Designer Dogs: Improving the Quality of Mine Detection Dogs

Geneva International Centre for Humanitarian Demining
Centre International de Déminage Humanitaire - Genève

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The **Geneva International Centre for Humanitarian Demining** (GICHD) supports the efforts of the international community in reducing the impact of mines and unexploded ordnance. The Centre is active in research, provides operational assistance and supports the implementation of the Mine Ban Treaty.

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Contents

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Photo credits: p. 5 (machine, dog), pp. 12, 16, 32, 36 (figure 13), all H. Bach; p. 27 Asiatic wolf, Eyal Bartov / Oxford Scientific Films; p. 27 northern wolf, p. 43 figure 14 ©DK; all other photos by I. McLean.

Foreword

In many post-conflict societies, mined areas are a major obstacle preventing the return of refugees and the re-use of land for civilian purposes. Mines have an enormous negative social and economic impact. Despite significant investment in technology, humanitarian demining remains a slow, costly and labour-intensive process.

The use of dogs in humanitarian demining is one of the most promising avenues to help affected societies. Because of their remarkable ability to detect hidden objects using odour, dogs are being used increasingly in the search for landmines. Dogs can contribute substantively to efficient programmes in many ways: they can be used for area reduction, to find individual mines, or to assure quality control of minefields cleared by equipment.

Unlike a rescue dog, or a dog that is trained to detect drugs, the mine-detecting dog needs to be one hundred per cent reliable. This is why the training of a mine detection dog is an extremely difficult and time-consuming training problem. Any procedures that might improve the efficiency of the training process, of breed quality, or of the operational potential of individual dogs, have significant implications for operational costs and productivity.

But no purpose-bred detection dog currently exists. Procedures for selecting dogs appropriate to the task are poorly developed, and the opportunities presented by different breeds have not been widely explored.

Since 1998, the Geneva International Centre for Humanitarian Demining (GICHD) has been engaged in a broad-based, application-oriented programme designed to explore many aspects of the use of dogs for demining. The final aim of this work is to improve the efficiency, safety and cost-effectiveness of humanitarian demining.

Work has been conducted in close and permanent co-operation with field practitioners. Studies are being conducted by the research team in many different places, including Afghanistan, Angola, Bosnia and Herzegovina, and Cambodia. We are convinced that the present study will contribute to ongoing improvements in the use of dogs for demining through diversification in choice of breeds, further development of training procedures, and improved safety.

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Ambassador Martin Dahinden
Director
Geneva International Centre
for Humanitarian Demining

Executive summary

The use of dogs as a mine detection device is expanding rapidly. This work identifies and discusses the essential and optional characteristics of a mine detection dog (MDD). Each characteristic is defined and / or described, and its features detailed. An extensive review of the literature on dog behaviour and origins is provided, and is linked to the identified characteristics. Recommendations are made about alternative ways to design an MDD, and are linked to current practice. Implementation of a broadened perspective on the selection and training of MDDs raises a variety of issues, which are identified and discussed. It is clear that any such change will require an experimental approach. To date, however, there has been almost no investment in research on the development and understanding of MDDs as a mine detection device, and such investment is justifiable.

Identified essential characteristics of an MDD and its use are:

- The dog's nose is always to the ground;
- Intensity of focus is high — the dog is concentrating on the sensory input to its nose and may even be snuffling or huffing in order to improve the flow of air through its nose;
- The actions are highly repetitive (usually involving walking a carefully prescribed narrow path);
- Reliability — the dog exhibits a series of carefully contrived actions (including staying on command) with 100 per cent reliability;
- The work is physically demanding;
- The dog is moving slowly;
- The dog wants to work — it is enthusiastic about the job.

Characteristics for which alternative perspectives are discussed include:

- Trainability;
- Presentation — overall appearance, human cultural and social issues;
- Size and shape — endurance, health issues;

- Cognition — intelligence;
- Handler issues.

The possibility of breeding for an MDD is discussed in relation to genetic and behavioural issues. Despite the widespread use of dogs in a detection role in modern times, there has been no breeding for a “designer detection dog”. Rather, the dogs commonly used for detection purposes were bred for other uses, either as general purpose working or hunting dogs, or specifically as scent hounds. The advantages and disadvantages of each of these general types of dog are discussed in relation to their potential for use in a mine detection role. A contradiction is identified: most analyses in the literature indicate that heritability of behavioural characteristics is low, yet stabilisation of behavioural characteristics has been achieved in many breeds using artificial selection procedures. Thus, selection for the behavioural characteristics sought in an MDD may be possible, but must be viewed as a long-term objective.

An alternative to breeding is to develop procedures for selecting young dogs suitable as MDDs, using behavioural predictors. The literature is clear on this point: the behaviour of young dogs gives only low to moderate predictability of behavioural outcomes of those individuals as adults. Thus, attempts to select good MDDs by testing young dogs will remain an inefficient process (although it is certainly used).

A review of the views of practitioners resulted in diverse views being expressed, but most agreed that breeds other than the standard shepherds should be trialled. Some indicated a view that other breeds were likely to be better than the standard shepherds, although that view was not based on experience.

The analysis identifies four alternative theoretical constructs as approaches to designing an MDD, and asks if breeds already in existence exhibit most or all of the characteristics identified in those constructs, or packages. One package is clearly the breeds already used: a general purpose working dog with high trainability for a wide variety of tasks (German shepherds and Malinois). The second package exploits available breed characteristics that minimise training issues and optimise a number of other features linked to the operational situation in which many MDDs work. This package is represented by a slow-moving scent hound, and a common breed in Sweden (the drever) is identified as potentially the best available example. The third example is termed “the cognitive dog”, and identifies problem-solving and intelligence as central characteristics of the package. Currently no appropriate example exists, as dogs with the required level of intelligence do not fit the package for other reasons. The fourth example is a bred detection dog. No such purpose-bred dog currently exists, but the principles and techniques for its creation are known and production should be straightforward — the only limitation is motivation and resources.

The analysis concludes by recommending that a broadening of perspectives on the selection, use and training of MDDs could improve safety and operational capacity in current practice. The investment required is realistic and supportable, and should be made.

1. Introduction

The abundance of landmines, unexploded ordnance, and other hidden explosive devices in many parts of the world has sparked a massive worldwide effort targeting the location and clearance of these devices (henceforth called mines). Motivated primarily by humanitarian concerns, clearance operations are usually designed to return land to the human communities that once used it, although concerns about effects on domestic animals and wildlife and the impact of abandoned land on local environmental issues are also relevant. The social and economic issues are reviewed elsewhere (GICHD, 2001).

Mine detection operations use a "toolbox" (Figure 1). Inside that box are three compartments containing: (i) technical devices (which include an array of detection and clearance tools), (ii) human deminers working manually, and (iii) mine detection dogs (MDDs). All three can

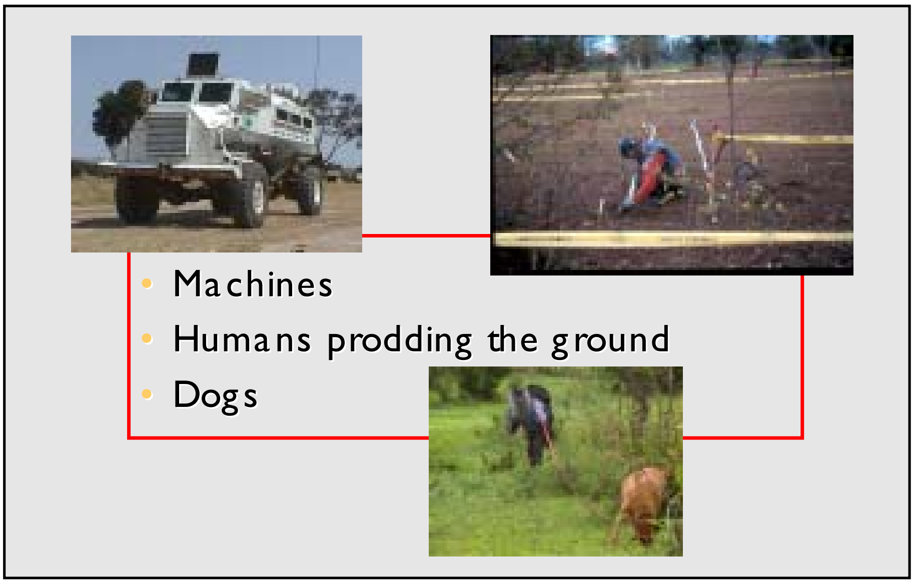


Figure 1. The demining toolbox.

be thought of as detection tools with particular strengths and weaknesses. The choice of which to use in a particular minefield will be influenced by too many factors to list here, and in reality, many demining organisations routinely use all three in varying degrees.

Although their potential for mine detection was probably recognised soon after the first mine was laid in the ground, dogs have only recently gained entry to the toolbox. The compartment in which they sit is by far the smallest, and investment in research and development (R&D) on dogs as a clearance device has been virtually non-existent. In contrast, the mechanical clearance device compartment contains an extraordinary variety of vehicles and tools for remote sensing, floating detection devices above the ground, undertaking remotely-controlled ground disturbance, metal or chemical detection, and so on (see Abinash et al., 2000, for numerous examples). Many of these tools are technically complex, impossibly expensive to purchase and operate, difficult and costly to maintain, and are unlikely ever to be deployed in real minefields. Yet the ongoing investment in R&D on these devices costs millions of dollars annually.

MDDs are not a clearance tool, and they are not an alternative to technical devices (whether used for detection or clearance). All three compartments in the toolbox are complementary and make important contributions to the demining objective. The main advantages that both dogs and technical devices offer are improvements in efficiency and safety for their human operators, and support for the primary clearance tool — humans prodding the ground.

MDDs are not cheap to either produce or maintain. At first deployment, an MDD trained by a western organisation will have cost in the vicinity of US$30,000. Ongoing maintenance costs for an operational dog are more difficult to estimate, but include direct costs such as handler salary, and time and equipment used for maintenance training, and indirect costs such as veterinary and kennel staff, food and housing, administration, security, specialised transport and downtime (e.g. due to sickness). Clearly, investment in R&D that will improve the operational efficiency of any of the above cost factors is desirable.

One advantage of MDDs over all but the most simple of technical devices is their potential for local production — essentially no industrial infrastructure is required (in contrast to, for example, a metal detector). Local salaries and land costs in most situations where MDDs are deployed tend to be much lower than in the western countries that currently provide most MDDs. Thus, production costs may be considerably reduced if the dogs are bred and trained in the operational theatre, as is the case in Afghanistan (where Hakimi, 1999, estimated the cost of producing an operational dog to be US$1,198). However, the training of an MDD requires an in-depth knowledge of the psychological principles underlying learning, and considerable sensitivity about, and understanding of, dog behaviour. Thus, it demands an educational infrastructure that is to be unavailable in most operational theatres.

Clearly, any adjustments to the dog that reduce overall training requirements will facilitate the possibility of local production.

Although dogs have only recently gained acceptance for humanitarian mine detection work, the use of dogs as detection devices has a long history. After World War I, the British created a canine war medal for valour to acknowledge the contribution made by dogs to activities such as finding injured soldiers (Fogle, 2000), and dogs were used for mine detection work both during and after World War II. For example, Finland was so impressed with MDDs used by other countries during World War II that it initiated a training programme immediately after the war, and even proposed to begin training "smaller" dogs, such as terriers, spaniels and schnauzers (Edstrvm, 2001). Wild dogs use their nose to search for prey, and this natural skill has been exploited and refined in breeding programmes to produce domestic breeds with extraordinary scent and behavioural skills. Although originally used for trailing prey (i.e. tracking), such dogs are now routinely used as search devices for people, drugs , foodstuffs, and explosives (Figure 2), and small numbers have been trained in highly-specialised roles such as the detection of cancers or pollutants.

Figure 2. A drugs detection dog at work.

Most bred search or detection dogs are classed as "scent hounds". They exhibit the general characteristics of an extraordinary nose and remarkable stamina, and can be termed "specialists" in that they were bred for a specific purpose. Many of the hounds are pack-hunting and fast-moving, such as foxhounds or greyhounds. But many of the scent hounds were bred to move slowly so that a hunter travelling on foot could keep up with the dog, and to work alone rather than as part of a pack or team. Such dogs naturally exhibit the search intensity and single-mindedness of purpose that are desirable characteristics in a modern detection dog. Unfortunately, they tend to exhibit other behavioural characteristics that make them less suitable for modern detection needs, and only a small number of scent hound breeds are used regularly for detection work (the beagle is probably the most popular).

