Available online at www.sciencedirect.com
SCIENCE DIRECT®
ELSEVIER
Applied Animal Behaviour Science 84 (2003) 297–305
APPLIED ANIMAL BEHAVIOUR SCIENCE
www.elsevier.com/locate/applanim

Directional tracking in the domestic dog, *Canis familiaris*

Deborah L. Wells*, Peter G. Hepper

Canine Behaviour Centre, School of Psychology, Queen's University Belfast, Belfast BT7 1NN, Northern Ireland, UK

Accepted 7 August 2003

Abstract

The ability of dogs to determine the direction of a track has been subject to little study. We conducted two experiments to examine the ability of dogs to identify the direction of human-laid trails and explore the mechanisms by which dogs determine directionality. Experiment 1 investigated the influence of canine sex and age on the ability of 22 police dogs to determine the correct direction of 10 human-laid trails. The direction in which the trail was laid on the dogs' ability to determine directionality was also explored. Eight (36.3%) dogs were consistently able to determine the correct direction of the trails. Male dogs identified the correct direction of the trails more frequently than females. Younger dogs were better at identifying the correct direction of the trails than older animals. Dogs identified the correct direction of those trails laid from left to right more frequently than those laid from right to left. Experiment 2 explored whether dogs use olfactory or visual cues to determine the correct direction of a human-laid trail. Eight dogs that were capable of following human trails in the correct direction were employed to track 10 trails that had been laid by a handler walking backwards, thereby rendering the trails devoid of accurate directional visual information. All of the dogs were consistently able to identify the correct direction of the trails. Overall, findings suggest that relatively few of the dogs in this study were accurately able to track in the correct direction, and that the dogs' ability to determine directionality was related to the animals' age and sex. Findings also suggest that the dogs employed olfactory cues to correctly elucidate direction.

Keywords: Dog; Direction; Odour; Olfaction; Scent; Smell; Tracking

1. Introduction

The ability to locate, or track, other animals is of vital importance to most predatory mammals' survival. Evidence suggests that the domestic dog, *Canis familiaris*, a species

* Corresponding author. Tel.: +44-28-9027-4386; fax: +44-28-9066-4144.
E-mail address: d.wells@qub.ac.uk (D.L. Wells).

0168-1591/$ – see front matter © 2003 Elsevier B.V. All rights reserved.
doi:10.1016/j.applanim.2003.08.009

renowned for its olfactory acuity, is highly proficient at both detecting, and following, trails (see Schoon, 1997 for review).

An important feature of any tracking exercise is that the animal determines the correct direction of the trail (Bryson, 1984), i.e. the direction in which the individual has gone. There is very little advantage in being able to detect a trail if there is only a 50% chance of the animal following it towards its quarry.

To date, the ability of the domestic dog to determine the correct direction of a trail remains largely unknown. Anecdotal reports from trainers suggest that dogs can accurately identify the direction of human-laid trails (Davis, 1974; Johnson, 1977). Empirical studies, however, suggest that there is individual variation in the ability of dogs to determine directionality. Thus, whilst some dogs are proficient at consistently identifying the correct direction of a trail, others perform no better than random chance on tasks requiring them to determine direction (Morrison, 1980; Mackenzie and Schultz, 1987; Schwartz, 1980; Steen and Wilsson, 1990). Unfortunately these existing studies vary greatly in their methodological design, rendering it difficult to generalise the results. One study, for instance, employed only two dogs that had been explicitly trained to determine directionality prior to testing (Steen and Wilsson, 1990); other studies have used dogs of mixed breed, ignoring the possibility that the ability to determine directionality may be breed-specific (e.g. Morrison, 1980; Mackenzie and Schultz, 1987; Schwartz, 1980).

As yet, it is unknown what variables may influence the ability of a dog to determine the correct direction of a trail. Identifying those factors that influence a dog's ability to determine directionality would prove very useful and have important applications. Numerous organisations employ dogs for tracking purposes, e.g. to locate criminals, lost individuals. Unfortunately, in relation to the number of dogs initially enrolled by such organisations, only a small proportion of animals are successful in passing the initial training programmes. Identifying what factors influence a dog's ability to track successfully may make it easier for organisations involved in the training of dogs for tracking purposes to select animals that are most suited to tracking at an early stage in the selection process.

