Anim Cogn (2005) 8: 143–150
DOI 10.1007/s10071-004-0236-9

ORIGINAL ARTICLE

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The role of context specificity in learning: the effects of training context on explosives detection in dogs

Received: 23 March 2004 / Revised: 5 August 2004 / Accepted: 10 August 2004 / Published online: 23 September 2004

Abstract Various experiments revealed that if an animal learns a stimulus–response–reinforcer relationship in one context and is then tested in another context there is usually a lessening of stimulus control, and the same discriminative stimuli that reliably controlled the behavior in the first context will have less effect in the new context. This reduction in performance is known as the "context shift effect." The effect of changing context on the probability of detecting explosives was investigated in seven highly trained explosives detection dogs (EDDs). In experiment 1 the dogs were trained alternately on path A, which always had five hidden explosives, and on a very similar path B, which never had any explosives. Within a few sessions the dogs showed a significant decrease in search behavior on path B, but not on path A. In experiment 2 the same dogs were trained only on path B with a target density of one explosive hidden every 4th day. The probability of the dogs now detecting the explosive was found to be significantly lower than in experiment 1. In experiment 3 the effect of the low target density as used in experiment 2 was investigated on a new but very similar path C. Both the detection probability for the one explosive every 4th day on the new path and the motivation to search were significantly higher than found in experiment 2. Finally, in experiment 4, an attempt was made to recondition the dogs to search on path B. Although trained for 12 daily sessions with one explosive hidden every session, the dogs failed to regain the normal levels of motivation they had shown on both new paths and on the paths that they knew usually contained explosives. The findings reveal that even a very intensively trained EDD will rapidly learn that a specific stretch of path does not contain explosives. The dog will then be less motivated to search and will miss newly placed targets. This learning is specific to the formerly always-clean path and is to some extent irreversible. However, the dog will search and detect normally on new paths even if they are very similar to the always-clean path. The data are discussed in terms of variables affecting renewal. The results suggest that following training designed to make a behavior "context independent," any extinction training will not generalize beyond that specific context used during the extinction training. In addition, if the behavior is extinguished in a specific context, it will be very difficult to restore that behavior in that context. These conclusions should be considered by anyone attempting to extinguish well-established trans-context behaviors.

Keywords Dog · Olfaction · Explosive · Context shift effect · Extinction

This research reports portions of a doctoral dissertation submitted by Irit Gazit to Tel Aviv University.

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General introduction

It is now well established that if an animal learns a stimulus–response–reinforcer relationship in one context and is then tested in another context there is usually a lessening of stimulus control, and the same discriminative stimuli (SD) that reliably controlled the behavior in the first context will have less effect in the new context (e.g., Thomas 1985; Thomas et al. 1993). This reduction in performance is known as the "context shift effect" and is found in many different experimental designs (for a review, see Balsam and Tomie 1985). Changing the context in which learning occurs also has a major impact on recovery from extinction (renewal) of behavior. Renewal is the term used to refer to the fact that when a context is changed, a previously extinguished behavior may be "renewed" and reappear in the new context (Bouton and Ricker 1994).

This phenomenon of renewal is of both theoretical and practical interest. The theoretical interest centers on the mechanisms by which the context modulates stimulus control. A major practical interest concerns the extent to which extinction generalizes between contexts. Since much behavior modification therapy involves extinction of previously learned associations, such as phobias, the generalizability of that extinction is of some importance to the therapist. If an extinguished phobia reappears whenever the situation is changed, then the treatment cannot be considered effective. Therefore it is important to determine the variables that affect the generalizability of renewal.

One variable that seems to be important in determining the generalizability of recovery of an extinguished behavior following environmental change is the number of contexts in which the target behavior was established compared to the number of contexts in which the target behavior was extinguished. Clinical textbooks on behavior modification (e.g., Pear and Martin 1990) suggest that the context shift effect can be diminished by either doing the therapy in the context in which the targeted behavior actually occurs and/or by doing the extinction training in as many contexts as possible.