Many modern detection dogs are actually sourced from working dog breeds, such as retrievers and shepherds. Such dogs can be termed "generalists" in that they tend to be all-purpose dogs with high intelligence. They exhibit behavioural characteristics of trainability and bonding with humans that facilitate learning a wide variety of skills. In general, they are more desirable as working companions, and more rewarding to work with for trainers and handlers, than are the scent hounds. Their versatility and good nature are attractive features, and it is not surprising that they are the dogs of choice in a support role for humans. A little more surprising is that they are currently the preferred breeds for use as MDDs.

It is provocative to suggest that working breeds are preferred as MDDs because of historical precedence and conservatism amongst dog trainers, but this is a likely explanation (this conclusion has been arrived at independently many times, and was recently proposed publicly by Almey, 2001). Dog training is as much an art as a science, and experience is an important predictor of training outcome. Additionally, "dog-people" routinely develop personal breed preferences for essentially the same reasons that people prefer particular makes of car, or particular types of breakfast cereal. The preference may have little to do with the function of the product, and much to do with personal history. Thus, a trainer who has worked with shepherds for 20 years will be a better trainer of shepherds than of beagles, and is also likely to prefer the company of shepherds. Most of the current trainers of MDDs have a long history of working with general-purpose support and protection dogs — usually shepherds and sometimes retrievers. Such people are not only likely to choose shepherds and retrievers for the new task (mine detection) because of personal preference, they are also likely to be better at training those breeds than others. The evidence is easily found in operational MDD situations, where the dogs, almost all of which are shepherds, can be seen to be both effective and productive.

2. Economics and ethics

Effective and productive devices can always be improved upon. In the (relatively unusual) situation where anything less than 100 per cent is unacceptable, as is the case with mine detection, even small improvements may be highly significant. Two standard ways to make improvements to any product are (i) to further develop the current product by refining its features, or (ii) to revise radically the design of the current product while retaining its desirable features. Clearly, the second course of action will be undertaken less commonly and is necessarily more experimental and costly. However, the second option is the primary conceptual target of this analysis. The first option is being addressed in separate reports (GICHD dog substudies 3 and 4, in preparation) and will only be discussed in passing here.

An underlying theme in this analysis is the notion that the MDD is a product, in the same way that a mechanical clearance machine or a metal detector is a product. In this context, there is nothing special about an MDD, even though it is a living organism held in high esteem in some human cultures. The primary issue of concern here is mine detection. A properly trained and motivated MDD is an efficient mine detection device, and nothing more. Its purchase and use will depend on economic realities, which in turn will be driven by the local context in which mine clearance is being undertaken.

In western cultures at least, there has been increasing sensitivity about the support role of animals, and the extent to which their needs must be considered when human objectives are being pursued (e.g. Fraser, 1999). The use of animals in many roles is now regulated by legislation, and animal rights issues must be considered in any operation that uses animals for its task. Dogs used in a demining role frequently end up in countries in which such protective legislation does not exist, and animal rights are not accorded the recognition they receive in western countries. Programmes may even be handed over in entirety to local operators for whom the notion of animal rights is incomprehensible. Clearly, local training on these issues is needed, both to fulfill legislative requirements of the country in which the training organisation is based, and to ensure that the operational capacity of the dogs is protected.

Fortunately, the ethical issues are reasonably effectively addressed by economic and functional realities. The quality of a product is reflected in its original purchase price. Most users will treat a quality product with care, and will maintain it to a higher standard than a cheaper, more disposable and replaceable option. Thus, from an ethical perspective, the relatively high purchase cost of an MDD is a benefit, as it encourages the user to treat that dog with care and respect, and to optimise the maintenance of both its health and its work skills. Even with improved breeding and training techniques, it is unlikely that MDDs will ever become a cheap item that can be treated as disposable, or mistreated, because it is easily replaceable.

Any breeding programme developed in an attempt to produce a dog specifically for mine detection will necessarily face a significant problem — the production of a large number of (possibly cross-bred) puppies, many of which are unsuitable for the objective. Disposing of such dogs in a responsible and ethically acceptable manner may be difficult, and needs to be resolved as a logistical component of the programme. Currently, most MDDs are sourced from breeding programmes for service dogs, or from private breeders. These programmes produce dogs for a much wider variety of roles and the rate of production of unwanted puppies is low. Tests of purpose-bred dogs for service roles suggest that reliability is improved to some extent by a breeding programme (Goddard and Beilharz, 1983; Wilsson and Sundgren, 1997; Slabbert and Odendaal, 1999). A more focused breeding programme for MDDs might therefore produce dogs better suited to the task. The problem of unwanted puppies could be resolved by according top priority to production of MDDs in a programme that produces dogs for a broader range of uses.

Perhaps the biggest issue of concern for ethics agencies is the question of what becomes of MDDs that are no longer productive. Ageing animals of any domesticated species are most likely to be allowed to live out their lives if they have developed a close relationship with particular humans. Destruction or abandonment of relatively young animals in the racing (horse or dog) business is a common practice, in part because the animals are only valued to the extent to which they can race. Here, the animal is simply a product, and is likely to be disposed of as soon as it is economically unproductive. The same problem may well apply to MDDs, especially in those operations where the dog-handler relationship is restricted to a functional working relationship and the dog lives in a kennel.

Having recognised that the issues raised above are significant, and require discussion and resolution, they will be ignored in the rest of this analysis.

3. Why dogs?

Clearly, exploiting the odour given off by a mine in order to search for that mine is a sensible option. Dogs have been used for centuries in a wide variety of search and detection roles because of their known olfactory skills, so it is not surprising that they would be used in this relatively new role.

Dogs, however, are not the only animals with an excellent sense of smell. With respect to searching for mines, there have been recent attempts to train ferrets and the African pouched rat (Figure 3). Animal species used in other roles by humans as sniffing devices include ferrets (for rabbits) and pigs (for truffles). Males of some moths are able to detect the existence of a female if just one molecule of the appropriate sex pheromone lands on his sensors, and this skill is exploited in pest control operations (Payne et al., 1986). Bees can locate sources of nectar from distances of hundreds of metres, and this skill is exploited by the apiary industry. At least one attempt to develop bees as detection devices is achieving some success (Almey, 2001). Many animals known to have extraordinary smelling abilities are not exploited by humans in any way. For example, a bird with extremely sensitive olfactory skills (the kiwi) spends its days (actually nights) probing the ground and sniffing for prey — such a lifestyle suggests it might be an ideal candidate for development as an MDB (mine detection bird). It seems likely that at least some of these examples represent levels of odour sensitivity that match or exceed the capabilities of dogs.

The problem is not one of locating examples, but of developing techniques for exploiting the known olfactory capabilities of animals in a mine detection role, in a sensible time frame, and with minimum cost. For example, it is likely that a few generations of careful selection with pigs would produce an animal able to be used in mine detection work, but many years would be required for such a programme. The image of genetically-engineered male moths flocking over a buried mine because they believe it to be a female is alluring, but unlikely ever to be more than a fantasy because of the costs and uncertainties involved. For both of these examples, the desired outcome could not be guaranteed even if the appropriate R&D was undertaken. On the other hand, such fanciful suggestions may have similar probabilities of success to some of the unlikely high-tech mine detection solutions that have proliferated in recent years (numerous examples in Abinash et al., 2000). In reality, it might be worth diverting a small portion of the massive expenditure on demining operations into research on such flights of fancy. The attempt with African pouched rats is just such an example.

Fundamentally, the answer to "why dogs?" is that this is a species that humans understand, and know how to communicate with. Because of a 12,000-year history of domestication (Morey, 1994), dogs are motivated to work for humans in a support role, and will do so reliably and consistently. Put simply, we know how to explain the problem to a dog better than for any other species. But it should be kept in mind there is no imperative to use dogs, and imaginative experiments with other possible mine detection species should be supported and encouraged.

Figure 3. The African pouched rat.
Experiments with this species conducted by APOPO in Tanzania suggest considerable potential as a tool for mine detection.

4. Designing an MDD

1. Origins

Although the modern science of genetics did not exist at the time, Darwin (1859) was the first to recognise that the known technique of directing a genetic lineage by a process of selection might have a biological basis. He therefore devoted the first section of his famous book to the process now called artificial selection.

Most breeders have specific design objectives in mind when operating such a programme of selection, and the extraordinary diversity of dogs today is evidence of the potential inherent in the genome of the original wolves from which dogs are descended (Vila et al., 1997).

Many modern breeds can trace their origins to just one breeder, and even just one dog (e.g. the abundant Australian kelpie can be traced to a female called “Kelpie”; Fogle, 2000). Once a new breed has been developed, the enthusiasts who produce it use stabilising selection to work to specific design characteristics (see Jackson, 2000, for an overview of the theory of dog breeding). If those standards are linked to the show ring, then they may have no functional relevance whatsoever and may not even be in the interests of the dog (Wolfensohn, 1981).

If the primary motivation driving selection is functionality, as with many working dogs, then the breed may be quite variable in form. But it will still exhibit the critical features that make it an effective working dog. A frequently discussed modern example is the American or pit bull terrier, which is so variable in form that attempts in some countries to isolate or eliminate this fighting breed have proved almost impossible.

The relevance of these points to the development of an MDD is that, if the characteristics (or standards) of an MDD could be agreed upon, then it should be possible to produce a breed that offered them. It is likely that slightly different characteristics would be preferred in different places — for example a short coat in hot countries and a wire coat in wet countries. Alternatively, the reality for an MDD is that it could end up working under a wide variety of climatic conditions, and tolerance of variability in conditions might be the important characteristic to breed for. Thus, a “characteristic” could be a particular feature, or something very general — more a concept than a characteristic.

2. Genetics

In dogs, as in many other organisms, particular features may be controlled by a relatively simple genetic switch. For example, coat colour and type may be controlled by either one or a small number of genes. Such features tend to be relatively easy to manipulate genetically in order to stabilise their presence or absence. Unfortunately, genetic control of behavioural characteristics is routinely complex — behaviour has been described as the "quintessentially complex phenotype", and is widely regarded as being highly variable due to its responsiveness to environmental influences (Wolf, 2001:117). For example, the stereotypical behavioural pattern of "pointing" does not have a simple genetic switch (MacKenzie et al., 1986). General characteristics that are essentially identifiable concepts, such as trainability, intelligence, intensity or mobility, are the least likely to have simple genetic controls and are therefore potentially very difficult to manipulate genetically. Most published research indicates that the heritability of such features is low in dogs, although it is not known whether this is because genetic variation for them has been exhausted, or because the genetic background to them is unresponsive to artificial selection procedures, (Scott and Fuller, 1965; Reuterwell and Rhyman, 1973; Goddard and Beilharz, 1983).

Despite these comments, heritability of a general behavioural feature ("nervousness") has been stabilised by artificial selection in dogs (Murphee et al., 1977), suggesting that the potential for genetic manipulation of desirable behavioural characteristics in an MDD is worth exploring (Goddard and Beilharz, 1983). In a recent unpublished study of about 2,000 dogs, heritability of specific behavioural features ranged up to a remarkable 0.6 on a scale of 0-1 (Bachem, 2001). Clearly, there is more research to be done on heritability issues.

It is now recognised that the behavioural characteristics exhibited by adult animals are a product of both evolutionary history (phylogeny) and personal experiences (ontogeny) (Adams et al., 2000). For example, Border collies have a long phylogenetic history of breeding for "rounding up" behaviour (usually of sheep). Many Border collies raised as pets have never seen a sheep, yet they still exhibit "rounding up" behaviour without any prompting — usually targetting the family cat, the children, the chickens, or even inanimate objects such as toys. With careful training, it is possible (although difficult) to stop such a dog from rounding up everything it encounters. In this example, individual experience (ontogeny) is used to counteract evolutionary history (phylogeny) in a process that could be called detraining (strictly, retraining). Detraining of bred skills is difficult, but any dog trainer knows that detraining of acquired skills can be just as easily achieved as the original training of those skills, if poor maintenance training techniques are used.

