J. exp. Biol. **180**, 247-251 (1993)

BEHAVIOUR OF DOGS DURING OLFACTORY TRACKING

AUD THESEN, JOHAN B. STEEN* and KJELL B. DØVING

Division of General Physiology, Department of Biology, University of Oslo, Norway

Accepted 11 March 1993

Summary

The ability to detect the direction of a track is of vital importance to animals of prey and is retained in many modern breeds of dogs. To study this ability, four trained German shepherd tracking dogs, equipped with head microphones to transmit sniffing activity, were video-monitored after being brought at right angles to a track where the position of each footprint was known. Three phases could be recognized in the dogs' behaviour: (1) an initial searching phase, during which the dog tried to find the track, (2) a deciding phase, during which it tried to determine the direction of the track and (3) a tracking phase, in which it followed the track. During ten tests on 20-min-old tracks on grass, and ten tests on 3-min-old tracks on concrete, the dogs always followed the track in the correct direction (i.e. in the direction the track was leading). During the deciding phase the dogs moved at half the speed and their periods of sniffing lasted three times as long as during the other two phases.

The deciding phase lasted 3–5s, while the dogs sniffed at 2–5 footprints. The dogs' ability to determine track direction in this time must rely on accurate methods of sampling air and a remarkable sensitivity for certain substances.

Introduction

The ability to follow the tracks of potential prey must be of major importance for the survival of predators. This ability has been retained in many modern breeds of dogs and has been perfected through breeding and training to serve humans in many situations. A good tracking dog is not only able to find a track, but it can also follow it in the correct direction, i.e. in the direction the maker of the track was moving. Studies of German shepherd dogs indicate that these dogs compare the strength of the scent of consecutive footprints and then follow the track in the direction of increasing concentration of scent (Steen and Wilsson, 1990). These results suggest a most remarkable accomplishment achieved by the olfactory system.

In the present study we investigated the olfactory tracking behaviour of German shepherds by recording their sniffing activity during video-monitored trials. We recorded how fast the dogs moved, the frequency of sniffing, the number of sniffs between respiratory ventilations, the time spent in each of the different phases and the

*Author for correspondence.

Key words: olfaction, sniffing, dog tracking, German shepherd.

number of footprints investigated during the process of deciding on the direction of a track.

Materials and methods

Four male German shepherd dogs, all trained to follow human tracks in the direction the maker of the track had moved, were used in this investigation. The experiments were not designed to test whether these dogs were able to detect the direction of the track. Rather, we wanted to study their behaviour when they were presented with tracks whose direction we knew (from earlier experience with these dogs) that they were able to detect. During all tests the dogs were handled by their trainers. The tests were carried out between 12:00 and 15:00h throughout May to October 1990 on an airfield near Oslo, Norway. The dogs were tested ten times on grass and ten times on concrete. The tests were carried out on dry ground on dry, calm days with fair temperatures (15–20˚C). One week before the testing started, a grid of 10×4 squares, each measuring 2 m×2 m, was painted on the ground (Fig. 1).

Five tracks were laid in each direction by a person who walked across the grid, right to left or left to right in random order, making two steps per square at a speed of about one step per second. In order to establish the exact position of each footprint the track-making was recorded on video. Neither the dog nor the handler was present when the track was made, nor did they have contact with the track-maker until after the test.

Sniffing and breathing sounds were picked up by a Sony WP 27 microphone fastened above the dog’s nose (Fig. 1). The signals were passed to a radio transmitter (military equipment) fastened to the dog’s collar, before being transmitted and recorded on the sound track of the VHS video camera. The sound of short sniffs could easily be distinguished from the sound of breathing. Before the tests, each dog was given a number of trials (4–8) to familiarise it with the equipment.

Each test on concrete started 3min after the track had been laid; tests on grass began 20 min after the track had been laid. This age difference was chosen because the handlers’ experience told us that the dogs were able to determine the direction of these tracks. The trial began with the dog standing at heel about 5m away from, and perpendicular to, the middle of the track. When given the order to track, the dog went straight forward (as it had been trained to do) while sniffing close to the ground. When it found the track, the dog turned either to the right or to the left. Dogs that tracked in the correct direction were rewarded by an object, usually a wooden stick, which the track-maker had left at the end of the track. The reward was not visible to the dog, to the handler or to us during the trial.

