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Operant conditioning of dogs *(Canis familiaris)* for identification of humans using scent lineup*

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Training of dogs to distinguish individual human scent has no well-established scientific basis. The aim of the study was to evaluate the progress made over three consecutive training phases and to compare the training results with those of the working phase. Six naive German Shepherd dogs (4 males and 2 females) were trained to match one target human scent, placed randomly in a lineup of five other human scents, with that sniffed directly before the trial. The dogs required on average 15.3, 23.0 and 0.3 trials with commands to spontaneously indicate the target scent in training phase I (food odour amidst blank samples), in phase II (human scent amidst blanks) and in phase III (individual human scent amidst other humans' scents), respectively. The differences among dogs in their trainability, as expressed by the number of trials with commands were significant in phases I and II. The mean percentage of false alarms (FA) and misses (MI) increased significantly in consecutive training phases. The dogs differed significantly in percentage of FA and MI in phases II and III. Non-significant rank correlation coefficients between FAs in consecutive training phases as well as between MIs indicate that it is difficult to predict future performance of a dog based upon its performance in the earlier training phases. All dogs easily learned to perform operant conditioning responses in the scent lineup, but displayed no significant improvement of the detection accuracy within particular training phases and during the working phase.

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The remarkable olfactory acuity and ability to perform well at operant conditioning make dogs good candidates for training to detect different kinds of scent in various contexts (e.g. Williams and Johnston 2002, Smith *et al*. 2003]. Dogs can be trained to detect human body odour [e.g. Lit and Crawford 2006] or various substances such as explosives [Gazit *et al*. 2005] or narcotics at field settings, and then be used at different sites as required by real-work scenarios. They may also be trained at fixed settings, where the testing procedure takes place in a room designated for this purpose using a lineup of scent samples and a match-to-sample-like protocol [e.g. Schoon 1996, 1997, 1998].

Lineups are used by police in some countries to identify the perpetrators on the basis of the match between scents collected at the scene of crime to scent samples taken from the suspect(s) [e.g. Brisbin and Austad 1991, Settle *et al*. 1994, Schoon 1996, 1997]. Although the reliability of this kind of identification is questionable, in some countries canine identification of perpetrators is permissible in courts as an additional evidence and dogs are still trained by the police for this special task.

Dog training for scent identification in a lineup is based on operant conditioning. The shaping exercises involve a number of issues which may influence both the progress in the training and the results achieved by "certified" dogs after they have completed their training. Although the ability of dogs to distinguish people by their individual scent has been well established both by anecdotal reports and scientific studies (e.g. Kalmus 1955, Hepper 1988, Brisbin and Austad 1991, Sommerville *et al*. 1993] there are no proven standards on how the dogs should be trained, certified, or used, either in the experimental design (e.g. what kind and how many samples should be placed in the lineup or how many rounds along the lineup should be repeated), or on how to evaluate the results (including or excluding "negative check" and "even-odd" paradigms) in order to achieve the highest possible reliability [Schoon 1996, 1997].

Inter-individual differences in olfactory abilities, memorization of odours, performance at operant conditioning, motivation to sniff all scents in the lineup, and reward sensitivity may influence the training process as well as the dog's performance at further tasks. Matching individual human odours in the lineup is a different type of task than detection of several learned substances producing distinctive odours as, for example, in the study of Williams and Johnston [2002].

We are not aware of any published work on the evaluation of progress during consecutive phases of canine olfactory training using a human scent lineup and on prediction of future individual dogs' performance on the basis of results achieved in earlier training phases.

The aim of the present study was to characterize the progress made by dogs in particular training phases and to compare this progress with results achieved during the working phases to identify individual humans on the basis of scent for forensic purposes.