The usual objective of training is to develop and refine bred skills in order to improve the efficiency and control of their expression. An artist may carve a beautiful object from a piece of wood. But the options available as an end product will be restricted by the original shape of the wood, the pattern of the grain, and the flow of colours. The dog trainer-as-artist may similarly achieve remarkable behavioural outcomes with a dog. But the breeding of that dog will lend itself to some outcomes, and not to others.

Two important reasons that Border collies are the breed of choice for working with sheep are that they are highly motivated to do the work, and they need relatively little training in order to become effective working dogs. Both features are a product of breeding (or phylogeny). But both require further personal development (ontogeny) if the full potential of the dog is to be realised. Any breed of dog will require training in order to work effectively with sheep, because every situation in which sheep are being moved will have its unique requirements. In effect, the dog must learn the language used by the farmer to make those requirements clear. It is simply more efficient to train a Border collie rather than some other breed as a working sheep dog, because both the ultimate quality of the dog's work and the time required to train the dog, have been optimised by its phylogeny.

If Border collies make better sheep dogs because of a history of selection for characteristics that are desirable in a sheep dog, then a programme of selection for the characteristics desirable in an MDD should have the same effect. What are those characteristics, are they already available, and how might they be obtained?

5. The essential characteristics of an MDD

An observer of a good MDD at work quickly notices the following features:

- The dog's nose is always to the ground;
- Intensity of focus is high — the dog is concentrating on the sensory input to its nose and may even be snuffling or huffing in order to improve the flow of air through its nose;
- The actions are highly repetitive (usually involving walking a carefully prescribed narrow path);
- Reliability — the dog exhibits a series of carefully contrived actions (including staying on command) with 100 per cent reliability;
- The work is physically demanding;
- The dog is moving slowly;
- The dog wants to work — it is enthusiastic about the job.

1. Why nose to ground?

The answer to this question is not as straightforward as it might seem. The dog has been trained to search for particular odours. If those odours are highly volatile, they might be more readily available in the air above the ground than at the surface. Or they might be more accessible on vegetation (due perhaps to being transported from underground through the plant's transport system). Through its experience searching for those odours, the dog will have learned where they are most likely to be found.

Research is still underway on the volatility and mobility of molecules of TNT and the associated chemicals likely to leak from an explosive device, but the following preliminary comments can be made (summarised from Kjellström and Sarholm, 2000, and Webb and Phelan, 2000). TNT has extremely low volatility. Most of the associated chemicals in an explosive compound (which are derived from a mix of impurities, stabilising chemicals, and breakdown products) have higher volatility than TNT. The binding properties of these molecules to soil particles depend on soil particle size and composition, and soil moisture. Recent adjustments to soil moisture (e.g. rain after a period of drought) can dramatically change volatility factors. The pattern of distribution of leakage products around an explosive device is erratic and may depend on local topography (e.g. there may be a plume along a moisture gradient). Overall, the volatility of all potentially available odour sources is low (in part because any odour sources with high volatility have long since been exhausted because of the time the mine has been in the ground). If volatility is low for an odour source hidden in the ground, then the most likely place to find chemical residues of that source will be at ground level, because most of the molecules available to the dog are bound to dust particles at the surface (George et al., 1999; Phelan, 2001). The dog's nose should therefore be to the ground, and "nose-to-ground" is a learned response resulting from experience.

2. Why is intensity of focus high?

Tired students quickly learn that it is possible to read entire pages of textbooks without comprehending any of the information contained on the page. It is very easy to process the words. It requires considerably more concentration to actually ingest the information that those words convey. The important point might be difficult to understand, or the text might be poorly written (both are often the case!). The central point may be contained in just one sentence somewhere on the page, but there is nothing to identify that sentence.

MDDs effectively face the same problem. They are searching for an elusive message — a critical but tiny morsel of information amongst a massive background of sensory input. As with the student, they do not know which "sentence" (or which square centimetre of soil) contains the critical message, so each square centimetre must be scrutinised with equal intensity. Any reduction in intensity of concentration increases the chance that the important message will be missed, even though the ground is apparently being covered. Thus intensity of concentration must always be high, even though the critical message is rarely encountered.

3. Why are the actions repetitive?

Safety concerns, and the need to ensure that all of the ground is covered, necessarily require the dog to move in a predictable manner. The job actually involves endless repetition of a very simple task in a rigorously controlled way. Search procedures that give the dog greater freedom of action (such as free roaming throughout a search area) are unlikely to provide effective search coverage, even though they may make the job more entertaining for the dog. An important benefit of a repetitive search pattern is that the dog becomes conditioned to undertaking the work in a very precise way — including high levels of search intensity and focus. Because the handler is closely monitoring the link between search zone and behaviour of the dog, they can choose to search again along a path where the dog's concentration lapsed.

4. Why is reliability high?

Any dog that behaves with less than 100 per cent reliability in a minefield is a danger to itself and to its handler. In effect, the highly structured series of behaviours exhibited by the dog represents its standard operating procedure (SOP). In a dangerous situation, any variation on a SOP should only be made after careful consideration and thought, and probably some experimentation. Such options are not available to the dog.

As a training problem, reliability issues are usually referred to using the term "obedience training". With respect to dog training, the GICHD has decided to avoid using the words "discipline" and "obedience", because their common use in the English language implies an association with unpleasant experiences and might even justify training based on punishment. Therefore, in this document, the word “reliability” is used in place of “obedience”.

5. Physical demands and pace of work?

Three features are relevant here: intensity of concentration, speed of action, and the repetitive nature of the task. All living organisms have a natural gait (or in most cases, gaits), and those gaits naturally lend themselves to particular speeds of movement. Some animals are actually physically unable to move at some speeds within their potential range because of design constraints — kangaroos are an example because of energy conservation mechanisms built into their hopping gait. For horses, the natural gaits are walking, trotting, cantering and galloping. For many medium to large sized dogs, the natural walking pace of a human (5-6 km / h) is an uncomfortable speed, leading to pulling or dragging on a lead because the dog wants to walk (3-4 km / h) or lope (8-10 km / h). The loping run can be maintained by dogs for hours, and it is often the gait used by MDDs while searching for mines. Unfortunately, while the loping gait allows the dog to cover a great deal of ground and work for long periods, it is probably moving too fast to conduct an effective search over the entire surface of the ground. To search effectively, the dog must move slowly by reducing its gait to a walk, or even a slow walk. Dogs that do so naturally are likely to be better MDDs.

Reasonably fit humans who have spent a couple of hours in a museum often report on how exhausting the experience was, usually with some surprise because they “did not do much”. The museum experience includes all of the components listed above. The action of constantly stopping to review displays is repetitive, interpreting the displays requires concentration, and the gait and rate of movement (a slow walk) are unnatural. Put simply, humans are not designed to move at a slow and erratic walking pace with frequent stops, and they quickly tire when doing so. Similarly, dogs also tire quickly when required to walk slowly and with frequent pace changes. Thus, the rate of movement of an intensively searching MDD may be slow, but the pace and activity are physically demanding.

6. What is important about the enthusiasm of the dog?

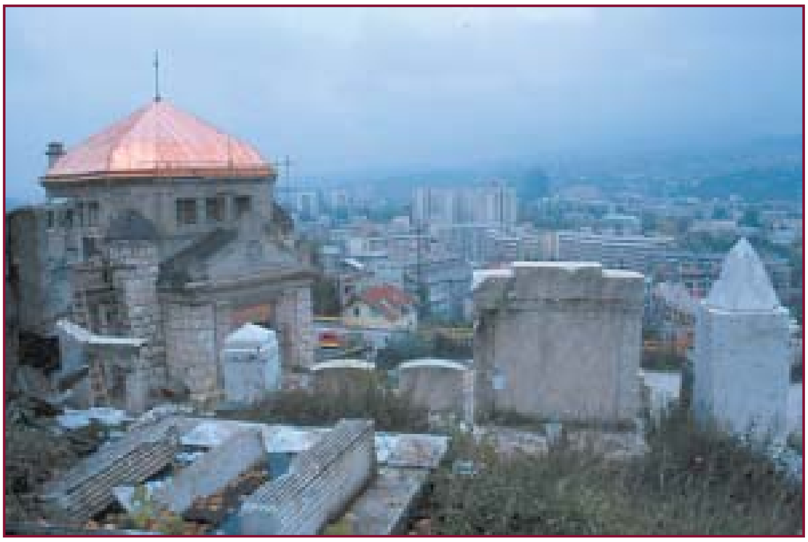
Little needs to be said here. Any creature undertaking a physically demanding and repetitive activity is likely to work more effectively and for longer if it enjoys what it is doing, where “enjoys” means that the activity is intrinsically rewarding. Further comments are made in section 4 of the following chapter (the cognition problem). The usual training solution with MDDs is to turn the search activity into a game, where the dog works for a highly-desired reward (usually a toy).

Thus the essential characteristics of an MDD are:

- A good nose;
- High motivation for work (or motivation easy to maintain);
- High natural fitness with good endurance (or these are easy to maintain);
- Tolerance of repetitive actions = motivation to undertake simple tasks;
- Ability to move at a slow pace for sustained periods;
- Tolerance of local environmental conditions;
- Resistance to local diseases.

The last two characteristics are features that improve the operational reliability of the dog in a particular context.

It is worth noting that none of these characteristics must be bred into the dog — all can be established and maintained with time, training, veterinary support, and careful management. However, any dog that requires a significant investment in the maintenance of an essential characteristic is unlikely to be a successful MDD.



The Jewish cemetery in Sarajevo from which several thousand mines were removed with the help of MDDs.

6. Essential characteristics of an MDD: alternative options

In the listing of essential characteristics above, the aim was to identify features about which there should be little disagreement in the MDD community. This section discusses characteristics that are more controversial. The aim is to explore those characteristics from alternative perspectives, leading to the possibility of creating different packages — essentially alternative "best" designs for an MDD. Much of the discussion is necessarily speculative and is likely to generate strong opinions among members of the MDD community (and among dog trainers generally). In the section above, the observable end product (i.e. operational MDDs) was used as the target from which the characteristics were sourced. In this section each characteristic is discussed in general terms, independently of the end product. Finally, suggestions are made about alternative ways to achieve the end product.

1. Trainability

a. Definition

No matter how well designed the basic MDD is, it will need training. Thus, some notion of trainability is an essential feature of an MDD. The notion of trainability is an intrinsic feature of any dog, and a rare point of agreement on this vexed issue is that different dogs will have different trainability. Defining the notion of trainability is difficult, but is fundamental to an effective analysis of the concept. If a definition can be developed, then an important step has been made towards optimisation of trainability in the designer MDD.

Listed in Table 1 (following page) are seven ways in which the notion of "trainability" is used. Together, they provide a preliminary attempt at defining the concept. Clearly, there is overlap between these points, but they serve as useful topics to help focus the discussion.

Concert musicians exhibit extremely finely-honed musical skills, built on a combination of extraordinary musical skills (phylogeny) and practice (ontogeny). We normally refer to such people as being highly talented, but we do not normally think of them as being highly trainable. In reality, it is training, or practice, that turns a talented musician into a concert performer. Most concert musicians are specialists on a particular instrument, or more rarely on a small number of closely-related instruments. But attend a folk festival and you will find individual musicians playing on an

Table 1. Different uses of the word "trainability"

- The potential for a dog to acquire trained skills in general terms;
- The potential for the dog to acquire particular trained skills;
- The ease with which trained skills can be built into the dog by a training programme;
- The diversity of skills that can be acquired by the dog;
- The complexity of skills that can be exhibited by the dog;
- The refinements (or subtleties) that can be achieved in the final training outcome;
- The need for different training techniques, or at least the need for adjusting the way training techniques are used, with each dog.

amazing array of instruments with approximately equal and consummate skill. Possibly none of those instruments are played with the subtlety and flair achieved by a concert musician, but we are still likely to refer to such generalist musicians as being highly talented. In some ways the diversity of their musical skills makes them even more awesome than the concert musician. Is one of these musicians more talented than the other? Is that an inappropriate distinction?

Most people would automatically consider the national obedience champion to be a highly trainable dog. Clearly, such a dog is very well trained, but was it highly trainable? We are unlikely to refer to the dog as talented, probably reserving that concept more for the trainer than for the dog. Linking back to the metaphor above, the dog is the instrument and the trainer is the musician. Instruments vary in quality (or "playability"), but surely they do not have talent in any meaningful sense. In fact, the more talented the trainer, the less necessary it may be for the dog to be highly trainable. A good musician can make even a bad instrument sound pretty good.