But what are the effects of training the original behavior in several contexts on renewal? It is reasonable to expect that the more contexts used in establishing the association the less will be the extent of generalized extinction following extinction training in only one context. Evidence supporting this can be seen in an experiment by Gunther et al. (1998), who found less renewal following training in multiple contexts.

The context shift effect is found in experiments, in therapy, and also in situations where animals are trained to perform applied tasks. For example, Sea World found that moving killer whales from one facility to another resulted in a loss of control over previously learned behaviors (Turner et al. 1991). Changing the context can also have detrimental effects on the performance of working animals such as explosives detection dogs (EDDs). The techniques recommended to reduce the context shift effect in humans are exactly the same as those traditionally and commonly used in the training of EDDs.

Once the dog learns the task of reliable explosive detection, that is, after the initial discrimination is established, it is then trained in as many contexts as possible to reduce contextual control of the search. As stated by Hilliard (2003) in a chapter on the principles of learning in a general handbook on the science behind mine detection dogs, "the best way to ensure that trained behavior is independent of context is to train in as many different places and situations as possible, once the initial learning phase has been completed." For an EDD to receive official certification as a reliable detector of explosives in operational situations, it must search and detect in several novel environments, showing that search and detection has become context independent.

Under normal EDD operating procedures, the effects of changing the context on a well-trained dog should be minimal; the dog should detect explosives in any context in which it is placed. However, what will happen if one context is continuously associated with the total absence of explosives? This can occur during operational work if the handler, for any reason, such as being in a hostile territory, is not able to place positive stimuli (a small amount of explosives) on a specific stretch of road. Under such circumstances, the handler will place a small amount of explosives in an area very similar to the operational area and command the dog to search this "training area" until it has detected the positive stimulus.

Such a situation is interesting in that, as opposed to the normal experimental procedures used in the study of context effects such as renewal, EDDs receive extensive training designed to make the context irrelevant. How will they respond if, after learning to ignore the context, they nonetheless receive training in one specific context that is associated with the absence of explosives? This question directly relates to the generalizability of renewal and was investigated in this study with very well trained EDDs. Prior to this study the dogs had been working for at least 1 year on the detection of explosives in many different contexts. Then, for the purposes of this experiment, the dogs were trained on one specific path that contained explosives (A), and then on a different specific path that never contained explosives (B). Following this, the dogs were tested on their ability to find explosives now placed both on the previously always-clean path (B) and on a new path (C).

Two questions were asked. First, do the dogs learn to search in one context and not search in another, but very similar context? Second, if the dogs do learn not to search in the non-explosive context, does this generalize to other contexts?

Methods

With the exception of the number of targets on the paths, the following methods and procedures were used throughout all the experiments.

Animals

The study utilized seven detector dogs (five Belgian Malinois and two Labrador retrievers) trained for explosives detection. The dogs had received initial training to detect explosives 1 year prior to the start of this experiment. After completion of this training, their search and detection capability was maintained by training and testing them at least three times per week, for 20–30 min/day, usually on the explosive C4.

During this experiment the dogs received 40% of their total daily food ration as reinforcement following correct detections. The remaining 60% of food was given to the dogs in the afternoon. The dogs were individually housed in 2×3 m kennels. The kennels, housing conditions, and care were under the supervision of a full-time veterinarian and meet the Israeli standards required for housing dogs.

Handlers

Throughout the experiment, each dog had its own personal handler who had had at least 6 months' experience with the dog before the start of this experiment. The handlers were blind to the purpose of the experiment and never observed the preparations and placement of explosives before each trial. The handlers were highly motivated to succeed and detect all possible explosives.

Explosives and containers

Individual 30-g quantities of C4 explosive were placed in a wide variety of small containers (glass salt shakers with metal lids, plastic soap holders, small metal cans, and wooden boxes) to ensure that the dogs were detecting the odor of the explosive as opposed to the odor of the container.

Identical containers to those containing explosives were filled with a wide range of odiferous materials such as soil, sugar, coffee, or bread or were left empty. These are termed "dummy containers" and the dogs were trained to ignore them. These containers were used as controls to ensure that the dogs were detecting the odor of the explosive and not other odors inadvertently attached to the container such as human odors resulting from improper handling techniques. During testing the dogs never responded to dummy containers, confirming that the only discriminative cue was the odor of the explosive C4.