Material and methods

Animals

Four male and two female German Shepherd dogs were used for human identification (ID) training. The dogs were 9-10 months old and were naive at the start of the training. Prior to the ID training all dogs underwent basic obedience training and showed interest in sniffing and retrieving objects both indoors and outdoors. During the ID training, dogs were maintained in individual kennels and fed standard pet dog feed with free access to water. The daily ration comprised 1200 g moist feed offered after each training session at 14:00 hr and 250 g dry feed in the evening. Every day, independently of the individual training in the sniffing room, dogs were walked twice a day for approximately 30 min being allowed to move freely. Four handlers trained and took care of the dogs for the entire study period. Each individual handler trained one or two dogs. The experimental procedure and maintenance conditions were approved by the Third Local Commission for Ethics in Animal Experimentation, Warsaw, Poland (Approval No. 10/2003).

Scent samples

The scent samples for the ID training were taken from scent donors who held two sterile cotton clothes (10 x 15 cm) in their palms for 15 min. The donors were alien to the dogs. A different set of donors was used for each training day. Altogether, used were scent samples taken from 186 humans of both sexes. No twins or close relatives served as the donors. The samples were stored in sealed, sterile glass jars at room temperature for a period of 1-10 weeks, prior to use.

Training procedure

The ID training was conducted at the Institute of Genetics and Animal Breeding, Jastrzębiec, in a room isolated from external distracting stimuli, in the presence of the handler and the experimenter. The experimenter who was hidden behind a curtain, remained invisible to the dog and to the handler, and watched the dog's behaviour through a video monitor. The terms used in sections Material and methods and Results and discussion of this report are explained in Table 1.

The ID training was divided into the preliminary phase and three training phases of increasing difficulty, followed by a working phase. The aim of the preliminary phase was to train dogs to visit and sniff all stands in the lineup, giving no indication. Small pieces of odorous feed were wrapped in cotton cloth and placed in jars on all five stands in the lineup. Another piece of food was thrown towards the lineup to persuade the dog to approach the lineup. If the dog approached and sniffed a stand, the handler immediately rewarded the dog with a piece of feed from hand, simulating the reward dropping out of the jar. Depending on the dog's motivation to sniff spontaneously, no more than five trials were usually necessary for dogs to check

Table 1. Explanations of some special terms used in the study

Term	Description
Active trial	A trial with a target sample in the lineup to be indicated by the dog
Blank sample	Sterile cotton cloth used for collecting human scent, containing no human scent
Clicker	A simple device producing a short "click" sound, manually operated immediately after a correct response by a dog. After a click the animal is rewarded, e.g. by a morsel of feed. Clicker reinforcement is commonly used in operant conditioning of animals to signals to the animal that its response or behaviour is correct. After the animal has been conditioned, the clicker sound itself may be perceived as rewarding
Decoy	A human scent sample placed in the lineup that does not match the sample given to sniff at the starting position
False alarm (FA)	False positive indication; indication by the dog of a decoy or a blank sample
Faultless trial	A correct choice and indication of the target sample without hesitation or false alarm
Indication	An operant conditioned reaction of the dog (sitting or lying down) in front of the target sample
Miss (MI)	False negative indication; lack of indication of the target sample in the lineup
Praise	Saying an approval, e.g. “good dog”, by the handler after a clicker sound which indicates that the dog’s response was correct
Rebuke	Saying mildly “no” by the handler to the dog after a false alarm (no clicker sound occurs after the dog's response)
Stands in the lineup	Heavy pots with glass jars containing scent samples, situated in a lineup of 5 stands on the floor, 80 cm apart, forming an arch to be visible for stationary videorecording
Target sample	A human scent sample or feed scent sample (in phase I) placed randomly in the lineup, to be indicated by the dog and matched to the sample given to sniff (“taking air”) at the starting position
Trial	Walking the dog along the scent lineup to sniff the samples and indicate the target sample by sitting or lying down. Dogs were initially trained to investigate all stands in the lineup before indication, but upon gaining experience, some dogs develop a habit not to check further stands after a correct response
Zero trial	A trial with only blank samples or decoys are placed in the lineup, and the dog should refrain from any indication

all stands in a systematic way. The results of the preliminary phase were not verified statistically.

