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Canine human-scent-matching: The limitations of systematic pseudo matching-to-sample procedures

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ABSTRACT

Here transfer performance is contrasted with baseline training performance to determine whether a relational solution strategy is learned from the systematic pseudo matching-to-sample procedures commonly used to train human-scent-matching dogs. Evidence indicates that due to the lack of constraints to control against simple discrimination solutions, dogs trained with systematic pseudo matching-to-sample arrangements do not learn to use the scent sample as a signaling cue and do not learn about the matching relationship between the scent sample and matching comparison. Moreover, during pseudo matching-to-sample training, dogs may learn to ignore both the scent sample and the discriminative dimension of human scent, such as genetic information. Thus, during subsequent random control matching-to-sample (MTS) conditional discrimination training, learning about the matching relationship between the individual-unique information on the scent sample and matching comparison can be retarded. Failure to identify the solution strategy that human-scent-matching dogs must learn in order to perform accurately and reliably during operations and to distinguish between simple discrimination, random control MTS conditional discrimination, and systematic pseudo matching-to-sample has been a major drawback to the advancement of scent-matching dogs and is a contributing factor to the continued controversy surrounding their use and reliability.

1. Introduction

In both mantrailing and lineup detection, a trial begins with the presentation of a scent sample. The dog's task is to sample the odor on the scent sample, compare the memory of that odor to two or more alternatives, and then choose the comparison that matches the individual-unique human scent information on the previously presented scent sample. In the random control matching-to-sample (MTS) conditional discrimination procedure used to study complex learning in animals, the subject's task is to compare two or more comparison stimuli with the memory of a previously presented sample stimulus and then choose the comparison that matches the sample. Although the tasks are the same, canine human-scent-matching training and testing can vary significantly from the MTS procedure used for scientific investigation. The former developed by members of the canine community and the later developed by the scientific community. Thus, there can be significant differences between the solution strategies learned and significant differences between canine accuracy rates with training stimuli and accuracy during real-world scent-matching operations.

It is well established that dogs can learn to reliably smell the human scent on a scent sample and then choose from among alternatives the alternative that matches the scent sample [1–10]. However, under appropriately controlled MTS conditions, many dogs fail human scent-matching tests. When testing involves constraints to control against alternative solutions, it is not uncommon to find dogs that have not learned to scent-match, even though it was firmly believed from their training they had successfully learned to use the scent sample as a signaling cue. The question is, why do some dogs learn to scent-match while other dogs fail?

Primarily, the solutions scent-matching dogs can learn during MTS conditional discrimination training can be divided into two categories; associative solutions that are training stimulus bound or a relational solution that can transcend training stimuli. Dogs can learn sample-specific associative chains with training stimuli, in which associations are formed between each specific scent sample, correct choice, and reinforcement, or dogs can learn about the matching relationship common to all trials between the scent sample and matching comparison [11]. Both are MTS conditional discrimination solutions in which the scent sample is used as a conditional cue to signal which discriminative stimulus is correct on any given trial. However, of the two, only the relational solution enables dogs to scent-match during operations when choice alternatives are novel. Furthermore, in systematic pseudo matching-to-sample (pseudo-MTS), solutions can be subdivided into simple discrimination, in which the sample stimulus is not used as

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a signaling cue, and conditional discrimination, in which the sample stimulus is used. During pseudo-MTS, in which simple discrimination solutions are not controlled against, dogs can form direct associations between discriminative stimuli that are systematically correlated with reinforcement, at the expense of learning to use the scent sample as a signaling cue or learning about the matching relationship between the scent sample and matching comparison.

Because associative learning requires prior experience to learn about the predictive relationship between cause and effect events, dogs that have learned associative solutions cannot accurately and reliably respond during operations when human scents to be matched and discriminated between are novel. Alternatively, a more complex cognitive achievement involves learning the matching concept, that over trials the correct choice is always the *same-as* the individual-unique information on the scent sample. Dogs that have learned about the matching relationship common to all trials can respond as accurately during scent-matching operations when matching and nonmatching human scents are novel as they can with training stimuli.