Study area

The study used three 2,800-m lengths of hard-packed dirt paths, each approximately 3 m wide. On each side of the path was at least a 3-m swathe of low vegetation, primarily grasses (see Fig. 1). The three paths (A, B, C) were within 1 km of each other and all on flat agricultural land. The paths were infrequently used by farmers to access their cultivated fields. Each path was divided into seven 400-m sections and each section was searched by only one dog per day. This was to avoid the possibility that an odor cue left by one dog would influence the behavior of another dog. The three paths were similar in every way except for the number of explosives hidden.

Before each search the explosives, containers, and dummies were thrown from a slowly moving car perpendicular to the axis of the path, 1–2 m from the path edge, along the particular 400-m long track being used for a given dog. The containers came to rest in the vegetation growing on each side of the path. Prior to every search all previous containers were removed and replaced with new containers to avoid odor contamination. Neither the dogs nor their handlers observed the placement of the containers, nor were the handlers informed as to their location. In addition, the containers were not visible to the handler from the path. Each dog performed only one search per day, each day on a different section of one of the seven 400-m paths, thus preventing it from using memory of the explosives found on the previous days.

Procedure

In experiment 1 the dogs were trained on both path A, which always had five hidden explosives, and on a very similar path B, which never had any explosives. In experiment 2 the dogs were trained only on path B, on which only one explosive was hidden every 4th day. In experiment 3 the effect of the same low target density used in experiment 2 was investigated on a new but very similar path C.

Description of search behavior

All dogs worked off-leash, instructed by the handler who remained at least 50 m behind the searching dog. Searches were terminated at the end of the 400-m section or when the handler said that the path was clean and did not contain any explosives. Each dog was continuously encouraged vocally to search by using phrases such as "where is it?" or "find it!", and the like. Upon detection the dog sat next to the container and the handler ran to the dog and reinforced it with a few pellets of commercial dog food. As the dog moved up the path, the handler slowly followed it, maintaining a distance of at least 50 m. The individual recording the data and videotaping the session maintained a distance

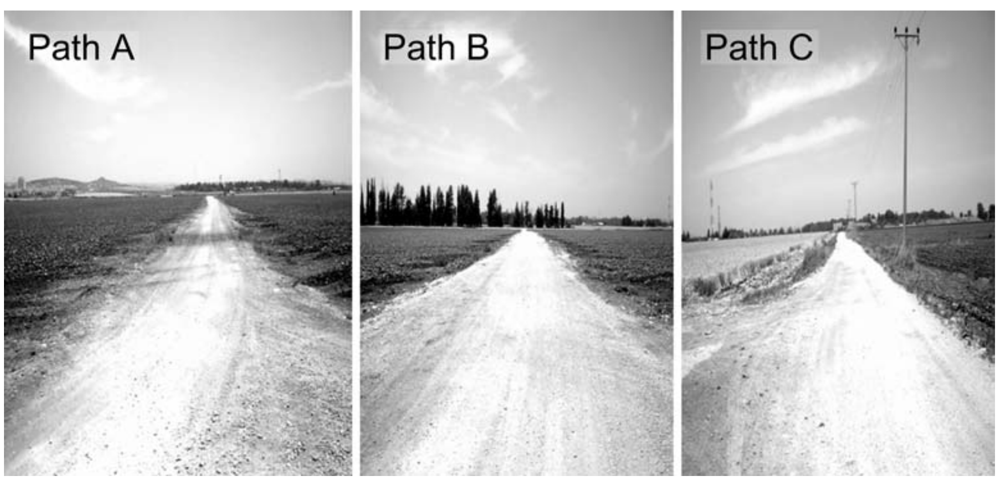

Fig. 1 The three paths used in the study

of approximately 5 m from the dog and was completely ignored by it. Periodically, the handler would call the dog back to him and send it out again to search. Every effort was made to keep the behavior of the trainer consistent from day to day and path to path.