In ID training phase I, one stand contained feed scent, whereas the other four stands contained blank samples. In this phase the location of the target sample in the lineup was known to the handler during the first trials. The dog was given a piece of feed to sniff (“taking air”) at the starting position approximately 2 m from the first stand of the lineup and was encouraged to walk along the lineup and to sniff

all the stands. The starting point was separated from the lineup by a curtain, so that the lineup was visible neither to the dog nor to the handler before the trial. After sniffing the stand with food scent, the dog was given the command "sit" or "down". The kind of command and the response was chosen by the handler depending on individual dogs' performance during basic obedience training. These responses were thereafter considered as dogs' choices of the target scent in the lineup. Immediately after performing that behaviour, the experimenter activated the acoustic clicker signal and dogs were rewarded by the handler with a morsel of feed and praise. The location of the target sample was changed randomly for each trial. From the fourth trial on, the dog was given a chance to perform the sitting or laying down response spontaneously, without command, by applying a delay between the sniffing and command. The dog was given the opportunity to sniff all stands up to three times during one trial. If the dog failed to indicate the target sample after sniffing it three times, the handler gave the command to the dog at the target sample after it sniffed the target sample for the fourth time. When the dog indicated the target sample correctly without command in three consecutive trials, the handler was subsequently blinded to the location of the target sample to avoid any unconscious cues to the dog. Thereafter, the location of the target sample was only known to the experimenter who activated the clicker after correct indication by the dog. If the dog, after some spontaneous indications, failed to perform the sitting or lying down response to the target sample for three consecutive trials, the handler was alerted to the target sample placement. He or she then gave the command to the dog until it indicated spontaneously. Three consecutive trials as a criterion to apply/cease commands were adopted intuitively by the handlers without any special theoretical grounds. The clicker was not activated after a false alarm. A false alarm was not rewarded by the handler and the dog was mildly rebuked. After the first false alarm the trial was classified as false alarm (FA), but for training purposes the dog was given a chance to indicate correctly. If the dog made two FAs within a trial or sniffed all samples in the lineup for three times without indicating any of them, it was recalled by the handler to the starting position. In the latter case the trial was classified as a miss (MI).

The criterion for a dog to pass to subsequent training or working phase was at least 50 faultless trials without any commands out of the 100 trials performed (50%) at a given phase. The theoretical basis for taking 50% faultless trials as a criterion was that it makes a significant difference (chi-square, $P<0.001$) to the percentage of correct by chance indications (20%) in the lineup of 5 samples. All dogs fulfilled this criterion. In all training phases and in the working phase, each dog passed through 8 to10 trials a day depending on its interest and motivation to work. There were 3 to 4 training days per week. All trials were videorecorded for a detailed analysis of dogs' behaviour. The floor was washed after every training day to remove scents which could distract the dogs.

In ID training phase II a human scent was placed in one stand as the target scent. The remaining four stands contained blank samples. The training procedure was the

same as in training phase I, except that the handler did not know the location of the target sample from the very beginning of the phase. In the case of more than three consecutive misses, the handler was informed at which stand in the lineup the target sample had been placed and the dog was encouraged by receiving a command and a feed reward.

In ID training phase III one target sample containing human scent was placed in a randomly selected stand and the remaining four stands contained decoy scent samples taken from different donors at approximately the same time as the target scent. The procedure of the trials was the same as in the training phase II - in the case of more than three consecutive misses the dog was given a hint or a command by the handler, who was aware of the location of the target sample.

After the dogs fulfilled the criterion of 50% faultless trials in training phase III, the **working phase** was arranged composed of tests identifying individual humans on the basis of their scent. During the working phase the dogs were exposed to both the human palm scent samples collected by the police at real forensic scenarios and stored for different periods of time and the samples collected only for the training.

In all training phases and in the working phase two kinds of trials were conducted. The majority of them were "active" trials in which one randomly chosen stand contained the target sample with a scent matching to that given during "taking air" at the starting position and dogs were expected to indicate this sample. One or two trials randomly applied during a training day were "zero" trials (no target sample in the lineup). As the "zero" trials seemed to be discouraging to the dogs, they were not performed at every training day especially at the beginning of a training phase or when dogs appeared less willing to work. After the dog was able to indicate spontaneously, *i.e.* without commands, the handler was blinded to which were "active" or "zero" trials.