The obedience champion is most likely to be a dog that exhibits finely tuned skills in a range of behaviours (points 5 and 6 in the trainability items above). On these items at least, it will be considered highly trainable. It will also have a very strong rapport with its handler (a point not usually considered when notions of "trainability" are being discussed). However, the notion of "potential" (expressed in the first two points above) requires further clarification before the dog can be assigned a trainability index on those measures. Discussion with the trainer could indicate that the dog was difficult to train even though the ultimate product was impressive. Thus its potential was high, but its willingness to learn was more questionable. Just as with a concert musician, this is a dog that required a great deal of practice for it to express its full potential. If the musician is talented, then, surely, so too is the dog.

In the three paragraphs above word games were used to develop at least two different, and somewhat contradictory, perspectives on trainability. Other arguments could easily be developed, but the point has been made that trainability is not an easy concept to either define or agree upon. It is reasonable to assume that dog trainers using the word "trainability" routinely talk at cross-purposes. For example, Hakimi (1999) suggested that MDDs need to be both talented and smart, Dyck (1999) indicated that MDDs should be intelligent (presumably=smart) and show "aptitude for this work"

(=talented?), and Smith (1999) indicated that potential MDDs should be mature and stable. The "courage" listed by Dyck was not mentioned by either Hakimi or Smith, and none of these three authors mentioned trainability per se, although they were presumably referring to this concept when using the other words. Lockwood (1999) used the word trainability along with stability. The authors all made their comments within one conference setting, so were talking to each other at the time. If some notion of trainability is to be used in relation to the design of an MDD, it is essential that the notion be explored in some detail if any clarity of discussion is to be obtained.

Consider this sentence: "trainability can be categorised both as a breed characteristic (e.g. there is reasonably general agreement that the hounds are more difficult to train than the working dogs) and an individual characteristic (even within a litter, dogs will vary in trainability)".

In contrast to the comment above, trainers of beagles (a hound) for fruit and vegetable detection work in airports consider them to be relatively easy to train. Beagles have a bred obsession with the nose and love of food, thus the training task is relatively straightforward. The beagle simply has to be taught that signalling the presence of certain odours will result in a food reward, and the appropriate signal to give is to sit down. The beagle does not have to be taught to sniff at bags (instead of, for example, watching the people milling around), or to maintain intensity of sniffing behaviour, because it does these things naturally. It does not have to be tricked into thinking that searching for fruit and vegetables is a game (in order to maintain motivation), nor does it need to develop an obsession with a convenient reward (such as a ball). It will need socialisation to accustom it to the noise and chaos of an airport arrival hall, but its natural tranquility means that it easily adjusts to that potentially stressful environment. Despite being hounds, perhaps beagles should be placed at the "trainable" end of the trainability scale.

On the other hand, most owners of beagles will go on at length about the difficulty of doing responsiveness training, the tendency of the dog to run away, its constant scavenging and stealing of food, and its dislike of water. There is no doubt that some training objectives are difficult to achieve with beagles. If those objectives are in mind, beagles will routinely be placed at the "untrainable" end of the trainability scale.

How does the beagle rate with respect to the seven factors extracted from the notion of trainability? On the general potential for acquiring trained skills, beagles rate *low*. On the potential for acquiring particular trained skills, beagles rate *high* (these are the skills that beagles exhibit naturally anyway). On the ease with which trained skills can be built into the dog, beagles rate *variable* because some are easy and some are difficult. On diversity of skills, beagles rate *low*. On complexity of skills, beagles rate *low*. On refinements in the final training outcome, beagles rate *low*. On the need for adjusting training with each individual dog, it is enough to say that the generally good nature of beagles means that they are probably at the *higher end* of the scale.

Overall, beagles appear to rate low to variable — not a very promising outcome. Yet beagles are the breed of choice for a critical detection role that potentially protects entire agricultural economies worth millions. Why? Because on just one trainability measure, they rate *high***,** and that is the critical measure for a food products detection dog.

The point of this exercise is not to mount an attack on beagles, but to dissect the notion of trainability into its component parts and to explore how those parts might be applied when considering breed-related trainability issues. Trainers of

MDDs appear to be in fairly general agreement that the original training of a new MDD is difficult, and takes considerable time (routinely a year, and sometimes much longer). Very little information is available on the relationship between notions of trainability and the maintenance training required once an MDD is operational. However, with respect to improving the overall efficiency of training for an MDD throughout its working life, the question of maintenance training may be even more important than the question of how difficult it is to train the dog in the first place.

b. Perspectives on trainability

The above discussion is directed towards two general perspectives on the notion of trainability.

➢ ***Perspective 1:***
The designer MDD will need high general trainability because it must undertake a variety of unnatural tasks in a highly constrained way. Training of such a dog will probably be assisted if the dog naturally develops a strong rapport with the trainer. Once trained, such a dog can probably be relied on to work independently, as long as motivation can be maintained, and the dog can potentially work to almost any SOP. Put another way, the dog is trained to fit a desired SOP. If it is to be passed from one trainer / handler to another, the issue of its tendency to rely on one person may require some management. Maintenance training may be quite demanding because of the complexity of the required tasks.

➢ ***Perspective 2:***
The main training requirement will be to direct and control behaviours that the dog exhibits naturally. Here, trainability may be rated low in most senses in which the word is used, and it may be necessary to fit the SOP to the dog. There is less likelihood of trainer / handler issues needing managing. Maintenance training should be less demanding than under perspective 1.

Clearly, perspective 1 describes the shepherds that are normally used as MDDs. Breeds that might be suitable under perspective 2 are considered below.

2. Presentation

"Presentation" means physical characteristics such as overall body size and shape, visual presentation (e.g. wolf-like, puppy-like), design of structural components (e.g. ears, nose, feet), coat colour and style, behavioural characteristics, and so on.

Much of the amazing diversity of dogs today can be explained by a combination of particular functional requirements, the idiosyncracies of fashion preference in different times and cultures, and the serendipitous exploration of curiosities that appeared in certain genetic lineages. For example, the unattractive undershot jaw and compressed muzzle of bulldogs was a functional requirement of bull-baiting, the pulsating hair of Afghan hounds was a popular fashion accessory in the 1970s, and the compressed face of a pug was designed to create an animal in the image of a human.

The curiosities and special-purpose examples aside, certain features of dogs appear repeatedly across many breeds, and the reasons for selection of those features are worth exploring.

Dogs were originally derived from wolves (Vila et al., 1997), probably with frequent back-crossing to wild wolf populations. The possibility of occasional introduction of genes from other species such as jackals is still controversial. In the evolutionary progression of dogs since their domestication, a process called ***neoteny*** can be found in both behaviour and physical presentation across breeds

(Goodwin et al., 1997). Neoteny is defined as the expression of juvenile characteristics in the adult form (Grandin and Deesing, 1998). It is not a rare or aberrant process and can be found in many wild species and most domesticated species. For example axolotls are the juvenile form of salamanders, yet axolotls are capable of breeding and may never metamorphose into fully adult salamanders — this is equivalent to tadpoles breeding without becoming frogs or caterpillars breeding without becoming butterflies. The flat face (strictly a compressed primate muzzle) of humans is a neotenous feature, and humans are possibly the most domesticated of any species.

The evolutionary process leading to changes in the bone structure of a dog can be mimicked using morphing software. The process involves the application of principles of artificial selection to real dogs, but the derived possibilities are constrained by the mathematics and biochemical processes of development. The behavioural perspective on developmental issues can be found in Cairns et al. (1996; see especially the chapter by Gottlieb). Put simply, effects such as lengthened or shortened bones are achieved by adjustments in the rates of bone development, and the achievable options are restricted by biology. The morphing software mimics this process remarkably closely (Figure 4). The example began with a line drawing of a German short-haired pointer originally produced by Konrad Lorenz in about 1935 (Lorenz, 1952). If the bones of the face are extended, a sight hound such as a borzoi or greyhound appears (i.e. a breed in which there has been selection for long bones and a lithe body). If the face is shortened (mimicking the process of neoteny), a series of recognisable breeds appears ranging down to the malformed pug.

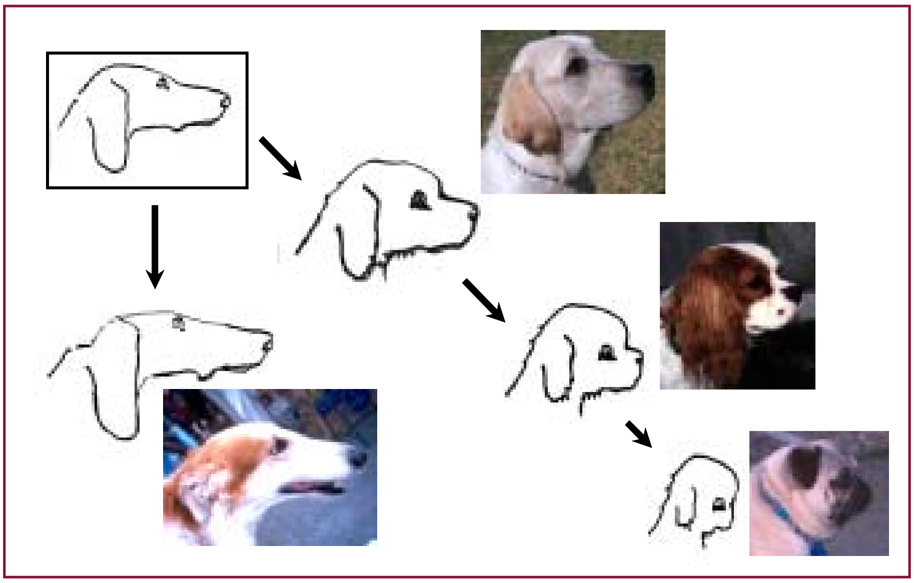


Figure 4. Developmental change and neoteny in dogs. A line drawing of a German short-haired pointer was manipulated using a morphing programme to mimic the process of artificial selection. As the shape of the head is adjusted, well-known breeds appear.

Why would dogs be neotenous? When humans chose to domesticate the original wolf, they were confronted with the problem of living alongside an animal that was a predator, a competitor for food, and a threat to children if not to adults. Even today, a wolf howl heard in the wilderness thrills and excites the senses by causing a rush of adrenalin — an endocrine response linked to fear. It is therefore likely that the original domesticated wolves were quickly modified to make them less threatening, effectively making them less wolf-like. Two obvious changes were decreased size and decreased aggression (or increased subordinate behaviour). Wolves signalling subordinate status make themselves appear less wolf-like by decreasing their size (lowering the body, flattening the fur, turning back the ears) and hiding their weapons (turning the head, lowering the lips) (Coren, 2000). The artificially selected changes to wolves to turn them into something less threatening for humans were more permanent representations of the same effects, and can be seen today in the village dogs that abound throughout Africa and Asia (Figure 5). These dogs are small, extremely subordinate to humans even when seriously provoked, and tend to have floppy ears and multi-coloured or red fur. Visually, they give the appearance of a submissive dog even when in a completely relaxed state, as this one is.

Figure 5. A typical village dog, photographed in Mozambique, Africa.

A second pattern of neotenous change can be detected in many breeds that were developed more as fashion accessories than for roles in hunting, fighting or guarding. These dogs, such as the King Charles spaniel, are often characterised as "cute" (Figure 6). They tend to be small in stature, with high foreheads, big eyes, a short muzzle and juvenile behaviour (i.e. "baby" features). Baby-like features appeal to the parental and protective instincts of humans for many reasons; most relevant here is that a cute animal is unlikely to be perceived as threatening.

What are the implications for the design of an MDD?

Many of the human cultures in which MDDs are required to operate are not dog-friendly. The village dogs of Africa and Asia are not integrated as pets into the human families with which they associate, and are frequently the subjects of abuse and disgust. The dogs may not be feared, but nor are they valued or respected. An MDD that must be integrated into such a community will face a double disadvantage: (i) the local population may react negatively to it, and (ii) any person chosen as a handler will come from a cultural background in which dogs are ignored or hated. Experiences in Afghanistan and Africa indicate that it is possible to overcome the disgust and loathing that such people feel initially

Figure 6. A King Charles spaniel, a breed commonly referred to as "cute".

towards dogs, and that MDDs and the profession of handling them can be accepted by the community. But people chosen from such communities for training as handlers will not bring an understanding of dog behaviour to the job as a background skill. Nor are they likely to comprehend the notion of the dog-human bond, which is an important issue with many breeds. With experience and training, they will develop better understanding, especially if they become interested in and enthusiastic about dogs in general terms. But the latter outcome cannot be guaranteed, and realistically, is unlikely.

a. Issues for handlers and communities

Four points are worth considering here in relation to the designer MDD.