Environmental temperature and humidity were measured prior to each search with a digital temperature and humidity gauge, ±1°C and ±3% accuracy, respectively; wind speed was measured with Windmeter, Davis Wind Wizard.

The following dependent variables were recorded: (1) explosives detection percentage; (2) control (dummy) signing percentage (percentage of false alarms); (3) search duration (in seconds); (4) verbal encouragements (average per 1 min of search); and (5) percentage amble (the percentage of time, out of total search duration, that the dog ambled as opposed to trotting or running). The logic behind percentage amble is that the speed at which the animal moves during the search is considered to represent its motivation to perform the assigned task. If the dog is walking or ambling during the search phase, we consider it as not motivated to find the odor. Higher motivation results in less walking and more trotting and a consequently lower percentage-amble score. When experienced handlers observe that the dog is walking or ambling they will either recall the dog and restart the search or, more usually, call encouragement to the dog to continue searching. The entire session was videotaped and archived.

Statistical analysis

The data were analyzed using Statistica software. The exact type of analysis depended upon the question being asked. In all cases the percentage detection data were transformed using an arcsine transformation (Winer 1962). Mean values are presented ± SE.

Experiment 1: effects of context on explosives odor detection

Introduction

This experiment was designed to determine whether EDDs show a context shift effect when the two contexts appear very similar. The dogs were trained on alternate days on two very similar hard-packed-earth paths. Path A always had explosives and path B never had explosives. Each dog searched the two path sections alternately (one per day for 16 days), for a total of seven sessions on path A and nine sessions on path B. Data were collected on the dogs' search behavior and sitting responses, which indicated possible detections. Our hypothesis was that the dogs would differentiate between the two paths and stop searching on the path never associated with explosives.

Results and discussion

The dogs moved significantly faster in searches performed on path A (five explosives) compared to path B (zero explosives) and therefore their percentage-amble score was significantly lower on path A (32.3±7.45% and 44.43±6.8%, respectively, arcsine transformation, one-tailed paired *t*-test, $t=-3.2$, $df=6$, $P<0.01$; see Table 1, Fig. 2). Mean number of verbal encouragements was higher during searches along path B in comparison to path A (5.47±0.78 and 3.3±0.48, respectively, paired *t*-test, $t=5.93$, $df=6$, $P<0.001$). Although there were more verbal encouragements on path B, the dogs' motivation to search along this path was lower. This suggests that the handlers' behavior was not the factor responsible for the decrease in the dogs' search behavior on path B.

Surprisingly, an examination of percentage-amble values throughout trials on path B reveals little difference in motivation between the first and last session on path B (41.6±7.0 and 46.6±7.47, respectively, paired *t*-test, $t=0.53$, $df=6$, $P=0.23$). The fact that the motivation to search was already low by the end of the first session on path B was probably due to frustration induced by the absence of any detected targets in dogs that were accustomed to finding explosives approximately every 60–80 m (as on path A). This abrupt shift in target density, equivalent to what is found at the start of extinction sessions, could have caused this rapid decrease in the dogs' motivation to search.

We also examined whether the decrease in motivation found in searching path B would generalize to searching path A (five explosives). However, no difference was found in either search speed or detection percentage

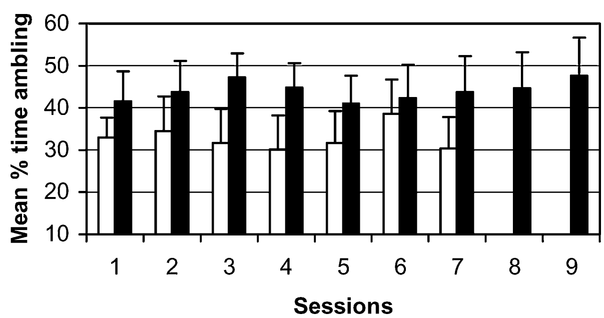

Fig. 2 Experiment 1: change in mean percentage time spent ambling (as indicative of motivation level) ± SE over trials for path A (*white*) and path B (*black*). Bars represent the average of all dogs combined. Note that greater value indicates lower motivation level

