18	Van der Waaij et al. (2008)
Temperament	Labrador Retriever	0.1	Wilsson & Sundgren (1997b)
Temperament	German Shepherd	0.18	Van der Waaij et al. (2008)
Temperament	German Shepherd	0.17	Ruefenacht et al. (2002)
Temperament	German Shepherd	0.15	Wilsson & Sundgren (1997b)
Tongue	Finnish Hound	0.13	Liinamo et al. (1997)
Tongue	Finnish Hound	0.16	Liinamo (2004)
Tongue	Finnish Spitz	0.07-0.08	Karjalainen et al. (1996)
Tongue	Finnish Spitz	0.02	Vangen & Klemetsdal (1988)
Total score	Finnish Spitz	0.04-0.06	Karjalainen et al. (1996)
Total score	Finnish Spitz	0.11	Vangen & Klemetsdal (1988)
Tracking	Short-Haired Pointer	0.48	Schmutz & Schmutz (1998)
Tracking	Wire-Haired Pointer	0.14	Schmutz & Schmutz (1998)
Tracking	Griffon	0.13	Schmutz & Schmutz (1998)
Tracking	Large Munsterlander	0.8	Schmutz & Schmutz (1998)
Tracking	Pudelpointer	0.17	Schmutz & Schmutz (1998)
Voice on trail	German Hunting Terrier	0.28	Beuing (1993)
Waiting passively in a group	Flatcoated Retriever	0.74	Lindberg et al. (2004)
Water affinity	German Hunting Terrier	0.31	Beuing (1993)
Waterwork/Retrieving	Short-Haired Pointer	0.13	Schmutz & Schmutz (1998)
Waterwork/Retrieving	Wire-Haired Pointer	0.32	Schmutz & Schmutz (1998)
Waterwork/Retrieving	Griffon	0.3	Schmutz & Schmutz (1998)
Waterwork/Retrieving	Large Munsterlander	0.24	Schmutz & Schmutz (1998)
Waterwork/Retrieving	Pudelpointer	0.31	Schmutz & Schmutz (1998)
Waterwork/Retrieving	Flatcoated Retriever	0.28	Lindberg et al. (2004)
Will to drive	Border Collie	0.06	Arvelius et al. (2013)
Work ethic	Border Collie	0.14	Arvelius et al. (2013)

7.4. Heritability of hunting traits in GHT

Table 18 Comparison of heritability estimates from GHT breeding tests

Trait	Current Project	Beuing (1993)	Difference
Conformation	0.08	0.12	-0.04
Fur score	0.19	0.25	-0.06
Chest-circumference	0.40	0.34	0.06
Height at withers	0.57	0.55	0.02
Nose	0.04	0.14	-0.10
Voice on trail	0.09	0.28	-0.19
Hardness		0.19	-0.19
Water affinity	0.23	0.31	-0.08

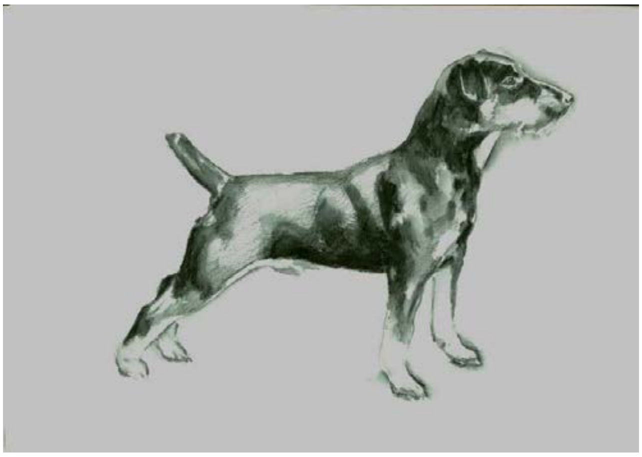
7.5. Breed Standard of GHTs

FEDERATION CYNOLOGIQUE INTERNATIONALE (AISBL)
SECRETARIAT GENERAL: 13, Place Albert 1er B – 6530 Thuin (Belgique)

26.05.2015/ EN

FCI-Standard N° 103

GERMAN HUNTING TERRIER
(Deutscher Jagdterrier)



TRANSLATION: Johan Gallant / Walter Schicker. Official language : DE.