The whole sequence was videotaped from the same position that had been used to record the track-making, thus allowing the dog’s behaviour to be studied in relation to the track. The videotape included a time marker with a resolution of 40ms. The recordings of a few tests were of poor quality because of technical problems, so the number of tests referred to below is not always 10.

We measured the following aspects of the dogs’ behaviour during tracking: number of sniffs per second; number of sniffs between each respiratory ventilation (breath); number of forepaw steps per second (stepping frequency); number of footprints sniffed at, and time elapsed between finding the track and deciding on the direction. A series of sniffs made between breaths is referred to as a sniffing period.

Results

In every test the dogs tracked in the correct direction (i.e. in the direction in which the track-maker had moved). However, they did not always turn in the correct direction when they first found the track. If the initial direction was wrong, the dogs turned abruptly and walked in the opposite direction. The initial direction chosen by dogs that had already been tested before on the same day was generally (8/9) the same as the correct direction in the previous test, i.e. the direction that had yielded the reward for correct tracking.

The dogs' behaviour appeared to consist of three phases. During the *searching* phase,

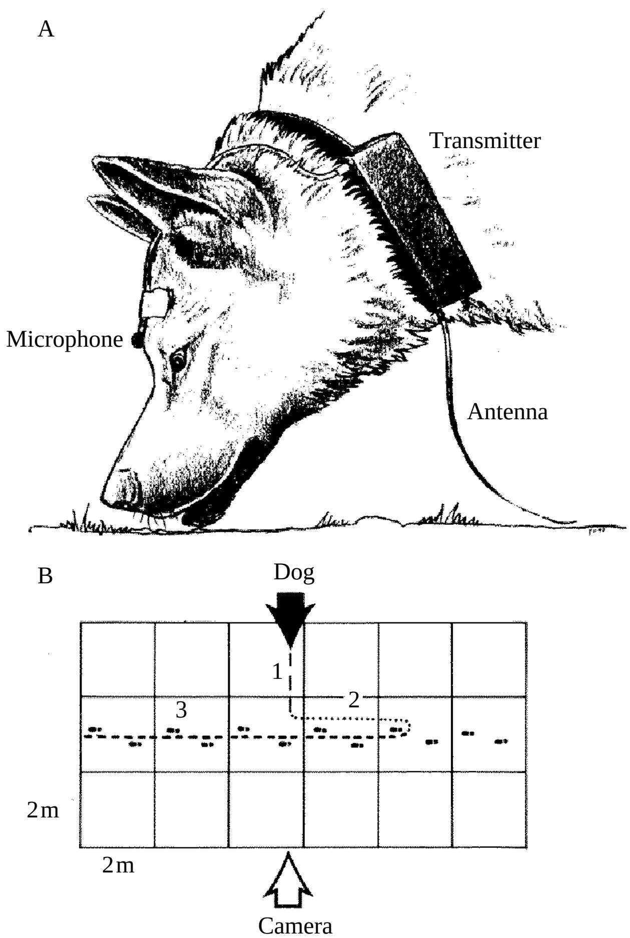

Fig. 1. (A) The position of the microphone and transmitter while the dog was tracking. (B) How the footprints were placed in the $2\,m\times 2\,m$ grid, and one example of a dog's path during the searching phase (1), the deciding phase (2) and the tracking phase (3). Only 18 of the 40 squares are shown.

Table 1. *Sniffing frequency, number of sniffs per sniffing period, stepping frequency (number of steps by the forepaws per second), number of footprints sniffed at and time spent to decide track direction for four German shepherd dogs*

Phase	Sniff frequency (s^{-1})	Number of sniffs per period	Stepping frequency (s^{-1})	Number of footprints	Time (s)
Search (C)	6	13.7±3.8 (7)	3.1±0.4 (9)	–	–
Decision (G)	6	–	1.9±0.5 (9)	3.1±1.1 (9)	4.7±1.1 (9)
Decision (C)	6	35.6±15.6 (7)	1.9±0.5 (10)	3.0±0.8 (7)	5.3±2.5 (10)
Tracking (C)	6	11.5±3.5 (7)	3.2±0.3 (9)	–	–

C, concrete; G, grass.