➢ If potential handlers are initially afraid of the dog with which they must work, then their ability to develop an effective working relationship with that dog may be compromised. Overcoming fear of dogs is possible, but much more is needed. The handler may be required to develop a close partnership with that dog, including living with it up to 24 hours a day. Dominance can be a significant issue with male shepherds in particular, and any fear exhibited by the human may be exploited by the dog to manipulate the relationship.

➢ If there is a requirement for the dog to be integrated into local communities, then that dog should be as non-threatening as possible. If the dog appears non-threatening, then it is more likely to be accepted, or at least to be tolerated, by the community. The designer MDD could be made non-threatening by exploiting known neotenous design trends already available among dog breeds. But it might equally be more acceptable if it simply looks nothing like the village dogs. For example, German shepherds are obviously dog-like, but they look nothing like a typical African / Asiatic village dog. Their distinctiveness might be enough to convince the community that German shepherds are something other than the dogs they know, and therefore to be treated as something other than a dog (and more acceptable).

➢ The third point makes the above argument more difficult to apply. Unfortunately, German shepherds exhibit a feature that could make them less acceptable to humans in general terms.

Figure 7. Similarities in appearance between German shepherd (lower right) and the northern European wolf (upper right), and Malinois (low left) and the Asiatic wolf (upper left).

German shepherds are a rare phenomenon — a breed that was specifically selected to look *more* like the large northern wolves that inspire a thrill of fear when heard or seen (Pullainen, 1967; Goodwin et al., 1997). It is more coincidental, but equally unfortunate, that the other commonly used MDD (the version of the Belgian shepherd called the Malinois) looks very like the smaller and leaner Asiatic wolf. If the (unnatural?) fear of wolves felt by many humans is a relevant issue in the overall operational requirements for an MDD, then it is difficult to imagine a worse choice of breeds than these two (Figure 7).

➢ Fourth, if the MDD can operate effectively with little requirement for the handler to have a sensitive understanding of dog behaviour, then a significant and potentially insurmountable training problem will be avoided.

b. The physical appearance of the scent hounds

A good nose is an essential requirement for an MDD, and the scent hounds have the best noses. Any review of the appearance of scent hounds leads quickly to the conclusion that they were not bred for looks. They tend to have large pendulous ears, a thick muzzle, and wet floppy lips (Figure 8), and they present a face that may have character, but is unlikely to be thought of as attractive (except, of course, by enthusiasts). All three of these features assist in the primary objective of the scent hound —to detect an elusive odour. The flopping ears and lips create air movement that helps to draw odours into the nose. The thick muzzle is a consequence of massive internal surface area of the nasal lining. The drooling mouth indicates that the nasal lining is being kept moist to optimise odour capture. If these features improve the ability of scent hounds to detect scents, then they are likely to be desirable features of an MDD.

Figure 8. The face of a scent hound (a bassett hound), indicating the broad nose, floppy lips and pendulous ears.

Most scent hounds are short-haired, although one group (the griffons) is usually wire-haired. Short hair offers the convenience of easy maintenance, and tolerance of hot climates — both useful features in an MDD. Wire hair offers waterproofing for wet climates. These features were selected in the hounds in order to minimise maintenance needs for handlers.

The colour of scent hounds is variable, with many being multi-coloured. In general, there is no obvious feature of colour that might be optimised in an MDD. Such dogs usually work close to a handler, so there is no need for contrast colouration to facilitate keeping them in view. Black dogs might be slightly more susceptible to heat than dogs of other colours, but this is likely to be a marginal difference. The possible aim of developing a dog that looks unlike the village dog will not be helped by the available colour variation in the scent hounds, because village dogs are also quite variable in colour and patterning.

Scent hounds offer considerable variability in length of leg, speed of movement, and willingness to work slowly and carefully. However, dogs with unnatural shapes (the basset and dachshund are extreme examples) tend to exhibit a variety of health problems, particularly of the back and hips, that make them unlikely candidates as MDDs. Overall, any attempt to design a slow-moving dog would be best achieved using a dog of normal proportions in which overall size and/or gait was adjusted.

3. Size and shape

On minimum size, the requirement for a good nose means that scale factors are likely to work against the designer MDD being very small. Small noses are simply unlikely to be as effective as large noses because of the relationship between odour sensitivity and surface area of the nasal lining noted above as a general feature of the scent hounds.

However, other economies of scale work to the advantage of smaller dogs. Smaller dogs require smaller kennels and less food, and in a big operation the savings could be substantial. Because of their lower body mass overall, smaller dogs are less likely to suffer from the back and joint problems that most very large dogs experience, potentially reducing veterinary and downtime costs. Smaller dogs are also less likely than larger dogs to be perceived as threatening by the community or by potential handlers unfamiliar with dogs.

In contrast to some commonly-held beliefs, small dogs do not necessarily require less exercise or a smaller area in which to play than larger dogs, and they can be just as aggressive as larger dogs. Some small dogs, especially some terriers, are powerhouses of energy with an ego to match (Figure 9). Most of the very small dogs were bred either as toy dogs (a wide variety of breeds) or as hunting (vermin) dogs (the terriers, chihuahua, dachshund). Although many of these dogs are very good-natured and bond well with humans, it is rare to find one that handlers refer to as “trainable”. Thus, even if a small dog with a good nose could be found, other factors are likely to work against its suitability as an MDD.

Figure 9. A typical terrier in action!

Should the designer MDD be large? Hakimi (1999) indicated that large size was preferred, apparently because he equated size with stamina. In reality, stamina is more related to breeds than to individual size of dog — very large dogs can have impressive power, but they tend to tire quickly relative to working dogs in the middle size range. Any dog will have greater stamina if its fitness and agility skills are maintained at a high level, but the associated maintenance costs (mostly handler time) will be higher for a large German shepherd than for a working breed such as a kelpie, because of the higher natural fitness of the kelpie.

Apart from scale factors in nose design, the only benefit of large size is likely to be the ease with which a handler can keep track of the dog. Large dogs are easier to see in tall vegetation.

Two important disadvantages are: (i) that many large, heavier-bodied dogs suffer to some extent from back and hip problems, and (ii) the largest breeds tend to live for a relatively short time. Clearly, breeds of very large size should be avoided.

In reality, with health factors in mind it seems sensible to design an MDD in approximately similar dimensions to wild dogs. Wild animals represent the best possible test of a design, and most wild dogs range in size from foxes (about 10 kg, ignoring a few tiny species) to northern wolves (up to 40 kg, but more usually around 25-30 kg). Thus, the designer MDD should be in the 10-30 kg range, with a possible bias towards the smaller end of the range in order to facilitate economies of scale in large operations.

With respect to shape and height, a tall, slim-bodied dog might be acceptable for health reasons, but such dogs tend to be fast moving — not a desirable characteristic of an MDD. A dog with very short legs might move slowly, but is likely to suffer from back and joint problems. Overall, it seems most sensible to retain the shape as well as the size of wild dogs.

4. The cognition question – intelligence

A simplistic but useful view of how an animal interacts with the world is to consider two perspectives: (i) the world presents problems that need solutions (the cognitive framework), and (ii) the world provides rewards linked to actions (the operant framework). A straightforward review of these concepts can be found in O'Farrell (1992). The first option makes sense from a human perspective — problem-solving has even been cited as a characteristic that distinguishes humans from other animal species. Certainly, the question of whether animals undertake problem-solving is controversial (Nicol, 1995), although the problem-solving skills of various dogs have been compared (Scott and Fuller, 1965), as have wolves and malamute dogs (Frank and Gialdini, 1985); wolves were better than malamutes). The problem with this empirical approach has been one of designing experimental protocols that demonstrate problem-solving by animals while rejecting the two alternative (and apparently simpler) explanations that: (i) the animals are either responding in a stimulus-response way to cues in the experimental environment (i.e. the operant framework), or (ii) it is species differences that explain the results and the comparison is meaningless. These theoretical problems are of no relevance here, but they provide the background for alternative perspectives on the best design for an MDD.

When dealing with the world *cognitively*, an animal receives information, and assesses the meaning and quality of that information against a background of other similar experiences. It then uses the combination of current information and background experience to decide on a behavioural outcome, i.e. to make a decision about what to do in the current situation.

When dealing with the world *operantly*, an animal responds to a current stimulus in either a negative or a positive way, depending on relationships between the stimulus and associated rewards. No information processing is involved. However, the animal can learn that different stimuli are linked (A→B→C), and can tune its response to stimuli that occur reliably in its environment. To give a relevant example, a trained MDD has learned the sequence: "detect odour→sit down→receive ball". No understanding of the relationship between odour and ball is either implied or required, but because the ball represents a positive reward for the dog, it will express the stimulus-response sequence of "detect odour→ sit down" consistently and reliably.

Dyck (1999) referred to MDDs as requiring "courage". The word was undefined in his presentation, but the implied meaning appeared to be a mix of robustness, determination and exploration — a courageous dog had good stamina and motivation, and was interested in its environment.

More usually, the notion of "courage" is linked to bravery and risk-taking. The implication here is that the risk was understood and the danger was accepted because of the need to undertake some important task. Thus, rescue personnel are frequently called on to be courageous, because they must enter a danger zone. Their courage is tempered by their training, which gives them a highly-refined ability to assess risk and judge margins of safety, and their SOPs, which have been designed with safety considerations in mind.

Could an MDD be courageous in this second sense? In effect, the implication is that the dog understands the dangers represented by a minefield, and accepts the associated risks, as human mine clearance personnel do. Presumably, it would also act to minimise risk by developing appropriate SOPs.

This scenario is not as outrageous as it might initially seem. The Border collie is an extremely intelligent dog, and most people that work sheep with Border collies will argue that the dog "understands the problem". Once the dog understands where the handler wants the sheep to go, it will *assess* the behaviour of the flock, *predict* the behaviour of strays, *make decisions* about when to run and when to stop, *judge* when to move to the left or to the right, and generally get the job done with a minimum of commands. The words in italics here are the language of the cognitive framework. At least with respect to handling sheep, a good Border collie is potentially operating at a cognitive level similar to that of the handler. Watch sheep being worked, and it is not hard to conclude that disagreements between the handler and dog are often because the dog is right!

The intelligence of Border collies has been exploited in many other service contexts — e.g. as search and rescue dogs and as assistance dogs. There have even been a few attempts to train them as MDDs (one is currently operational in Cambodia, Figure 10). They have quite a good nose, a well-developed wish to please the handler, and they love to work. Yet they appear only rarely in any of these service roles, perhaps because too much down-time is involved, and Border collies need to work all the time.

a. The need for intelligence?

It is extremely unlikely that a dog already exists which could be trained cognitively as an MDD, similarly to how a Border collie learns to work with sheep (Border collies and / or standard poodles are the most likely candidates here because of

Figure 10. A Border collie at work as an MDD in Cambodia.

their intellectual skills). Of course, any dog able to understand the problem is likely to immediately refuse the work, for the same reasons that many humans would consider mine clearance to be an undesirable profession. Strictly, that problem would be overcome by breeding — the bred intellectual MDD would be motivated to search for mines in the same way that Border collies are motivated to exhibit rounding up behaviour. For Border collies, "understanding the problem" really means that they have the intellectual ability to understand and predict the behaviour of sheep (see a similar argument made about the intellectual skills of sheep in Kendrick, 1997). It does not mean that they understand why the farmer is moving the sheep from one field to another. In the same sense, the intellectual MDD does not need to understand the dangers represented by mines. Rather, it needs to understand that mines occur unpredictably, have a characteristic odour, and should be treated with caution when found. In other words, it will have the ability to predict the behaviour of mines, if such a concept makes any sense.

Although unlikely, the possibility of undertaking cognitive training with an MDD is raised here for two reasons. First, in the interests of completeness — the concept may have some application in the future even if it is unrealistic now. Second, because it focuses attention on the value or importance of intellectual skills in the designer MDD.