Table 1 Detection percentages and percentage amble (relative percentage of time out of total search duration that the dog walked, rather than trotted or ran) during experiments 1, 2, and 3. Data present mean ± SE

Experiment	Variable	Detection	Percentage amble
1	Path A: 5 explosives	86.93±2%	32.3±7.45%
1	Path B: no explosives	No explosives	44.43±6.8%
2	Path B: 1 explosive	52.46±6.1%	46.89±5.7%
3	Path C: 1 explosive unfamiliar track	95.83±2.6%	28.62±7.6%

between the first and last session on path A (session 1, percentage amble=33.08±6.64% and session 9, percentage amble=34±7.4; paired *t*-test, *df*=6, *t*=0.3, *P*=0.77; detection percentage on path A session 1=84.7±3% and on path A session 9=87.3±3.4%; paired *t*-test, *df*=6, *t*=0.65, *P*=0.5). The decreased motivation shown on path B therefore had not affected the dogs' motivation when searching path A. No difference was found between mean number of verbal encouragements on the first and last sessions on path A (2.53±0.6 and 3.25±0.53, respectively, paired *t*-test, *t*=1.26, *df*=6, *P*=0.25). Since the dogs never made false positive responses this variable was thus discarded.

We found a higher percentage of ambling on path B than on path A. This suggests that the dogs had become less motivated to search on the path that never contained the explosive while maintaining good search motivation with a high percentage of detection on the path with the explosives. This learning was quite rapid and suggests that dogs use subtle environmental cues (i.e., odor and/or visual) in determining the possible presence of explosives. However, as no explosives were ever placed on path B, it was impossible to determine whether the dogs had actually stopped searching or were still searching but in a more haphazard way. The only way to resolve this question was to place an occasional explosive on path B and see if it was detected by the dogs. This was done in experiment 2.

Experiment 2: probability of detection on a previously clean path

Introduction

The results of experiment 1 suggested but did not prove that the dogs were no longer actively searching on the "clean" path. However, regularly planting explosives on path B might lead the dogs to learn that the path now always contained explosives, thus causing them to increase their amount of search behavior. We therefore decided to place a very few explosives on the previously clean path. Specifically, one explosive was placed on the path every 4th day. The dependent variables again included the probability of detecting the explosive and percentage amble.

Procedure

One explosive was hidden along path B every fourth session. However, if the dog did not detect the explosive, we placed it again on the next day. Each dog performed 1 session daily only on path B, for a total of 6 sessions with explosives and 15 without. Between each session with an explosive, there were at least 3 sessions without. The general procedures were identical to those in experiment 1.

Results and discussion

The average percentage amble (46.89±5.7%) was similar to that found on the same path B (44.43±6.8%) in experiment 1. The percent detection of the explosive was significantly lower than on path A in experiment 1 (52.46±6.1% and 86.93±2%, respectively, arcsine transformation, one-tailed paired *t*-test, *df*=6, *t*=5.48, *P*<0.001; see Table 1). In experiment 2, furthermore, we did not observe any improvement in search behavior even following detections on the formerly clean path. This suggested that reconditioning the dog to search this path properly would be difficult to implement.

Examination of mean percentage-amble values of all dogs between first and last trials on path B reveals no significant difference in the dogs' motivation to search along this path even following detection of explosives on it (52.8±8.6 and 40.6±12.5, respectively, *t*-test, *df*=6, *t*=0.84, *P*=0.2; see Fig. 3). No differences were found in vocal encouragement between first and last trials on path B (4.6±0.7 and 3.8±1.5, respectively, *t*-test, *df*=6, *t*=0.5, *P*=0.3; see Fig. 3).

The finding in experiment 2, that the higher percentage of time ambling on the formerly clean path B was accompanied by a lower percentage detection of explosives, indicates that the dogs were not searching this path efficiently. These results support the hypothesis in experiment 1 that the dogs had acquired lower motivation to search path B, resulting in a low probability of detection of explosives. An alternative explanation for the lower detection percentage was that, irrespective of any previous knowledge of the path, the frequency of placement of explosives (one explosive on a 400-m path every 4th day) is insufficient to maintain the dogs' motivation to search. This was tested in the next experiment.