ORIGIN: Germany.

DATE OF PUBLICATION OF THE OFFICIAL VALID STANDARD: 19.03.2015.

UTILIZATION: Versatile hunting dog, suited in particular for the hunt under the ground and as a flushing dog.

FCI CLASSIFICATION: Group 3 Terriers. Section 1
Large and medium sized Terriers. With working trial.

BRIEF HISTORICAL SUMMARY: After the first World War a group of active hunters separated from the numerically strong Fox-Terrier Club. It was their aim to create a breed, the sole purpose of which would be hunting performance. The experienced hunters and cynologists Rudolf Frieß, Walter Zangenberg and Carl-Erich Grünewald decided to select a black and tan hunting dog in particular suitable for the hunt under the ground. A coincidence came in support of their efforts. A zoo director, Lutz Heck / Hagenberg presented Walter Zangenberg with four black and tan terriers which were said to come from pure-bred Fox-Terrier lines. These dogs became the foundation stock of the German Hunting Terrier. At the time Dr. Herbert Lackner joined the founders. After many years of intensive breeding efforts, and through skillful crossings with the Old English Wirehaired Terrier as well as with the Welsh Terrier, they succeeded to fix the appearance of their breed. At the same time they put great emphasis on breeding a multitalented, well trainable, hard, tongue-giving and water-happy dog with an explicit hunting instinct. The German Hunting Terrier Club (Deutscher Jagdterrier-Club e.V.) was founded in 1926. As ever, the breeders continued to value most carefully their breed for its usefulness as a hunting dog, its steadiness of character, its courage and drive.

GENERAL APPEARANCE: A smallish, generally black and tan, compact, well proportioned working hunting dog.

IMPORTANT PROPORTIONS: Proportion of chest circumference to height at the withers: The circumference of the chest is 10 to 12 cm more than the height at the withers. Body length to height at the withers: The body is insignificantly longer than the height at the withers. Depth of chest to height at the withers, circa 55
– 60 % of the height at the withers.

BEHAVIOUR / TEMPERAMENT: Courageous and hard, takes pleasure in work, enduring, vital, full of temperament, reliable, sociable and trainable, neither shy nor aggressive.

HEAD

CRANIAL REGION: Elongated, slightly wedge-shaped, not pointed. The muzzle is slightly shorter than the skull, from occiput to stop. Skull: The skull is flat, broad between the ears, narrower between the eyes.
Stop: Slightly marked.

FACIAL REGION :
Nose: In harmony with the muzzle, neither too narrow nor too small, not cleft. **Always** black, but when the colour of the coat is dominantly brown, a brown nose is also permitted.
Muzzle: Strong, **pronounced jaw-muscles and** distinct **lower** jaw, strongly pronounced chin.
Cheeks: Well pronounced.
Lips: Tight and well pigmented.
Jaws/Teeth: Big teeth. Strong jaws with a perfect, regular and complete scissor bite, whereby the row of upper incisors, without gap, perfectly locks over the lower incisors, and with the teeth standing vertically to the jaws. 42 teeth in accordance with the teeth formula
Eyes: Dark, small, oval, **deep**; the eyelids are tight. Resolute expression.

Ears: Set high, not explicitly small, V-shaped; slightly touching semi-drop ears.

NECK: Strong, not too long, well put on and blending strongly into the shoulders.

BODY:
Topline: Straight. Withers: Well defined.
Back: Strong, straight, not too short.
Loin: Well muscled.
Croup: Well muscled and flat.
Chest: Deep, ribs well sprung, not too broad, long breastbone with ribs well reaching backwards.
Underline: Elegantly curved backwards; short and firm flanks, belly slightly drawn up.

TAIL: Well set to the long croup (docked for circa 1/3). Is rather carried slightly raised than steeply erected, but should never incline over the back. (In countries where tail docking is prohibited by law, it can be left in its natural state. It should be carried horizontally or slightly sabre-formed.)