Values are means ± S.D. Numbers in brackets are *N* values.

The number of sniffs per breath could not be determined for trials on grass because of noise caused by the dog's nose touching the grass.

Sniff frequency has been rounded to the nearest whole number, reflecting the accuracy of the sound track from which it was measured.

i.e. when the dogs were supposedly trying to find a track, they moved quickly and sniffed at a frequency of 6Hz ten to twenty times between each respiratory ventilation (Table 1). Once they had found the track they entered the *deciding* phase, which was characterized by a reduced stepping frequency and longer sniffing periods. The transition from searching to deciding was clear because the dogs halted for a moment when they detected the track. The deciding phase lasted 3–5s, during which the dogs sniffed at 2–5footprints, usually within one sniffing period. During this phase the dog's nose was held close to the ground, about 1cm from the concrete, but this was more difficult to judge in trials on grass. The dog sometimes appeared to move its nose along the track at constant speed, but more often it slowed down or stopped when it passed a footprint.

The deciding phase was followed by the *tracking* phase, when walking frequency and sniffing periods became similar to the values recorded during the searching phase. The frequency of sniffs was remarkably constant: about 6 per second in all phases. Judging from the sound tracks, the intensity of individual sniffs was uniform.

Regardless of phase, the time taken for respiratory inspiration and expiration was always less than 10% of the sniffing period.

Discussion

This study demonstrates that tracking by dogs is divided into three phases and that different tracking strategies are used in each phase. This is evidently common knowledge among dog handlers, but has not been substantiated before by direct recordings. During the first phase, when the dogs are searching for a track, they move quickly, with short sniffing periods. In the second phase, when they have detected a track, they slow down, possibly to help determine its direction. Once the direction has been found they move faster, suggesting that following the track (the third phase) is a simpler task than determining its direction. Thus, the deciding phase seems to be the most difficult one; it is certainly the most impressive one from a human point of view. Our dogs needed to smell only 2–5 footprints to decide in which direction the track had been laid, regardless of whether it was on grass or concrete (other dogs under different conditions may require more prints).

We assume that the dogs determine the track direction by perceiving differences in the concentration of certain substances deposited by the track-maker. This implies that, in some of our tests, the dogs must have determined a difference in the concentration of scent in the air above two consecutive prints which were made 1s apart, either 3min or 20min earlier. To a human, this feat may appear unrealistic. However, although the sensitivity of individual olfactory receptors is similar in humans and dogs (Moulton *et al.* 1960), dogs have many more receptors than do humans (Adrian, 1956). Thus, a dog's detection threshold for acetic acid, which is one constituent of human skin secretions, may be 10^8 times lower than a human's threshold (Neuhaus, 1953).

It is reasonable to assume that perception of scent intensity depends on the number of scent molecules detected per unit of time. We suggest that during the deciding phase the dog behaves in a way that gives constant detection variables, as far as possible. These variables include the distance between the source of the scent and the nose, the volume of each sniff and the sniffing frequency. Recordings of sniffing activity in our laboratory suggest that the latter two variables are remarkably uniform. However, there are likely to be other, as yet unidentified, factors which contribute to these dogs' baffling ability to discriminate between different concentrations of scent.

We wish to thank 'Nordisk samfunn's fond for alternativer til dyreforsøk' for support; Roar Åsland, Bjørn Cato Hjemsæter, Hogne Hole and Ingrid Eidstumo (the dog handlers) and Arne Erik Hennum for practical assistance.

References

ADRIAN, A. D.(1956). Olfactory discrimination. *Annee psychol.* **50**, 107–113.

MOULTON, D. G., ASHTON, E. H. AND EAYRS, J. T. (1960). Studies in olfactory acuity. 4. Relative detectability of *n*-aliphatic acids by the dog. *Anim. Behav.* **8**, 117–128.

NEUHAUS, W. (1953). Uber die Riechscharfe des Hundes fur Fettsauren. *Z. vergl. Physiol.* **35**, 527–552.

STEEN, J. B. AND WILSSON, E. (1990). How do dogs determine the direction of tracks? *Acta physiol. scand.* **139**, 531–534.