Statistical

The mean number of commands and mean percentage of FA, separately for "active" and "zero" trials, and of MI for active trials were calculated for each training phase. Since the numbers of "active" and "zero" trials were not equal, calculated were the percentages of FA within these trials. To characterize the dogs' performance, means, range and 95% confidence intervals were calculated. To assess the progress during each training phase the mean number and standard deviations of commands, FAs, and MIs were calculated for the five series of 20 trials.

To verify the differences between dogs and between "active" and "zero" trials in the number of commands, FAs and MIs, the chi-square test was applied. Spearman rank correlations were calculated for the training parameters (commands, FA and MI) within and between training phases for n = 6 dogs. The non-parametric Friedman two-way ANOVA test and Wilcoxon test were used to evaluate differences between training phases, between consecutive series of 20 trials within training phases in FAs, MIs, and in number of commands. The Bonferroni correction was applied for multiple comparisons using the Wilcoxon test.

Results and discussion

Commands

The dogs required on average 15.3 (range 6-24) and 23.0 (range 11-54) trials with commands to spontaneously indicate the target sample with feed (training phase I) and the target sample with human scent amidst blanks (training phase II), respectively (Tab. 2). No commands were necessary after transition from training phase II to training phase III, except for one dog that needed two trials with commands to improve indications during trials 60-80 in the training phase III (Tab. 2, Fig.1b).

Table 2. Results of operant conditioning in particular training phases *vs*. the working phase

Phase	Mean number of trials with command needed to work independently	Per cent of correct responses in active trials	Per cent of false alarms in active trials	Per cent of false alarms in zero trials	Per cent of misses in active trials
Training phase I					
mean	15.3	96.0	2.9	3.5	1.1
range	6-24	91.8-99.2	0.8-5.4	0-14.3	0-2.7
95% conf. interval	9.9-20.8	93.5-97.2	2.1-3.8	1.1-5.9	2.1-3.6
Differences between dogs d.f.=5	$chi^2 = 16.7$ P = 0.005	$chi^2 = 8.9$ P = 0.112	$chi^2 = 10.4$ P = 0.064	$chi^2 = 9.5$ P = 0.091	$chi^2 = 15.1$ P = 0.010
between active and zero trials d.f.= 1				$Chi^2 = 0.9$ P = 0.35	
Training phase II					
mean	23.0	79.9	17.2	26.2	2.9
range	11-54	55.4-90.0	10.0-35.2	14.7-55.2	0-8.9
95% conf. interval	8.4-37.6	65.2-84.0	13.1-21.2	20.1-32.3	1.6-4.2
Differences between dogs d.f. =5	$chi^2 = 32.2$ P = 0.0001	$chi^2 = 48.7$ P = 0.0001	$chi^2 = 102.9$ P = 0.0001	$chi^2 = 17.1$ P = 0.004	$chi^2 = 42.8$ P = 0.0001
between active and zero trials d.f.= 1				$Chi^2 = 9.2$ P = 0.008	
Training phase III					
mean	0.3	70.9	21.4	34.8	7.7
range	0-2	54.7-89.3	7.3-31.3	10.0-72.2	3.4-14.0
95% conf. interval	0-0.98	62.3-81.1	17.9-24.9	26.2-43.4	5.9- 9.4
Differences between dogs d.f. =5	$chi^2 = 9.0$ P = 0.103	$chi^2 = 25.7$ P = 0.0001	$chi^2 = 28.6$ P = 0.0001	$chi^2 = 14.5$ P = 0.012	$chi^2 = 16.2$ P = 0.006
between active and zero trials d.f. = 1				$Chi^2 = 10.0$ P = 0.003	
Working phase					
mean	0	58.1	31.4	55.9	10.5
range		30.6-76.8	21.5-50.8	41.8-78.7	1.7-18.6
95% conf. interval		42.7-64.9	26.6-36.3	49.8-62.0	7.7-13.3
Differences between dogs d.f.=5		$chi^2 = 96.2$ P = 0.0001	$chi^2 = 343.0$ P = 0.0001	$chi^2 = 23.3$ P = 0.0003	$chi^2 = 265.2$ P = 0.0001
between active and zero trials d.f. = 1				$chi^2 = 87.7$ P<0.0001	