Experiment 3: probability of detection on a new path

Introduction

In experiment 1 we had found that searching the clean path B did not reduce either the dogs' motivation to search for explosives on path A (as measured by percentage amble) or the probability of detecting explosives on

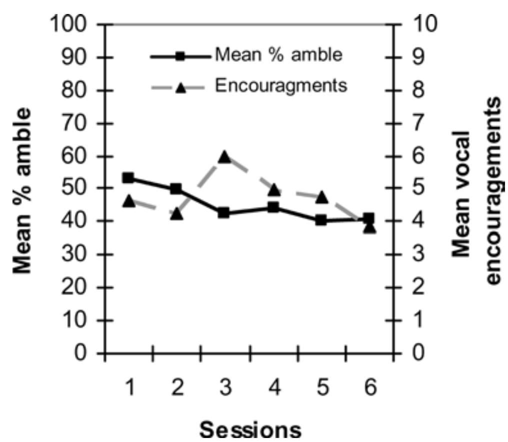

Fig. 3 Experiment 2: dogs' performance (mean values ± SE) on path B trials with explosives. Mean percentage amble, mean number of vocal encouragements (per 1 min of search)

path A. In experiment 3 we asked whether the previous experience with path B would reduce the motivation to search and detect explosives on a new but very similar path. Having tested the effect of low target probability on a familiar path in experiment 2, we now tested the same low reinforcement (one explosive every 4 days), on maintaining search behavior on a new path.

Procedure

The third path C used for this experiment was very similar to paths A and B. As in experiment 2, only one explosive was placed on path C every 4th day. The dogs were tested for 21 sessions, 6 sessions with explosives (starting on the first session) and 15 sessions without. Explosive placement and search procedure were the same as in experiments 1 and 2.

Results and discussion

The percentage amble of the dogs in this experiment was lower than in experiment 2 (28.62±7.6% and 46.89±5.7%, respectively, one-tailed paired *t*-test after arcsine transformation, $df=5$, $t=4.29$, $P<0.01$; see Table 1), indicating a greater motivation to search. Detection percentage was significantly higher than in experiment 2 (95.83±2.6% and 52.46±6.1%, respectively, one-tailed paired *t*-test after arcsine transformation, $df=5$, $t=6.2$, $P<0.001$; see Table 1). The high percentage of detection supports the interpretation that the poor search behavior found on path B in experiments 1 and 2 was not related to the low rate of reinforcement but was directly due to the dogs having learned that path B did not contain explosives and therefore they had little motivation to search.

Interestingly, in experiment 2 we did not observe any improvement in search behavior even following detections on the formerly clean path. This suggests that reconditioning the dog to search this path (B) properly would be difficult to implement. We tested this in the next experiment.

Experiment 4: reconditioning search behavior on the formerly clean path

Introduction

The three previous experiments supported the role of context in the reduction of both search motivation and the consequent probability of detection of the explosive odor. The results also showed that this reduction was specific to path B, where the dogs had originally learned that there were no explosives. The later planting of one explosive every 4 days on this path did not seem to improve the dogs' motivation to search, and the detection percentage was much lower on path B than on either the new path C with the same low density of explosives, or on the original path A that always contained explosives.

The dogs had rapidly learned that path B did not contain explosives and this learning seemed to be resistant to extinction. This resistance contrasted with the ease with which the dogs had learned not to invest in searching the path. We thus next decided to investigate whether we could recondition this resistance to extinction.

Procedure

The dogs were now trained on path B for 12 daily sessions, 1 session per day. One explosive was placed on the path each time. If the dog passed the location of the explosive the individual recording the session told the handler and the dog was recalled and sent again. If the dog still did not detect the odor, its handler brought it to the explosive and reinforced the dog when it made a detection. In this experiment neither percentage amble nor percentage of detection were useful variables due to the experimental design, since the percentage amble was artificially manipulated by stopping the dogs and forcing them to make the detection (100% detection). Therefore, we introduced a new dependent variable of motivation that was based on the following rating scale: At the end of each session, the experimenter, dog handler, and two senior dog handlers independently gave the dog a score on "relative eagerness," where 1=total lack of eagerness (apathy) and 10=the normal level of eagerness shown by the dog when searching paths known to contain explosives. Since all the raters had become extremely familiar with the behavior of each dog over a period of 1 year while running on paths, it was felt that their rating would be a valid means of measuring the motivation of each dog.