In the following study we investigated the ability of trained police dogs to identify the correct direction of 10 trails laid by one human (Experiment 1). The influence of the dogs' sex (male, female) and age (juvenile, i.e. <2 years, adult, i.e. >2 years) on the animals' ability to determine directionality correctly was examined. The direction in which the trail was laid by the human (left to right, right to left) on the dogs' ability to determine directionality correctly was also explored.

Whilst dogs generally employ olfactory cues to track, visual information can also be employed (Steen and Wilsson, 1990). Thus, instead of using scent-based information, dogs may manage to determine the correct direction of a trail simply by following the appearance of the track-layer's footprints from heel to toe.

Experiment 2 was conducted to elucidate the primary mechanism (i.e. olfaction or vision) used by dogs to determine the correct direction of a human-laid trail. Those dogs which successfully identified the correct direction of the odour trails in Experiment 1 were required to track a further 10 trails that had been laid by a handler walking backwards. Laying the tracks in this manner provided spurious visual information on the true direction in which the tracks had been laid, allowing us to determine whether dogs were following the direction of the track-layer's footprints (i.e. using visual cues) or scent (i.e. using olfactory cues).

Table 1
The number of dogs that participated in the study according to the animals' sex and age

Sex	Age		Total
	Juvenile (<2 years)	Adult (>2 years)	
Male	6	6	12
Female	4	6	10
Total	10	12	22

2. Method

2.1. Subjects

Twenty-two German shepherd dogs employed by the Royal Ulster Constabulary (RUC) in Northern Ireland, for general purpose duties (e.g. crowd control, tracking), were used as subjects. Table 1 presents information regarding the sex and age of the animals. All of the dogs had been trained by the RUC to find and follow a human trail on command but were not trained, explicitly or implicitly, to follow the direction of a trail.

2.2. Procedure

2.2.1. Trail-laying

Each trail, measuring 100 m in length, was laid by one male adult dog handler walking in a straight line in a 2 hectare grass field (see Fig. 1). Each trail was laid at a 90° angle to the direction of the on-coming wind to reduce the possibility of the dogs' using air-borne scent to determine directionality. The beginning and end of each trail was marked with a 3 ft pole. Ten individual trails were laid for each dog. Half of the trails for each animal were laid in a left-to-right direction; the remaining five trails were laid in a right-to-left direction. The trail-layer was driven to the start of each trail by a car and picked up at the other end by a car, thus removing any odour cues from the handler outside the 100 m trail.

2.2.2. Experiment 1

Each tracking test started 1 h after the trail had been laid, since reports indicate that this is the optimum time for successful tracking (Johnson, 1977). Each dog was led to the middle of the trail by a handler who was blind to its direction. Both the dog and the handler approached the trail at right angles to its orientation (see Fig. 1). At 10 m from the trail the dog was ordered by the handler to track. Each dog was tested on 10 different trails, with an intervening period of 20 min between each trial. No two dogs were tested on the same trail.

For each tracking test, information was collected on whether or not the dogs as a group, or individually, managed to identify the correct direction of the trail, i.e. reach the correct end pole (yes:no).

2.2.3. Experiment 2

This study aimed to elucidate the primary mechanism (i.e. olfaction or vision) used by dogs to determine the correct direction of a human-laid trail.