LIMBS

FOREQUARTERS:
General appearance: Seen from the front the forelegs are straight and parallel, viewed from the side they are placed well under the body.
The distance from the surface to the elbows is approximately equal to the distance from the elbows to the withers.
Shoulder: The shoulder-blade lies well oblique and backwards; it is long and strongly muscled. There is good angulation between shoulder-blade and upper arm.
Upper arm: As long as possible, well and dry muscled.
Elbow: Close to body, neither turned inward nor outward. Good angulation between upper arm and forearm.
Forearm: Dry, straight and upright with strong bones.
Carpus (wrist): Strong.
Metacarpus (Pastern): Slightly angulated to the ground, bones rather strong than fine.
Forefeet: Often broader than the hind feet, the **well closed** toes lying close to each other with sufficiently thick, hard, resistant and well pigmented pads. They are parallel, in stance as well as in movement neither turned inward nor outward.

HINDQUARTERS:
General appearance: Viewed from behind straight and parallel. Good angulation between upper thigh and lower thigh and also at the hocks. Strong bones.
Thigh: Long, broad and muscular.
Stifle (Knee): Strong with good angulation between upper- and lower thigh.
Lower thigh: Long, muscular and sinewy.
Hock joint: Strong and placed low.
Metatarsus (Rear pastern): Short and vertical.
Hind feet: Oval to round, the **well closed** toes, with sufficiently thick, hard, resistant and well pigmented pads. They are parallel, in stance and in movement neither turned inward nor outward.

GAIT / MOVEMENT: Ample ground covering, free, with good reach in the front and powerful drive from the rear. In front- and hindquarters parallel and straight; never stilted.

SKIN: Thick, tight, without folds.

COAT

Hair: Plain, dense; hard rough hair or coarse smooth hair.

Colour: The colour is black, dark-brown or greyish-black, with yellow-red clearly defined markings at the eyebrows, muzzle, chest, the legs and at the base of the tail. Light and dark mask is equally permitted; small white markings on chest and toes are tolerated.

SIZE AND WEIGHT:

Height at the withers: Males: 33 to 40 cm.
Females: 33 to 40 cm.
Weight:
Weight in males and females should be according to build, not too light nor too heavy.

FAULTS: Any departure from the foregoing points should be considered a fault and the seriousness with which the fault should be regarded should be in exact proportion to its degree and its effect upon the health and welfare of the dog **and its ability to perform its traditional work**.

SEVERE FAULTS:

Narrow skull, narrow and also pointed muzzle. Falling away under-jaw, narrow jaws.
Weak bite, any slight irregularity in the placing of the incisors. Light, too big or protruding eyes.
Erected, flying, too small, too low set or heavy ears. Steep forequarters.
Soft or roached back, too short back. Short breastbone.
Too narrow or too wide in front. Steep hindquarters, overbuilt.
Elbows clearly turned in or out.
Too narrow or too wide in forefeet; cow-hocked, bow-legged or narrow hocks in stance as well as in movement.
Stilted or tripping gait.
Splayed feet, cat feet, **hare feet**.
Tail inclining over the back, tail set too low or hanging.
Short, woolly, open or thin hair, bald at the belly or at the inner sides of the thighs.

DISQUALIFYING FAULTS: Aggressive or overly shy dogs.
Any dog clearly showing physical or behavioural abnormalities shall be disqualified.
Untypical dogs.
Over- and undershot bite, wry mouth, pincer and partial pincer bite, **cross-bite**, irregularly placed teeth **in the upper and/or lower row of teeth,** missing teeth except for M3.
Incorrect pigmentation.
Entropion and ectropion, eyes of different colour, blue or spotted eyes.
Any departure of the described coat colour. Over- and undersized.

N.B.:
Male animals should have two apparently normal testicles fully descended into the scrotum.
Only functionally and clinically healthy dogs, with breed typical conformation, should be used for breeding.

The latest amendments are in bold characters.