Results and discussion

The findings from the "relative eagerness" scores showed that although there was some improvement in motivation on path B, even after 12 sessions the dogs had still not reached their normal level of eagerness (Fig. 4). Although this is a subjective measure, there was good agreement among the raters and we believe that the data accurately reflect the relative eagerness of the dogs to search.

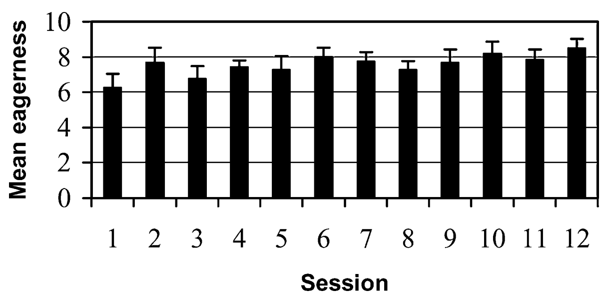

Fig. 4 Experiment 4: eagerness estimation (scale 1–10) ± SE of dogs' search behavior on path B during daily encounter with explosives (previously experienced by the dogs as a "clean" track)

The findings from this experiment thus indicate that once a dog has learned not to search a path because there are no explosives, it is difficult to restore the original search motivation shown on other paths that do contain explosives.

General discussion

The first and most basic finding of the four experiments is that the dogs were able to learn that one specific path did not have explosives. This in itself is important and shows that even very similar areas are easily discriminated by dogs. We do not know what cues the dogs used to discriminate between the two paths but presumably it was a combination of odor and visual cues.

A summary of the results of all the experiments is given in Table 1. These results show that continued experience with the always-clean path resulted in a decrease both in motivation to search and in the probability of detecting an explosive placed later on this path. Furthermore, both search behavior and detection percentage failed to increase to baseline levels even following extended experience with explosives planted daily on the previously always-clean path. This failure was shown not to be due to the low reinforcement schedule (every 4th day) since the same schedule on a new path yielded high levels of motivation and detection.

Before the implications of these results are discussed, the role and possible effects of the handler must be addressed. The dog does not work alone but as part of a team. The dogs are very quick to pick up non-verbal signals from their handler, especially since each dog had the same primary handler for at least several months. Although the handlers were not told either the number or location of explosives on the path, it is quite likely that they learned (as did the dogs) which paths contained explosives and which did not. Thus, it is theoretically possible that the handlers unwittingly transmitted some sort of message to the dog, which resulted in its decreased motivation to search. There are, however, several reasons why we regard handler influence on the search behavior as unlikely. First, the handlers were all experienced and dedicated to their task, and they were instructed and encouraged to behave in the same way in every session. Neither the experimenter nor the chief trainer could detect any differences in the handlers' behavior as a function of the path being searched. Importantly, the handlers believed that their dogs would obey them and that they could make the dog search thoroughly by the use of verbal encouragement. It was a challenge for the handler to ensure that his dog would detect all of the explosives. Misses were taken personally and were considered failures.

Furthermore, during both experiments 2 and 3 the handlers learned that explosives might be present on the path but they did not know when or where. Since they encouraged their dogs to detect all possible explosives, the differences in detection probability could only be due to differences in the dogs' motivation to search. In experiment 4, in which the handlers tried to recondition the dogs to search the previously clean path, they were surprised at being unable to restore each dog's motivation to its original level. For these reasons, we are confident that the differences in search behavior between the different experiments are true reflections of the dogs' behavior and not of the handlers.