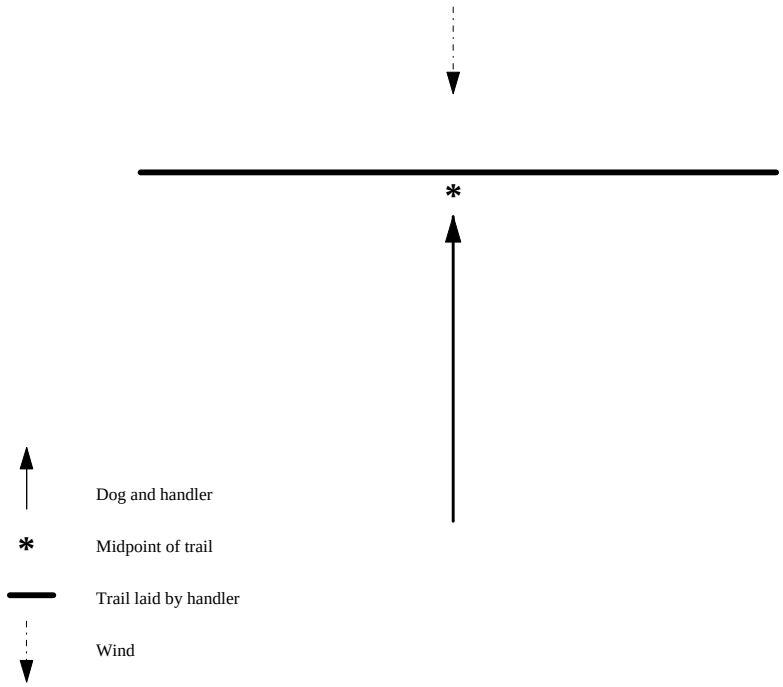

Fig. 1. Diagram representing the orientation of the dog to the human-laid trail.

Experiment 2 was identical to the previous study, with two important exceptions. First, only those dogs ($n = 8$, see Table 2) that were consistently able to determine the correct direction of the tracks in Experiment 1 were employed as subjects. Second, rather than the trails being laid by the handler in a normal forwards direction, the trails were laid in a backwards direction, i.e. the handler laid the trails by walking backwards rather than forwards. Laying the tracks in this manner provided spurious visual information on the true direction in which the tracks had been laid. It was assumed that if the dogs were following the handler's footprints from heel to toe (i.e. using visual, rather than using olfactory, cues) the animals would be more inclined to follow the incorrect direction of the trails.

2.3. Data analysis

For both experiments, binomial tests (e.g. Howell, 1992) were conducted for each dog, and in total, to determine whether or not the dogs could accurately determine the correct direction of an odour trail.

Fisher's Exact Tests (e.g. Howell, 1992) were conducted to determine whether there was an association between either the dogs' age (juvenile, i.e. <2 years: adult, i.e. >2 years) or sex (male:female), and whether or not the dog managed to identify the correct direction of the trail (yes:no).

A Chi-squared analysis (e.g. Robson, 1973) was also carried out to explore whether there was an association between the direction in which the trails were laid by the handler (right to left: left to right) and whether or not the dogs managed to identify the correct direction of the trails (yes:no).

3. Results

3.1. Experiment 1

As a group, dogs were unable to determine the correct direction of the trails more accurately than one would have expected by random chance ($P = 0.286$, binomial test).

Individually, eight (36.4%) of the dogs were able to consistently determine the correct direction of the trails ($P < 0.05$, binomial tests) [see Table 2].

The ability of the dogs to determine the correct direction of the trails was significantly related to the animals' age ($P = 0.006$, Fisher's Exact Test). More of the younger dogs (70.0%) consistently managed to identify the correct direction of the trails than dogs over the age of 2 years (8.3%) [see Table 2].

The dogs' sex was also significantly associated with the animals' ability to track the correct direction of the trails ($P = 0.03$, Fisher's Exact Test). More of the male dogs

Table 2
The number of times that each dog tracked the correct direction of 10 human-laid trails, according the animal's sex and age

Dog	Sex	Age (years)	Number of times dog chose the correct direction	*P*
1	Male	<2	10	<0.05
2	Male	<2	10	<0.05
3	Male	<2	10	<0.05
4	Male	<2	9	<0.05
5	Male	<2	9	<0.05
6	Male	<2	9	<0.05
7	Male	>2	9	<0.05
8	Male	>2	7	NS
9	Male	>2	4	NS
10	Male	>2	4	NS
11	Male	>2	3	NS
12	Male	>2	4	NS
13	Female	<2	9	<0.05
14	Female	<2	8	NS
15	Female	<2	7	NS
16	Female	<2	7	NS
17	Female	>2	5	NS
18	Female	>2	4	NS
19	Female	>2	4	NS
20	Female	>2	4	NS
21	Female	>2	4	NS
22	Female	>2	3	NS

Table 3
The number of times that each dog tracked the correct direction of 10 human trails laid in a backwards manner, according to the animal's sex and age

Dog	Sex	Age (years)	Number of times dog chose the correct direction	*P*
1	Male	<2	10	<0.05
2	Male	<2	10	<0.05
3	Male	<2	10	<0.05
4	Male	<2	10	<0.05
5	Male	<2	10	<0.05
6	Male	<2	9	<0.05
7	Male	>2	9	<0.05
8	Female	<2	9	<0.05

(58.3%) consistently managed to track the correct direction of the trails than their female counterparts (10.0%) [see Table 2].