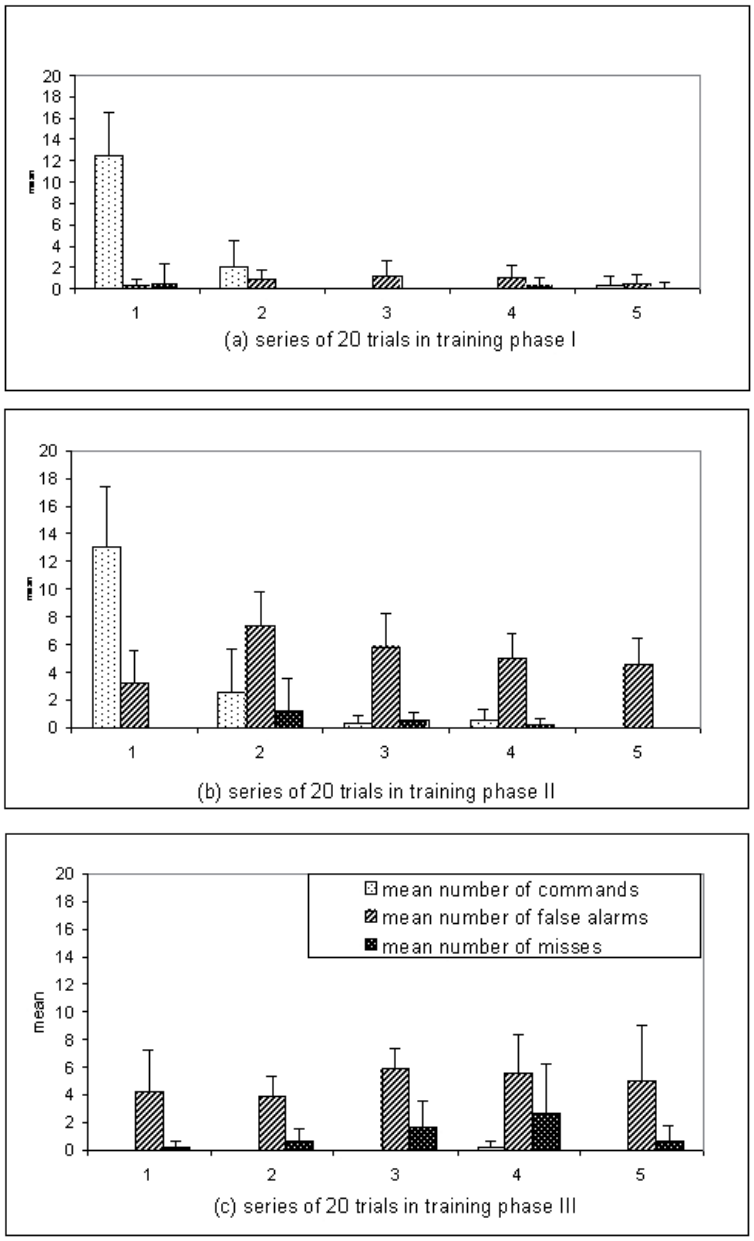

Fig. 1 a, b, c. Distribution of commands, false alarms and misses in consecutive series of 20 trials in training phases I, II, III.

No commands were necessary during the working phase. The overall differences between phases in number of commands were found significant (Friedman ANOVA $chi^2 = 16.4$, d.f. = 3, P = 0.0009). For comparison of particular phases in pairs, the Bonferroni correction applied to the Wilcoxon test using n = 6 dogs eliminated the significance of differences in all parameters.

The differences between dogs in the number of commands were significant at $chi^2 = 16.7$, d.f = 5, P = 0.005 and $chi^2 = 32.2$, P = 0.0001 within phases I and II, respectively.

Almost all commands needed in phases I and II were given within the first 40 trials (Fig.1a and 1b). Some extra commands were necessary as reminders between the trial 80 and 100 in phase I and trial 40 and 80 in phase II. Although almost all dogs required more than 10 commands in the first series of 20 trials in training phases I and II, almost no commands were required in further series of 20 trials, and the Wilcoxon test showed significant differences between the first and further series (P = 0.0277). After applying the Bonferroni correction for multiple comparisons no significant differences in the number of commands could be identified between consecutive series of trials.