The data for experiment 2 show a quite substantial decrease in both the motivation to search and the probability of detecting the explosives. There was 25% more ambling on path B than on path C. Moreover, even following 24 sessions on path B with an average of only three detections out of a possible six (indicating a 50% decrease in probability of detecting explosives) there was absolutely no indication of reduced motivation to search a new path (path C). This very meaningful difference appears due to the dogs having learned that one path (B) was not associated with explosives. This loss of motivation to search was thus highly specific to path B, and there was no evidence of generalization of the extinction of search behavior seen in experiment 2 to path C (in subsequent work with these dogs on other explosive detection tasks there also was no evidence of any decreased motivation to search other paths).

Our results, together with other research on context specificity of extinction, suggest an interesting progression from a broad generalization of extinction to extreme specificity of extinction. The ability of any new context to cause renewal of a previously extinguished behavior seems to be a function of two variables. The first variable is the amount of change between the two contexts. The greater the difference, the larger will be the context shift effect (Zhou and Riccio 1996). Although the two paths used in experiment 1 seemed to us to be very similar, our training procedure in experiment 1 of alternating training on path A with path B probably served to increase the dogs' discrimination between the two paths. Blair et al. (2003) discuss literature showing that exposure to a pair of stimuli, especially when arranged to promote comparison between them, will increase the later ability to discriminate between them. This has been found both for pre-exposure to stimuli later used in Pavlovian conditioning (e.g., Mondragon and Hall 2002) and pre-exposure to stimuli later used as reinforcers (Blair et al. 2003).

The second variable that seems to influence the generalizability of extinction is the ratio of the number of contexts used in establishing the behavior compared to the number of contexts used in extinguishing it. When only one context A is used for training, only one context B for extinction, and only one context C for testing, the extent of recovery of the extinguished response is substantial (e.g., Bouton and Bolles 1979; Rodriquez et al. 1999; Thomas et al. 2003). However, when the original training is only in one context A and extinction is in multiple contexts B1, B2, and B3, then the extent of renewal is attenuated, suggesting that multiple extinction contexts make the extinction more context independent (e.g., Gunther et al. 1998). In an experiment with rats in which both training and extinction occurred in all three contexts, the extent of recovery was greater than that found when the original training was only in one context (Gunther et al. 1998). In our experiments, the pre-experimental conditioning was in a very large number of contexts (A1, A2, A3, ..., A*x*) and extinction was only in one context, B. When tested in a new context C, there was no evidence of the previous extinction training done in context B; renewal of the extinguished response was complete. The high context specificity of extinction found on path B can be most easily explained by the context modulating the stimulus cues (Bouton and Ricker 1994). After extensive training of the search behavior in many contexts, the dog learned that the only relevant cues for searching were the encouragement of the handler and removal of the leash just before the dog was sent forward onto the path. Due to constant training in different contexts, context cues become irrelevant in regard to the search behavior. The dog was then given discrimination training on a novel section of path, and the normal cues of encouragement were given, yet, contrary to all previous experience, no explosives were ever found. Only on path B did the context cues of that specific path thus become strongly and rapidly associated with the absence of explosives, resulting in a drop in search motivation and poor search behavior. However, in the original path A and the novel path C, the context cues were irrelevant and the handler cues were associated with searching and detecting explosives. In this situation the dogs learned that the context was important only on path B; therefore, the extinction of the search behavior occurred only in context B.

The above analysis suggests that the resistance to retraining found in experiment 2 may be due to the fact that the dogs had learned that the context of path B was the only cue signaling the absence of explosives. Later, when a low density of explosives was placed on path B, no additional cues were available to help disambiguate the situation. The learned association of context B with no reinforcement had apparently blocked any subsequent learning that the same context B was now associated with reinforcement.

These results have implications beyond the obvious ones for training and maintenance of EDDs. They suggest that following training designed to make a behavior "context independent," any extinction training will not generalize beyond that specific context used during the extinction training. Furthermore, if the behavior is extinguished in a specific context, it will be very difficult to restore that behavior in that context. These conclusions should be considered by anyone attempting to extinguish well-established trans-context behaviors.

Acknowledgements We gratefully acknowledge Dr. A. Terkel and Ms. N. Paz for help in preparation and editing of the manuscript, and Ms. I. Gunther and Ms. N. Gazit for help with data analysis. We also thank the dog trainers, handlers, and dogs themselves for participating in this study.

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