The ability of dogs to determine the correct direction of the trails was significantly related to the direction in which the trails were laid by the handler ($\chi^2_1 = 10.39$, $P = 0.001$). The dogs successfully tracked more of those trails that ran from left to right (74.8%) than those that ran from right to left (54.1%).

3.2. Experiment 2

As a group ($P = 0.007$, binomial test), and individually ($P < 0.05$, binomial tests), the dogs were able to determine the correct direction of the trails more accurately than one would have expected by random chance (see Table 3).

4. Discussion

The findings from the present study indicate that relatively few of the dogs in this particular sample were accurately able to identify the correct direction of human-laid trails and that their ability to determine directionality was influenced by their sex and, in particular, their age.

The dogs in the present study were highly proficient at tracking. Thus, all of the animals were able to detect, and follow, all of the trails. Fewer dogs, however, were consistently able to identify the correct direction of the trails, with only eight of the 22 dogs performing better than random chance. These findings concur with previous research in this area (Morrison, 1980; Mackenzie and Schultz, 1987; Schwartz, 1980).

Those dogs that were consistently able to identify the correct direction of the trails, appeared to use scent, rather than visual cues, to do so. This concurs with previous research in this area, albeit on only two dogs (Steen and Wilsson, 1990). The dog is well renowned for its olfactory acuity (e.g. Brisbin and Austad, 1991; Hepper, 1988; Kalmus, 1955), thus it comes as little surprise that the animals in the present study employed scent as their primary mechanism for identifying the correct direction of the trails. Whether or not dogs can, or

do, employ visual cues to determine the directionality of human-laid trails still remains unknown and warrants further investigation.

The dogs' tracking performance was significantly related to the direction in which the trails were laid. Dogs were able to identify the direction of those trails that ran from left to right more accurately than those than ran from right to left. Existing information regarding the directional preference of tracking dogs is conflicting. Johnson (1977), for instance, suggests that dogs have a tendency to head towards the right hand side of a track. Lubow et al. (1976), by contrast, suggest that dogs show a greater tendency to move towards the left. More recently, a study of the frequency of back tracking in dogs revealed no significant difference in the animals' position preference (Mackenzie and Schultz, 1987). Further studies need to be conducted to identify whether or not the direction a dog chooses to track is related to the odour cues it is detecting, or simply a preferred direction for tracking. It is also possible that the dogs' apparent directional 'preference' reflects little more than a tendency for their handlers to display a consistent left to right bias when they send their dogs out to track (see later).

The ability of dogs to determine directionality was related to the animal's sex. Male dogs were considerably better at identifying the direction of the trails than their female counterparts. Studies suggest that there are sex differences in the olfactory acuity of humans, with females having a greater acuity than males (e.g. Cain, 1982; Doty et al., 1984a,b, 1985; Cain et al., 1988). To date, differences between the sexes in the olfactory acuity of dogs has been largely overlooked. From an evolutionary point of view it would make sense for male dogs to have a more finely tuned sense of smell than females. For instance, male dogs tend to engage in olfactory activities (e.g. location of mate, determination of territory) more frequently than female dogs. Further study needs to be conducted to examine the influence of sex on the olfactory acuity of dogs.

The dogs' ability to determine directionality in the present study was significantly related to the animals' age. Younger dogs were much better at identifying the direction of the trails than older animals. Studies on the olfactory ability of humans indicate a decrease in olfactory acuity with age (see Murphy, 1986, 1989, 1995 for reviews). The findings from the present study suggest that, like humans, dogs also show a decrease in their olfactory acuity as they get older. Organisations employing dogs for tracking purposes would thus be wiser training their dogs from as early an age as possible. Alternatively, it may be the case that the older dogs in the present sample had simply received less effective training than the younger cohort of animals. The older dogs may, for example, have been subjected to more changes in training regimes or handlers, than the juveniles, with these changes effecting their ability to determine directionality accurately. Moreover, it is possible that some dogs, whilst not trained during working hours to determine directionality, were trained by their handlers to undertake this type of exercise in their spare time. An exploration into the training history of dogs may yield useful information on the effect of this factor on the ability of such animals to determine the direction of an odour trail.