The usual training approach with MDDs does not utilise the cognitive or problem-solving perspective described above. No attempt is made to train MDDs to "understand the problem". Rather, searching for that elusive odour is developed as a game. The game has some very specific rules involving how and where to walk, required intensity of concentration, and appropriate behaviour when the odour is found. From the dog's point of view, the aim of the game is to manipulate the handler to provide a desired object, such as a toy with which the dog is obsessed as a result of previous training. If food rewards are used, then the aim is to manipulate the handler into providing a highly desirable treat. Here, the approach is strictly operant. The cognitive potential of the dog could even work against the training objective if the dog is clever enough to understand that the handler can be tricked into providing the reward.

Intelligence is not a requirement for an animal functioning in an operant environment. Demonstrations of conditioned responses can be found for virtually all animals (down to unicellular organisms) and even some cellular preparations (Turkann, 1989), suggesting that stimulus-response learning is a fundamental feature of nervous systems. However, dogs are intelligent creatures relative to most animals, and intelligence may make a difference to the quality or subtlety of learning that can be achieved in a stimulus-response environment.

Both Dyck (1999) and Hakimi (1999) identified intelligence as an essential feature of an MDD, probably because intelligence was perceived as being linked to trainability. However, it seems likely that these authors were not talking about dogs in general when they noted the requirement for intelligence in an MDD. They were talking about the breeds they knew best as MDDs — German shepherds and Malinois (henceforth called the shepherds). In this context, they are probably right. Intelligence is an important requirement if individuals of these breeds are to be effective as MDDs. Why? Because the shepherds are derived from general purpose working dog lines. They were not bred for the purpose of mine detection (or, more generally, as detection dogs). Their training as MDDs will therefore require learning of a complex and unnatural array of skills with very high reliability. That training objective is more likely to be achieved with an intelligent dog, because, on average an intelligent dog is likely to have higher trainability for unnatural tasks. The shepherds have an additional characteristic that lends itself to the training problem: they bond strongly with humans and have a strong desire to please. That bond makes them more willing to undertake whatever task a handler asks of them, and with very high reliability once they understand and have practiced the task. With these breeds, the operant context of learning (a game) is just one of several incentives that generates motivation and reliability.

It does not automatically follow that the requirement for intelligence in the shepherds as MDDs predicts intelligence as a requirement in any breed used as an MDD. If intelligence were so important as a general feature, then surely there would be more Border collies and standard poodles used as MDDs. Lockwood (1999) and Almey (2001) provided one explanation for their absence: a bias towards shepherds in the training background and experience of the people that train MDDs. Lockwood was careful to emphasise that the comment was not meant critically — it makes sense for trainers to work with the breeds they know, and there is no doubt that the shepherds make effective MDDs. A second possibility is that Border collies and poodles have been tried, and found to be unsuitable for other reasons, such as high activity levels or an inadequate nose. There is almost no evidence for this second suggestion.

Here is an alternative perspective on intelligence in the designer MDD. The more motivated a dog is to perform a task, the less need there is to train that dog to undertake the task. Many dogs currently kept as pets were actually bred for specific purposes, and frequently express bred behaviours in inappropriate contexts because the appropriate context is unavailable to them. A pointer that points leaves in the garden, or a Border collie that rounds up the children, is amusing. But a fighting dog that bites is dangerous and unacceptable. Blocking the expression of bred behaviours can be very difficult, and dogs are destroyed every year simply because they express bred behaviours in inappropriate contexts. The relevant point here is that such behaviours represent very high motivation for a task. If a dog can be bred to exhibit most of the behavioural requirements needed in an MDD with determination and reliability, then there will be little need to train either motivation or a complex array of unnatural tasks, both of which require extensive training in the shepherds. The only training problem with the bred MDD will be to direct naturally expressed behaviours into a particular format, presumably using operant techniques. There would be little or no need for such a dog to be intelligent in the sense that shepherds need to be intelligent.

Few if any breeds have been created specifically for dangerous service roles, despite the mythology surrounding the St. Bernard. However, some breeds do undertake potentially dangerous service work with dedication and enthusiasm. The Newfoundland has the (unfortunate!) tendency to pull anybody from the water whether or not they need to be rescued. Stock guarding breeds, such as the maremma, Briard and Balkan shepherds, will fight to the death to protect their charges. Such dogs are not usually noted for either their trainability or intellectual skills — it is their breeding that dedicates them to the role. If such breeding outcomes can be achieved in those contexts, then why not for mine detection? Perhaps a dog already exists which exhibits most of the bred characteristics needed in an MDD.

7. Behavioural opportunities: behavioural features of MDDs

The discussion so far has focused on general features of an MDD. Such features form the background to the specific problem — one of creating a dog that expresses a carefully constructed behavioural repertoire in a reliable manner.

1. Types of MDD operational today

Currently at work today, there are four behavioural types of MDD:

- ***Unleashed*** (also called free-running) dogs search for mines without being under the direct physical control of a handler;
- ***Long-leash*** dogs (Figure 11) are linked to the handler by a line, but may work at distances up to 10 metres away so are operating semi-independently;
- ***Short-leash*** dogs (Figure 12) work alongside a handler while controlled on a short line (a typical leash);
- ***REST*** (Remote Explosives Scent Tracing) or *MEDDS* (Mechem Explosive and Drug Detection System) or *EVD* (Explosive Vapour Detection) dogs (Figure 13) may be leashed or unleashed, but they have a very specific task: to check a series of samples for the presence of odour from mines.

Although each of these dogs must learn a different behavioural repertoire, there is also considerable overlap in their required skills. They must all learn to (i) distinguish from the background specific odours that indicate the presence of a mine; and (ii) give a signal when the odour is detected, usually by sitting down. All except the REST dogs must (iii) exhibit high levels of responsiveness as a safety factor; and (iv) have good fitness and stamina.

Unleashed dogs have the most autonomous control over their behaviour. They are frequently used for preliminary surveys and for back-up checks after a human search team has moved through (Joynt, date unknown), although they may also be used to search in a box construction. Thus, unleashed dogs can be used in a variety of contexts, requiring different skill factors. When doing preliminary or backup survey, they might not be expected to cover 100 per cent of the ground and may be free to wander reasonably widely. But if searching in a box construction they may be required to operate with the same intensity and

Figure 11
Long-leash dog.

Figure 12
Short-leash dog.

Figure 13
REST dog.

completeness of ground cover as long-leash dogs. They may also use search patterns other than lines (such as a 'figure 8'). If unleashed dogs cover only some of the ground, the main requirements are the four listed above, because search patterns are relatively unconstrained. Theoretically, any dog with a nose good enough to distinguish the odours of mines, which is motivated to sniff at everything in its path, and is capable of developing reasonable responsiveness, will be able to function as an unleashed dog. But if the required search patterns and skill factors are equivalent to long-leash dogs, then the same requirements and limitations will apply (see below).

Long-leash dogs are required to learn the most complex and highly-structured (=unnatural) behavioural repertoires of all the MDDs. In general, the SOP is to walk slowly along a line, concentrating intensely on the nose which must be continuously to the ground. Unless trained to search in both directions, they must turn one way (usually left) when called back to begin a new line. The lines must be straight and narrow, although casting back and forth by the dog is acceptable to widen the line, as long as it is done consistently. The dog will sometimes be asked to recheck a line if the handler believes it was not searched properly, and such a check must be carried out with the same intensity as searches of new lines. Despite being connected to the handler by a line, long-leash dogs operate almost as independently as unleashed dogs, but their actions are extremely constrained. They may be asked to undertake the first search in a minefield, and are frequently used for area reduction (in which case they are expected to encounter mines). On average, they are exposed to the greatest risks of all the MDDs, and their reliability and intensity of search must therefore be of the highest quality. Dogs suitable for this role are likely to be the most difficult to find.

Short-leash dogs walk alongside or in front of the handler, but must otherwise exhibit the same intensity of search as long-leash dogs. In principle, they do not need to learn to walk a line or to move slowly, because their direction and speed of movement are under the direct control of the handler (in practice, they will learn to search slowly and carefully along a line as part of their training). Thus, the main requirement apart from the four above is intensity of search. Many short-leash dogs began their training as potential long-leash dogs, but failed to meet the requirements of consistency in independent action. As a result, it is likely that short-leash dogs will be easier to find than long-leash dogs.

REST dogs work in a completely different operational context to the other MDDs. They do not work in minefields and are exposed to no risk. Issues of behavioural responsiveness are therefore of relatively minor concern, although they must learn to give a signal when an odour is detected, and responsiveness to the handler will be required to facilitate both training and operations. The primary requirement for a REST dog is an excellent nose and a willingness to sniff at objects (jars containing samples). It is unlikely that the noses of REST dogs *need* to be better than the noses of the other MDDs, but on average REST dogs probably have finer discrimination skills because of more concentrated and focused training, and more extensive maintenance training. As a consequence, the odour discrimination skills of REST dogs potentially provide a standard against which the other MDDs could be tested, in order to investigate the amount of maintenance training required for operational MDDs. Certainly, REST dogs of the standard breeds (the shepherds) have been trained to signal odours reliably at impossibly low vapour pressures (Hayter, 2000; Joynt, date unknown). The task for REST dogs is repetitive, but they work for short periods and have long breaks (while other dogs check the same targets). Thus, REST dogs do not need the stamina and motivation for a repetitive task required of the other MDDs. The designer REST dog can therefore be a very different animal to the other MDDs, even if it is of the same breed.

2. Behavioural requirements in operational MDDs

Reviewing the comments above, the following behavioural characteristics of an MDD can be identified:

- **Nose to ground;**
- **Consistency of repetitive action;**
- **Responsiveness to the handler;**
- **Endurance;**
- **Focus;**
- **Slow-moving.**

Note that the notion of "drive" is not listed here because it is obtained as a combination of several of the listed characteristics.

All six of these characteristics can be trained into a dog, and are routine training objectives for current MDDs. They must be primary objectives of both the original training programme, and the maintenance training undertaken for any operational dog. It is known that they can be achieved for the shepherds. Might they be obtained as efficiently or effectively in other breeds?

With the possible exception of responsiveness, it is possible to find many breeds that naturally exhibit any one of these features more reliably than (untrained) shepherds. As a generalist bred from a working dog background, shepherds have the potential for undertaking a wide variety of tasks, they are relatively intelligent and trainable, and they have good natural responsiveness because of a willingness to please. But the entire behavioural repertoire needed by an MDD must be trained into a shepherd. Here are some examples of these behavioural characteristics in other breeds.

Most scent hounds will focus the nose on the ground much more consistently than the shepherds, who routinely use a mix of sight and smell when investigating their surroundings.

Probably in part because of their large size, the shepherds are not high-stamina dogs and do not have high natural fitness. They tend to lose fitness and endurance capacities quickly relative to smaller breeds, particularly working breeds such as Border collies or kelpies, and the terriers. Put another way, fitness and endurance can be maintained in the shepherds, but at considerable cost in time and effort relative to many smaller breeds.

As intelligent dogs, shepherds rapidly become bored with repetitive actions unless tricked (actually, conditioned) into undertaking the repetitive actions for a carefully contrived reward (the game concept). Because of their obsession with the nose, the scent hounds in particular will maintain the repetitive action of "focus on nose to ground" for much longer periods than the shepherds. Scent hounds are not usually noted for their intelligence, although whether that is of any advantage in relation to the repetitive nature of the MDD SOP requires further investigation.

Natural rate of movement is a more difficult concept to make comparisons about in this context. Dogs that walk naturally at the slow pace preferred in an MDD tend to be either small, or with short legs. Both of these features were rejected above as acceptable characteristics of an MDD. If given the choice, most dogs will lope rather than walk (unless they are tired), and loping is too fast a rate of movement in an MDD. If a dog prefers walking to loping because of laziness or low fitness, then it is unlikely to be acceptable as an operational MDD. Probably, a preference for a slow walk as the natural pace is a characteristic that will be found in some individual dogs of many breeds, and it may be no more or less likely in the shepherds than in many other breeds. Naturally high-energy dogs such as working dogs and terriers are likely to provide few if any candidates exhibiting this characteristic. But hunting dogs such as Labrador retrievers are required to exhibit patience, and are good candidates.