Correct indications

Percentage of correct responses decreased significantly in consecutive training phases and was lowest in the working phase (Tab. 2, Friedman ANOVA $chi^2 = 17.0$, d.f. = 3, P = 0.0007).

Significant differences between dogs in percentage of correct responses were found in training phases II and III and in the working phase (Tab. 2).

False alarms

The percentage of false alarms (FA) increased significantly in consecutive training phases and in the working phase, both in active and zero trials (Tab. 2, Friedman ANOVA $chi^2 = 14.6$, d.f. = 3, P = 0.0022 and $chi^2 = 17.0$, d.f. = 3, P = 0.0007 for active and zero trials, respectively). In training phases II and III and in the working phase the percentage of FA was significantly higher in zero trials compared to active trial (Tab. 2). The number of FA did not change significantly in consecutive series of 20 trials in all training phases (Fig.1a, 1b and 1c). No differences were found between consecutive series of 20 trials within the working phase.

Misses

Similarly to FA, the percentage of misses (MI) increased significantly in the training phase III and was highest in the working phase (Tab. 2, Friedman ANOVA $chi^2 = 9.8$, d.f. = 3, P = 0.0203). Significant differences in MI percentage were found between dogs in all training phases and in the working phase (Tab. 2). No significant differences in the number of MI were identified between consecutive series of 20 trials within all training phases (Fig.1a, 1b and 1c).

Correlations

The rank correlation coefficients between correct responses, FA and MI in particular training phases calculated did not reach the significance level.

It has been well established that dogs are able to communicate a location of hidden feed or favorite toys to their owners [e.g. Miklosi *et al*. 2000]. What is more problematic for dogs is to communicate a location of a scented article, which is neither feed or favorite object, nor contains the familiar scent of the dog's master among unfamiliar human stimuli. Williams and Johnston [2002] trained dogs to discriminate 10 selected chemical substances in pure form, known to produce distinctive odours and used as targets, from 13 other substances used as non-target odours. They found that the number of trials to train dogs on each new odour discrimination tended to decrease as more new odour discriminations were trained. We believe that this was an easier task for dogs than matching from the 186 individual human scents in different sets on each day in our training. Nevertheless, in the present study our dogs also required a decreasing number of commands in consecutive series of trials within the training phases and the number of commands significantly decreased from the training phase II to training phase III. The per cent of FA did not correspond to the number of odours tested by Williams and Johnston [2002], which was consistent with our results in which there were no significant changes in percent of FA in consecutive series of trials within the training phases and the working phase.

The match-to-sample procedure of scent identification using a lineup involves not only the dog's olfactory acuity, but also the ability to respond correctly and unequivocally to operant conditioning and to work systematically over a duty period. The results of various studies indicate that dogs are not 100% accurate at identification of human scents. For example, Brisbin and Austad [1991], using three certified dogs, demonstrated correct discrimination of their handler's hand scent from no human scent in 93.1% of trials and the scent from their handler's hands from that of a stranger in 75.7% of trials. Our results may stand out when taking into account that in tests conducted by Brisbin and Austad [1991] the scented articles were presented to the dogs in pairs, thus the probability of choosing a proper article by chance was 50%. Schoon and de Bruin [1994] demonstrated that familiar persons were indicated better than persons who were not well known but often used in training sessions; complete strangers were correctly indicated in only 25% of trials. Using four different experimental designs and 6-7 scented tubes in two lineups, Schoon [1996] reported 65% and 25% correct retrievals for the best and the worst performing dog, respectively, which is comparable to our results in the working phase taking into account the number of stands in the lineup. Errors made by the dogs were explained by problems in operant response rather than by inability to distinguish the scented articles with the dogs' sense of smell.