The earliest scientific reports involving systematic pseudo-MTS and random control MTS conditional discrimination procedures were in the late 1700s when Itard initially used a pseudo-MTS procedure to teach stimulus-matching to Victor, the wild boy of Aveyron. Once Victor reached performance criterion, subsequent tests revealed he ignored the sample stimuli and did not learn about the matching relationship from the pseudo-MTS arrangement in which presentation position of alternative stimuli were not varied over trials. Yet, when the arrangement was changed to MTS, Victor learned to use the sample stimuli as signaling cues and succeeded in learning a MTS solution strategy [12].

Instructions of stimulus-matching tasks, to choose the comparison that matches the sample, sound so simple that it is difficult to imagine learning a matching solution could pose a problem. However, when Itard used a pseudo-MTS procedure to teach stimulus-matching to a feral boy, Victor learned the systematic stimulus presentation position solution that was not controlled against in the pseudo-MTS arrangement. Furthermore, although Victor succeeded in learning to use the sample stimuli as signaling cues and learned a matching solution from the subsequent MTS procedure, Itard reported it was substantially more difficult for Victor to acquire than the alternative solution not controlled against in the initial pseudo-MTS arrangement.

In a more recent study, Ono et al. [13] examined whether sample stimuli would acquire a signaling function based on the stimulus-stimulus pairing between the sample and matching comparison in a pseudo-MTS procedure and whether the function of sample stimuli differed between humans and pigeons. In their pseudo-MTS procedure, when sample stimulus S1 was presented, the choice alternatives were C1 correct and C2 incorrect over trials. When sample S2 was presented, the alternatives were C3 correct and C4 incorrect. Thus, rather than use the sample stimuli as a signaling cues, subjects could learn two simple discrimination solutions between C1+ predicting reinforcement and C2− predicting the omission of reinforcement and between C3+ predicting reinforcement and C4− predicting the omission of reinforcement. Once undergraduate students and pigeons reached criterion, both groups were tested to determine the solution strategy learned. The results showed that only humans learned to use the sample stimuli as signaling cues. Humans learned both a relational matching solution and the simple discrimination solutions, whereas the pigeons' response performance were affected solely by the simple discrimination reinforcement contingencies inherent in the pseudo-MTS procedure.

Very little scientific research has been conducted to investigate canine human-scent-matching training. Moreover, the solution strategy that human-scent-matching dogs must learn to perform accurately and reliably during operations has not been reviewed in any scientific journals. Additionally, although mantrailing and lineup detection dogs are often termed scent-specific, to date canine human-scent-matching literature has not distinguished between simple discrimination, random control MTS conditional discrimination, and systematic pseudo-MTS procedures. Thus, rather than, or in addition to, training with the MTS conditional discrimination procedure developed to meet scientific standards of objectivity, canine human-scent-matching training typically involves pseudo-MTS procedures developed by dog trainers who lack scientific methodology. In systematic pseudo-MTS procedures, simple discrimination solutions are not controlled against. Thus, although dogs may be scent-specific in that they discriminate between alternatives, unless training involves MTS in which reinforcement is contingent upon use of the sample stimulus, dogs may not learn to use the scent sample as a signaling cue and may not learn about the matching relationship.

Therefore, the primary purpose of this paper is to examine the evidence to determine whether dogs learn to use the scent sample as a signaling cue and learn a scent-matching solution strategy from systematic pseudo-MTS training arrangements. However, because the solution strategy that human scent-matching dogs must learn to perform accurately and reliably during operations has never been reviewed, a brief history to acquaint readers of the issues will be helpful. Also, to help resolve some key training obstacles, additional MTS guidelines that comparative learning and cognition researcher have found can enhance novel stimulus transfer performance will be briefly reviewed.