The issue here is not so much one of whether particular dogs or breeds exhibit particular characteristics, but one of optimising all of these characteristics in one package. The shepherds represent one example of such an optimisation exercise. In the shepherds, trainability and generality of behavioural potential are the primary features that optimise their capability as MDDs. Are there alternative packages with equivalent or better potential?

8. Genetic opportunities – existing genetic resources in dogs

To date, there has been no attempt to breed specifically for an MDD (or for any detection dog, Almey, 2001). A few cross-breed experiments have been undertaken. For example, cross-bred shepherds x village dogs were produced in Afghanistan and some training was attempted with these dogs. Unfortunately, the dogs were not subjected to further breeding and selection beyond the F1 (first) generation, and none became operational. An attempt to train village Cambodian dogs as MDDs by the Swedish armed services was similarly unsuccessful, and did not progress as far as a breeding programme. For operational convenience, many trainers of MDDs sterilise their dogs at an early age, so would be unable to breed from an unusually good dog even if they were motivated to do so.

The literature on the behavioural genetics of dogs has few specifics to offer. However, five things are reasonably clear (Elliott and Scott, 1963; Reuterwell and Ryman, 1973; MacKenzie et al.; 1986; Goddard and Beilharz, 1986; Goodwin et al., 1997; Price, 1999).

- Dogs have retained many of the behavioural characteristics of wolves.
- The process of domestication has resulted in a progressive loss of wolf characteristics, which varies across breeds.
- Heritability of behavioural characteristics is low.
- Heritability of even apparently simple behavioural features is complex.
- Breed characteristics (including behavioural characteristics) show reliable heritability, but the predictability of behavioural outcomes in cross-breeds is low.

On even these five issues, contradictory results can be found in the literature (e.g. Scott and Fuller, 1965, found low behavioural variability amongst breeds, but more recent work clearly contradicts their result: Bachem's 2001 results suggest higher heritability of behavioural characteristics than is usually found).

At least two of these results are contradictory: some breed characteristics (which breed true) are behavioural, and yet behavioural characteristics have low heritability. These results really mean that the heritability of behavioural characteristics is a complex process with low predictability. They imply that any attempt to produce and stabilise a cross-bred dog for mine detection purposes will require an extensive breeding programme and some (many?) generations. On the other hand, the objective of stabilising behavioural characteristics in a cross-bred strain has been achieved many times in the past, and is presumably possible again with enough time and motivation. It might even be argued that the predictability of behavioural characteristics in a cross-bred dog will be as high as in a pure-bred dog (although most breeders would probably disagree).

An alternative perspective is to exploit the general observation that individual dogs exhibit considerable within-breed variability in behaviour (Fox, 1971; Plutchik, 1971; Goddard and Beilharz, 1985). This approach has been tried for decades in some breeding programmes for service dogs. Unfortunately, despite fairly strong evidence that developmental experiences (rather than genetics) drive individual variability, there is very little understanding of the source of that variability and no understanding of how it might be effectively manipulated. Bland generalisations about social issues within the litter and influence of the dam (e.g. Wilsson, 1984) provide hypotheses, but little predictability. Available reports of attempts to pre-select puppies that will exhibit desirable characteristics in an adult dog usually indicate some success, but considerable unreliability of outcome (Scott and Fuller, 1965; Reuterwall and Ryman, 1973; Goddard and Beilharz, 1986; Wilsson and Sundgren, 1997; Slabbert and Odendaal, 1999). Certainly, any programme of breeding for the designer MDD should also include extensive analysis of behavioural issues with the aim of predicting behavioural outcomes. But the current evidence is that the process is unreliable. Thus, both breeding and behavioural prediction should be used.

Ignoring the problems of how many generations are required to stabilise the breed and the number of dogs that will be discarded along the way, it is worth asking whether the desirable features needed in an MDD are available. The features were listed earlier. The dog must have a good nose, have a high natural motivation to search, have high natural fitness, exhibit a willingness to work at repetitive tasks for long periods, and be slow moving. Disease resistance might be obtained from local village dogs. “Pointing” exists as a genetically-programmed behaviour, so could be introduced into the line. Although not central to the mine detection role, a naturally gentle and non-aggressive nature would facilitate management of the dogs. Nevertheless, some trainers of MDDs appear to prefer naturally dominant and / or aggressive dogs.

Unfortunately, breeds that “point” tend to be lithe, fast moving, air-scenting dogs that range widely while hunting and have a highly-strung temperament (“requires gentle training” can be found in Fogle’s descriptions of most pointing breeds). Some have been successfully trained as search dogs and one is currently operational in Cambodia as an MDD, but they work best where large distances need to be covered in a relatively unstructured way. It might be difficult to separate pointing behaviour from these other unwanted behavioural and morphological characteristics. Breeding in disease resistance from village dogs without also introducing a wide range of unwanted behaviours (due probably to a combination of low trainability, limited motivation and determined independence of action), might also be difficult, but is worth trying. It would also be worth investigating whether village dogs could provide disease resistance through a process of inoculation rather than breeding.

The reality is, that except for disease resistance and pointing behaviour, all of the above features can already be found in one package. Apart from the beagle, a number of dogs from Scandinavia and the Balkans could be suggested, but all are designed to exhibit approximately similar characteristics. The Scandinavian drever (loosely translated meaning "drive") is an excellent example (Figure 14). Here is Fogle's description (2000:177): "The drever has a first class nose and is a powerful tracker … it often wants to continue working long after its human companion is satisfied … it is slower than other hounds". The drever is also an excellent companion and good natured house dog, and exhibits low aggression. Fogle notes that these dogs can be "overzealous". The relatively short legs of this breed appear to contradict the argument made above that the body shape should be "standard dog". However, the health of this breed has been thoroughly tested and it exhibits no known problems. Additionally, there is one wild species (the African bush dog) with similarly short legs.

Figure 14. A Scandinavian drever. Literally translated, the name means "drive".

As has been described above for the beagle, drevers are noted for willful and determined behaviour rather than for trainability. As MDDs, they would certainly have to be worked on a leash, probably a short leash. Whether they can be trained or bred to exhibit the reliability required of a long-leash or unleashed dog remains to be seen. Whatever is possible as a result of breeding and experimental training in the long-term, they already appear to have the nose required to allow discrimination of the odours provided by mines, and the dedication to the task that ensures good productivity. Their love of food will be easily exploited in operant designs for training odour discrimination and indication behaviours.

Two important and unanswered questions will require testing with such dogs:

- First, can dogs bred for tracking transfer their skills to searching for an odour that appears unpredictably, and is never available as a trail? Once a scent trail has been located, tracking involves a process of constant reinforcement due to the regular or continuous nature of the trail. Mines will never offer that possibility.
- Second, can such dogs focus on the search for mines and not be constantly distracted by scent trails leading to game? Dealing with this issue might require some imaginative odour-imprinting work, including discouraging interest in the odours provided by game.

Ultimately, these issues might be the most difficult to resolve in the development of a scent hound for mine detection work.

Global Training Academy, Texas: German shepherd in training.

9. Other issues

1. The operational situation for thedesigner MDD

The current SOPs for MDDs have been developed with current MDDs in mind — essentially the shepherds. These SOPs work reasonably well for those breeds. However, the objectives of the SOPs, and the appropriateness of their operational design for particular breeds, should not be confused. The fundamental objectives are to ensure complete coverage of the ground by the dog's nose in the safest possible way. It may well be that the operational capacity of the designer MDD will be optimised using a different SOP to the designs typically used with shepherds.

As awareness about, and acceptance of, different ways of using dogs in a mine detection role increase in the future, operational procedures will evolve. For example, a wider acceptance and implementation of REST dogs for area reduction will have several desirable consequences. It will allow a more targeted use of field dogs to search for mines known to be present, but at fairly low density (dogs are not generally used where mines are at high density). If the field dogs are only searching where mines are present, then safety and reliability factors should be improved because the hit rate will be higher (providing an effective reward structure for the dog), and handlers will not suffer from the lapses of concentration known to occur when mines are not encountered for long periods. In this scenario, field dogs will have a more focused role in the toolbox, potentially allowing a more precisely defined training and operational programme.

If used in conjunction, dogs that are of very different breeds potentially offer a greater detection capacity overall. Currently, a boxed area is usually searched by two dogs of the same or similar breeds, which have had similar training and use the same search technique. If one dog misses a mine, then the likelihood that the other dog will miss the same mine is correlated, because they have the same skills and training. If two different types of dogs are used in different ways, then the problem of correlated misses should be decreased.

The implication that there is value in using different types of MDDs is inescapable. Thus, a designer MDD developed from a scent hound such as a drever might not replace the shepherds currently used, but may work alongside them. Ultimately, the most effective test of a designer MDD will be to work it alongside dogs that are currently operational. Only through doing such tests will the real potential and appropriateness of such a dog be thoroughly investigated.

2. Designing a handler

Throughout this analysis the question of the role of the handler has been ignored. However, it is widely recognised that the handler has a critical role to play in the operation of an MDD. Perhaps the discussion should have been about the dog/handler team, rather than the dog per se.

The trainers of African pouched rats for mine detection work pointed to the complete absence of relationship with a handler as a *benefit* of their detection device (APOPO, 2000). Pouched rats are trained to respond to particular odours by giving an unambiguous signal. They have no interest in, or bond with, humans, so will not rely on interaction with a handler to assist them in making a decision. With dogs, it is usually argued that a good handler makes for a better detection team, and it seems likely that a good dog/handler team will give more reliable mine detection than will a pouched rat (at least under most circumstances). Managers of mine clearance operations put considerable thought into the problem of matching the personalities of dogs and handlers in order to optimise the working relationship. Any handler will have been given extensive training about management of a detection dog, will understand the basics of learning theory, and will be able to administer maintenance training. However, their qualities as a handler depend on factors that are subtle, and may be unmeasureable. Relevant factors are ability to read the dog, understanding of the dogs current needs, dominance relationship with the dog, and ability to allow the dog to make independent decisions without influence.

The issues listed above represent training and management costs that might be avoided if pouched rats were used. More relevant here, is that those costs might also be minimised if taken into account when creating the designer MDD. A potential benefit of a scent hound such as the drever is that it does not depend on the human/animal bond as strongly as the shepherd breeds. Certainly, it will have a different working relationship with its handler, and might be more readily transferred between handlers, than the shepherds. It is likely that training requirements for a handler of a drever will be quite different to those for a shepherd. If the differences generate operational efficiencies, then those savings count as an additional benefit of the designer MDD.

An objective of most programmes producing MDDs is to use local people as handlers for operational dogs. An ultimate but more difficult objective to achieve in third world countries is to have all training and operations undertaken and managed by locals. Any adjustment to the designer MDD that makes training and operations simpler, and less reliant on issues such as the subtleties of the dog/handler relationship, must be viewed as a benefit in terms of the potential for achieving local control.

3. Maintenance training

Conversations about training issues tend to focus on the requirements for the original training of an MDD. Equally, and possibly even more important, is the issue of how much maintenance training is required once the dog is operational. In general terms, there are two issues to be addressed: maintenance of the dog's odour discrimination skills, and maintenance of its operational skills.

There is some good news. Using eight shepherds trained to discriminate odours of various explosives, Williams et al. (undated) found first, that dogs retained learned odour discrimination skills for long periods (up to 120 days without reinforcement), and second, that learning of new odours has no impact on the ability to discriminate previously learned odours (up to 10 different odours). Williams et al. suggested that the main maintenance training requirement will therefore be for other operational skills (responsiveness to the trainer, search pattern, etc), because learned odour discrimination is robust. Although the results are promising, the experimental dogs were not operational during each period of “downtime” (15-120 days), so there was no opportunity for learned discriminations to be confounded by operational experiences — the possibility that dogs working daily in a minefield relearn their odour discriminations because of reinforcement errors (false indications are rewarded, real targets are detected but not indicated or rewarded). Overall, the research supports the notion that little maintenance of odour discrimination skills is required, but the operational manager still needs to be concerned about the possibility of accidental detraining of learned odour discriminations.

The question of how much maintenance of operational skills is required, particularly of responsiveness to the handler and the SOP, is more difficult to address. In practice, assessment of these needs is made daily by the handler. The costs are potentially quite high. As an example, in the Norwegian People’s Aid dog programme in Bosnia and Herzegovina the handlers work a five-day week. Monday is assigned as a training day and the dogs are given a small amount of reminder training every day. Thus, more than one-fifth of operational time is spent on maintenance training. Clearly, any designer MDD that minimises the needs for maintenance training will have significant benefits for operational capacity over the eight to ten-year working life of the dog. The most likely mechanism for achieving this objective is to minimise the amount of training required overall. Dogs that come pre-programmed to exhibit many of the required tasks needed in an MDD offer that potential.