There are no experimental studies indicating how the shaping training of ID dogs should be structured in steps and in time, and what criteria should be fulfilled for the transition from one training step to another. Recently, it has been shown by

Meyer and Ladewig [2008] that learning performance of dogs may be influenced by training schedule. These authors found that weekly training resulted in better learning performance than training five times a week. In the study in question, however, the learning performance was measured by the number of training sessions to reach a criterion of at least 80% correct responses in shaping exercise to train a simple response in form of touching a pad by the dog with its front paw. It is difficult to speculate how a different training schedule would affect our training results in which the olfactory modality was involved and the dogs had the opportunity to make false alarms.

The "zero" trial is regarded as a proof that dogs are able to inhibit the conditioned response and would not randomly indicate any sample in the lineup in order to get a reward when the target sample is absent. This may be difficult for dogs since they usually made more false positive indications in the "zero" trials as compared to the "active" trials. Similar phenomena were observed by Smith *et al*.[2003] in dogs trained at field settings to find and distinguish scats of two species of foxes. These dogs were 100% accurate at choosing scats of endangered kit fox species *(Vulpes macrotis mutica)* when red fox *(Vulpes vulpes)* scats were present, but were less accurate at ignoring red fox scats in trials where a kit fox scat was absent.

Non-significant correlation coefficients between the characteristics of dog training in consecutive training phases demonstrate that good performance at early training phases does not necessarily predict good performance in later phases of work for early selection of the best ID dogs.

Despite significant inter-individual differences, the present report demonstrates that dogs learn relatively easy to work in the scent lineup. However, no significant improvement of the detection accuracy in consecutive trials within a training phase was achieved. It may be concluded that it is difficult to predict the performance and accuracy of individual dogs in the real detection work on the basis of their performance in the earlier phases of training.

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Warunkowanie instrumentalne psów (*Canis familiaris*) do identyfikacji osób w szeregu zapachowym

S t r e s z c z e n i e

Szkolenie psów specjalnych przeznaczonych do identyfikowania osób na podstawie śladów zapachowych jest dotychczas w małym stopniu oparte na metodach naukowych. Celem pracy była ocena postępu dokonującego się w trzech kolejnych fazach szkolenia takich psów i porównanie go z efektami ich późniejszej pracy przy identyfikacji osób do celów kryminalistycznych. Sześć owczarków niemieckich (cztery psy i dwie suki) szkolono w kierunku wskazywania próbki zapachu człowieka umieszczonej w szeregu zapachowym wśród czterech próbek zapachu innych osób, odpowiadającej zapachowi powąchanemu przez psa bezpośrednio przed testem. Nauczenie samodzielnego i poprawnego wskazywania właściwej próbki w szeregu zapachowym wymagało przeprowadzenia średnio 15,3, 23.0, i 0.3 prób, w których wydawano psom komendy, w trakcie odpowiednio: I fazy szkolenia (wskazywanie zapachu pokarmu wśród próbek bezzapachowych), II fazy szkolenia (wskazywanie indywidualnego zapachu człowieka wśród próbek bezzapachowych) oraz III fazy szkolenia (wskazywanie indywidualnego zapachu człowieka wśród próbek zapachu innych osób). Różnice między psami w pojętności wyrażającej się liczbą prób, w których konieczna była komenda, były istotne w fazie I i II. Średni odsetek wskazań fałszywie pozytywnych i takiż odsetek braku wskazań rosły w kolejnych fazach szkolenia. Psy istotnie różniły się między sobą odsetkiem wskazań fałszywie pozytywnych i odsetkiem braku wskazań w fazie

II i III. Stwierdzono nieistotne współczynniki korelacji rangowej między odsetkiem wskazań fałszywie pozytywnych w kolejnych fazach szkolenia oraz odsetkiem braku wskazań, co świadczy o trudności w prognozowaniu osiągnięć psa w późniejszej pracy, na podstawie jego wyników we wcześniejszych fazach szkolenia. Wszystkie badane psy pomyślnie przeszły proces szkolenia oparty na warunkowaniu instrumentalnym z użyciem szeregu zapachowego, jednak nie stwierdzono istotnego postępu w prawidłowości identyfikowania w kolejnych próbach w ramach poszczególnych faz szkolenia oraz w trakcie dalszej pracy psów.