One cannot overlook the possibility that the dogs' performance on the trials was related to external factors. It is possible, for instance, that the animals were unwittingly guided in one direction or the other by their handlers. This makes some degree of sense when one considers the fact that dogs and their handlers are trained to work together as a 'unit' or 'team'. Whilst the handlers in this study were blind to the actual direction of the odour

tracks, it is still possible that the dogs picked up on cues (correct or incorrect) unintentionally emitted by their partners when they reached the mid-point of the trails. This might explain why the older dogs, who would have had more time to learn their handlers' signals, were less able to determine directionality than their younger counterparts.

Overall, the findings from the present study suggest that the dogs in this particular sample were highly proficient at detecting, and following, human-laid trails, but were less able to determine the direction of such tracks. The findings may be of particular interest to organisations that select dogs for tracking purposes. The results suggest that a dog's ability to determine the direction of a trail may be related to both the sex and age of the animal. It appears that young male dogs are more proficient at determining directionality than older and/or female animals. By investing their time and energy in training young male dogs, organisations may be able to increase the number of animals which become successful trackers.

Acknowledgements

We would like to thank Prof. K. Brown, School of Psychology, and the Royal Ulster Constabulary, for providing the facilities to enable this research to be undertaken. D.L.W. acknowledges the financial support of the Association for the Study of Animal Behaviour. The co-operation of the handlers and dogs who participated in the study is also gratefully acknowledged.

References

Brisbin, I.L., Austad, S.N., 1991. Testing the individual odour theory of canine olfaction. Anim. Behav. 42, 63–69.

Bryson, S., 1984. Search Dog Training. Box Press, California.

Cain, W.S., 1982. Odor identification by males and females: predictions and performance. Chem. Senses 7, 129–141.

Cain, W.S., Gent, J.F., Goodspeed, R.B., Leonard, G., 1988. Evaluation of olfactory dysfunction in the Connecticut Chemosensory Clinical Research Center. Laryngoscope 98, 83–88.

Davis, L.S., 1974. Go Find! Training Your Dog to Track. Howell Book House, New York.

Doty, R.L., Shaman, P., Applebaum, S.L., Giberson, R., Siksorski, L., Rosenberg, L., 1984a. Smell identification ability: changes with age. Science 226, 1441–1443.

Doty, R.L., Shaman, P., Dann, M., 1984b. Development of the University of Pennsylvania Smell Identification Test: a standardized microencapsulated test of olfactory functioning. Physiol. Behav. 32, 489–502.

Doty, R.L., Applebaum, S., Zusho, H., Settle, R.G., 1985. Sex differences in odor identification ability: a cross-cultural analysis. Neuropsychologia 23, 667–672.

Hepper, P.G., 1988. The discrimination of human odour by the dog. Perception 17, 549–554.

Howell, D.C., 1992. Statistical Methods for Psychology. Duxbury Press, California.

Johnson, G., 1977. Tracking Dog Theory and Methods. Arner, New York.

Kalmus, H., 1955. The discrimination by the nose of the dog of individual human odours and in particular the odour of twins. Br. J. Anim. Behav. 3, 25–31.

Lubow, R.E., Kahn, M., Frommer, R., 1976. Information processing of olfactory stimuli by the dog. II. Stimulus control and sampling strategies in stimulus discrimination learning. Bull. Psychon. Soc. 8, 323–326.

Mackenzie, S.A., Schultz, J.A., 1987. Frequency of back-tracking in the tracking dog. Appl. Anim. Behav. Sci. 17, 353–359.

Morrison, H., 1980. He went that-a-way. Off Lead 6, 10–11.

Murphy, C., 1986. Taste and smell in the elderly. In: Meiselman, H.L., Rivlin, R.S. (Eds.), Clinical Measurement of Taste and Smell. Macmillan, New York, pp. 343–371.
Murphy, C., 1989. Ageing and chemosensory perception of and preference for nutritionally significant stimuli. Ann. N.Y. Acad. Sci. 561, 251–266.
Murphy, C., 1995. Ageing and odor memory. In: Schab, F.R., Crowder, R.G. (Eds.), Memory for Odors. LEA, New Jersey, pp. 109–131.
Robson, C., 1973. Experiment, Design and Statistics in Psychology. Penguin Books, London.
Schoon, G.A.A., 1997. The performance of dogs in identifying humans by scent. PhD thesis. Department of Criminalistics and Forensic Science, University of Leiden.
Schwartz, C., 1980. Project: which way? Off Lead 7, 22–25.
Steen, J.B., Wilsson, E., 1990. How do dogs determine the direction of tracks? Acta Physiol. Scand. 139, 531–534.