4. Gender and aggression

A review of gender issues in pure-bred dogs of 49 breeds indicated clear gender differences: male dogs are more likely to exhibit aggression, and are more immature as adults; females are more cooperative, more demanding of attention, and easier to train (Bradshaw et al., 1996). Summaries of reports to clinics about behavioural problems support the general pattern of males exhibiting more territorial aggression towards people and other dogs (Borchelt, 1983; Wright and Nesselrote, 1987; Sherman et al., 1996). However, females can be very aggressive towards other female dogs, especially within-house (i.e. within-pack), and within-pack dominance aggression between females has the highest probability of serious injury. No consistent breed-related patterns were reported in these studies, although German shepherds routinely rate as exhibiting high levels of aggression, and the “sporting dogs” tend to rate low. Anecdotal reports suggest that management of aggression by Malinois is even more difficult than for German shepherds, although any difference has not been documented.

One study found that females showed higher levels of olfactory exploration than males (Goddard and Beilharz, 1984).

Desexing had little impact on behavioural problems in the published work, although the belief that desexing can make a difference is widely held.

Behavioural issues such as aggression may represent a management issue in a mine clearance programme, but have little direct bearing on operational issues. In fact, higher levels of aggression by males is usually linked to notions of "courage", and is often cited as a positive feature by trainers of detection dogs (see comments from practitioners in section 5 of Chapter 9, and in section 1 of Chapter 6 on trainability). This view is voiced consistently by trainers of police and military dogs, who do not appear to regard the more cooperative, obedient and trainable nature of females as a benefit. One practitioner indicated no gender preference when selecting an MDD.

5. The views of practitioners

The views of 31 agencies and individuals were canvassed in a written survey during the process of preparing this report. Although only four written replies were received, others were received verbally, and all of the comments are valuable. The commentators were asked to reflect on why the shepherds were the preferred breeds for training as MDDs, and to make comparisons with other breeds. All commentators indicated extensive experience at training and working with detection dogs, and some to extensive experience with MDDs.

Clear in the comments was the view that the shepherds were excellent all-purpose dogs that exhibited courage and were willing to protect the handler. One respondent indicated that the tendency towards protectiveness might be a disadvantage in a minefield. It was their trainability for almost any purpose that made them the dog of choice for training as MDDs. None of the respondents felt that the dog needed to be "large", and one indicated a preferred weight for the shepherds in the 25-30 kg weight range. It was generally agreed that a selection process would be required to identify individual dogs particularly suited to the task of mine detection, and that many individuals would not be suitable.

One respondent felt that a dog suited to being an MDD needed to be reasonably large because of nose issues, but otherwise indicated no preference for a particular breed — the needed qualifications for mine searching can be found in "ordinary normally healthy dogs". Two respondents felt that it was easier to find good German shepherds than good Malinois, because of the more nervous and protective nature of the Malinois.

Two respondents indicated a preference for breeds other than shepherds as MDDs, one indicated no preference, and one preferred the shepherds. One respondent indicated that Labrador retrievers were preferred over the shepherds as MDDs or EDDs — they have a "better nose, better concentration and good motor". It is important to obtain dogs from "hunting" rather than "show" strains — the hunting dogs exhibit such a high motivation to search that the ball should not be used because it generates too much stress (= excitement). The same point was made by one of the trainers referred to at the end of this section, who also works with breeds other than shepherds.

One respondent with a very broad training experience focused on the reasons why breeds other than the shepherds were *not* preferred. Pointers could not be slowed down or trained to a structured search pattern. Doberman pinschers had many drawbacks (including health). The beagle and bloodhound were too independent, especially at distances from the handler. The bloodhound in particular was only interested in tracking. Cairn terriers were almost untrainable and developed no rapport with the handler. The Bouvier des Flandres was only suited to protection work and represented a major maintenance problem. The Rottweiler was too territorial, and very dependent on the handler once rapport was developed.

This respondent went on to list the qualities of the shepherds (German and Dutch shepherds, Malinois and Belgian turvuren). The listed qualities related more to trainability, protection and general purpose police and detection work than to mine detection specifically. Bonding with the trainer/handler was easily achieved and important. Labrador and golden retrievers were both indicated as making good detection dogs, although no specific comments were made about skills that would make them desirable for mine detection purposes.

Two of three trainers of MDDs interviewed verbally indicated that breeds other than shepherds were likely to be better as MDDs (the third had no opinion), and all three indicated that other breeds should be tested.

The overall pattern in these comments strongly supports the notion that training of dogs other than shepherds as MDDs should be attempted. "Hunting" strains of the Labrador retriever should certainly be tried.

Table 2. A tentative scaling of breeds using categories relevant to the design of a mine detection dog.

Assignment is necessarily subjective and speculative, and in some cases is unknown. A high value (4) indicates that the breed offers good potential or capabilities for that feature. A low value (1) indicates the breed is difficult or poor on that feature. High, medium and low are used to indicate the breed will be difficult (high) or easy (low) on that feature. Most of the breeds are self-explanatory, but “cattle dog” refers to an Australian breed (blue or red heeler) that was specifically bred in recent times to include the genes of wild dogs (dingos). G.S. pointer refers to German short-haired pointer. Schnauzer refers to the medium-sized mittelschnauzer, and not to the giant form, which is a very difficult dog to handle and manage. The Lagotto Romagnolo is an Italian breed purpose-bred to search for truffles. Where “show” and “working” varieties exist within the one breed (e.g. labrador, spaniel), it is assumed that working varieties would be used. The breeds are all either general purpose working dogs (including for protection), purpose-bred dogs for farm support, or sporting dogs bred for scent work and/or retrieving. The last two breeds are relatively rare, and procurement would be a problem if they were chosen for future development as an MDD.

	Malinois	German Shepherd	Border Collie	Cattle dog	Drever	Beagle	G.S. Pointer	Labrador	Springer Spaniel	Schnauzer	Lagotto Romagnolo
Nose	3	3	2	2	4	4	4	4	4	3	4
Trainability	4	4	4	3	1	1	1	4	2	2	
Work motivation	3	3	4	4	4	4	4	3	4	3	3
Natural fitness	2	2	4	4	4	3	4	2	4	3	3
Repetitive tasks	2	2	1	2	4	4	4	3	3	3	
Climate tolerance	3	2	3	4	4	3	2	3	2	3	
Disease resistance	2	2	3	4	?	2	2	2	2	2	
Presentation	1	1	3	2	3	4	2	3	4	3	3
Size and shape	3	3	4	4	2	4	2	3	4	4	
Intelligence	3	3	4	3	2	2	1	3	3	2	
Overall health	2	2	4	4	4	2	2	3	3	2	
Maintenance training	high	high	med	med	low	low	med	high	med	med	
General nature	high	high	med	high	med	low	med	soft	med	med	
Aggression	high	high	med	med	low	low	med	low	med	med	

10. Conclusion

The points raised in this analysis are summarised in Table 2, and are linked to a range of dog breeds, including breeds used in many working roles. Breeds produced strictly as companion animals have been ignored. Judgements have been made about the quality of particular characteristics offered by each breed for mine detection work, but assigning a rating to the need for that characteristic was not attempted. Readers will make their own judgements. As an example, a dog that rates highly on every requirement except the nose cannot make an effective MDD, because the nose is an essential requirement.

The overall conclusion of this analysis is that there are potentially four routes to producing an MDD.

- ***Route 1***, is to emphasise trainability and intelligence, use a general purpose working dog with a good nose, and give it all of the skills that it needs in a mine detection role using operant training procedures. Such dogs are the current dog of choice and are already used successfully in mine detection work. However, they have a high training overhead and may be sensitive to ongoing maintenance training issues. Maintenance of their skills is a critical issue and may be difficult using handlers with little understanding of dogs and the principles of learning.

- ***Route 2*****,** is to choose breeds that already exhibit most of the characteristics needed in an MDD, and use operant training procedures to adjust the expression of essential behaviours in order to ensure safety and 100 per cent ground cover. The development and use of such dogs may require adjustments to operational SOPs and maintenance training procedures, relative to current practice. Such dogs offer several possibilities for improving training and operational efficiency relative to route 1, and might be easier to hand over to inexperienced handlers. Ultimately, they may be used alongside dogs produced using the principles in route 1, rather than as replacements. Breeds offering potential for development as route 2 dogs already exist and the cost and time frame for testing and development are realistic. Some are already in use as REST dogs: e.g. spaniels are currently being used by NOKSH AS, and Labradors are used by Norwegian People’s Aid in Angola and Mechem in South Africa (personal observation). There have been too few attempts to train such dogs as field-search dogs to assess their viability.

➢ ***Route 3***, is to emphasise intelligence and use a cognitive or problem-solving training approach. The production of such a dog will require considerable breeding and experimentation with training procedures, as well as an imaginative approach overall. Currently, this is the least realistic option because of the research and development required.

➢ ***Route 4***, is to breed for the essential characteristics needed in an MDD. Once created, such a dog would then become a developed version of a Route 2 dog, and would be used in the same way. Significant development costs would be involved, in part because the training programmes for these dogs would require considerable experimentation. However, the principles underlying such development are well-known and the only blocks to establishment of such a breeding programme are motivation and resources. A proposal to undertake such a development programme already exists (see: <www.ustk9.com/landmine.htm>).

Clearly, some investment in R&D will be required if the designer MDD is to be created. The obvious preliminary experiment is to select a range of breeds that fulfill as many of the requirements discussed in this analysis as possible, and attempt to train them in a mine detection role in a controlled way. Labrador retrievers and a medium-sized scent hound such as the drever, are two obvious choices. Other likely candidates include beagles (which are faster-moving but otherwise similar to the drever), the Lagotto Romagnolo (the Italian-bred working dog used to search for truffles), pointers, the standard poodle or Border collie (one of these very intelligent breeds should be tried), springer spaniels and schnauzers. All of these breeds are used in search roles and / or as REST dogs, and a few individuals of most have been trained as MDDs in the past. The cross-bred "labradoodle" has had some success as a support dog for handicapped people, and is also a likely candidate. The experiment would need to include either or both of German shepherds and Malinois (effectively as controls), and a broadly-based experiment would include some random-sourced cross-breed dogs as another control.

Through such an experiment, the operational potential of the dogs will be explored, and the opportunities and limitations of their capacities for mine detection will be more carefully considered than is currently the case. If a breed that offers potential as a route 2 dog shows promise, then further breeding can be used to improve the line. But it would be desirable to establish the dogs in an operational capacity as well, ensuring that breeding and development are closely linked to operational needs. Clearly, therefore, sterilising these dogs at a young age is not an option.

The message in the literature is that attempts to use behavioural features of young dogs to select individuals with potential for mine detection work will have only moderate success. Such procedures have been used for decades in attempts to select service dogs, and although some success is always reported, there is no evidence of any improvement in selection success through time. It is clearly time for some diversification in the techniques used for choosing and training dogs for a mine detection role, and for investment in R&D to support that diversification.

Here is a view of the future:

- **First, *REST dogs* are used for area reduction and to identify the general locations of mines, potentially in a large box construction.**

- **Second, *route 1 dogs* are used on long leads to search for mines in areas where they are known to be present (the REST boxes would probably be subdivided for this purpose).**

- **Third, *route 2 dogs* are used on short leads for the second box search, and as a final clearance check before the ground is declared safe. Some form of mechanical clearance might be used between the first and second steps. The work of manual deminers will be reduced to clearing safe lanes during box construction, removing the mines found by dogs, and clearing mines in high-density areas or areas widely contaminated with explosives, where it is inappropriate to use dogs.**

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Index

Glossary

EDD	Explosive and Drug Detection
EVD	Explosive Vapour Detection
GICHD	Geneva International Centre for Humanitarian Demining
MDB	Mine Detection Bird
MDD	Mine Detection Dog
MEDDS	Mechem Explosive and Drug Detection System
NPA	Norwegian People's Aid
R&D	Research and Development
REST	Remote Explosives Scent Tracing
SOP	Standard Operating Procedure

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