1.1. The history of canine human-scent-matching

The first examples of scent-matching failure became evident in the early 1900s. Following the publication of George J. Romanes' book, – Animal Intelligence – in 1882 [14], reports involving exceptional feats of animal intelligence rapidly became popular among the public. So much so that his book, based on anecdotal evidence and ejective inference, marks the beginning of the field of comparative psychology. Remarkable stories of animal intelligence were so inspiring that a few years later when Romanes [15] wrote about tracking experiments he conducted with his setter, the paper not only prompted wide spread use of police tracking dogs, it also became popular to use police dogs as detectives to identify suspects in homicide cases. Accounts of extraordinary achievements involving scent-matching tracking dogs helped to quickly popularize their use worldwide. However, it soon became evident that convictions based on canine scent-matching evidence were highly questionable. Between 1913 and 1914 the popularity of scent-matching police dogs began to give way to much controversy when the results from several types of highly-controlled scent-matching tests conducted by Prussian officials revealed that police tracking and lineup detection dogs from around the country did not scent-match [16].

1.2. Prussian tests

The objective during canine human-scent-matching testing is to determine whether dogs will reliably smell the novel human scent on a scent sample, compare the memory of that scent to two or more novel alternatives, then choose the comparison that matches the human scent on the previously presented scent sample. Therefore, scent-matching tests require more than just double-blind controls against cueing from the handler and testers. Tests need controls against all potential alternative solutions. Specifically, test trials require random control MTS conditional discrimination procedures, rather than systematic pseudo-MTS arrangements that lack controls.

The Prussians were critical of the solution strategies dogs can learn. They understood that correct response in scent-matching tests are only correct if dogs compare their memory of the scent sample with alternatives and choose the matching comparison. The Prussians identified other solutions that did not require the use of the scent sample and controlled against them during testing. Moreover, the Prussians knew that if a scent-matching solution was learned during training, the solution must be one that can transcend training stimuli because real-world operations involve strangers. Therefore, tests involved novel human scent transfer trials in which novel matching and nonmatching comparisons of the same saliency are presented in random order over consecutive trials.[1]

In the 1913–1914 Prussian human-scent-matching tests, all dogs failed to respond only to the matching comparison when given a choice between stranger matching and nonmatching alternatives of equal saliency. Over test trials, performance scores for all dogs corresponded with chance. Tests revealed, no dogs learned a scent-matching solution. The findings, in addition to later test results, led the Prussian government to prohibit the use of police dogs as detectives in criminal cases.

1.3. Scent-matching capacity

The Prussian tests led to a ban on the use of police dogs as detectives. Although this ended a threat to prohibit all use of police tracking dogs, the scent-matching controversy remained unresolved. Many believed dogs were incapable of learning to scent-match. However, there was also good evidence that when training arrangements are changed, the solution strategies that dogs learn change accordingly. Consequently, there were others who believed dogs are capable of learning to scent-match; that the problem stemmed from the training arrangements.

By 1926, Blunk [17] provided support for the training arrangement argument when he successfully trained a dog to reliably sample the odor on a scent sample from a stranger and then choose from among other stranger-scented items of equal saliency, the item that matched the human scent on the previously presented scent sample. Additionally, during the same period, it was well accepted from highly controlled testing that the Menzels' had trained dogs to reliably scent-match human scented items from strangers when novel nonmatching alternatives were the same saliency. Moreover, the Menzels' dogs could not only reliably scent-match human scent from strangers, the *Schäferhund Verein* (1928) published reports of tests they conducted in which the Menzels' dogs would suppress response when there was no matching scent present among alternatives [16].

1.4. Pseudo-MTS training and MTS testing

The finding that dogs are capable of learning to accurately and reliably scent-match human scent from strangers is very significant. However, although it is thought that scent-matching acquisition and accuracy arises from changes in training arrangements, those changes in training responsible for acquisition and accuracy remain largely unidentified in the canine community. Thus, when dogs are tested under properly controlled MTS conditions, reliable scent-matching performance is often not obtained. In the absence of a satisfactory account of the changes in training responsible for scent-matching acquisition and accuracy, history will continue to repeat itself and canine human-scent-matching will forever remain controversial.

One notable difference between early police dog training and the Prussian tests was that dogs were trained one way and tested another way. Since it is reasonable to suppose that the police dog-handlers believed their dogs learned to scent-match prior to the 1913–1914 Prussian MTS tests, it is also reasonable to suppose the dogs were trained one way, without constraints to control against alternative solutions (pseudo-MTS), and tested another way, with constraints to control against alternative solutions (MTS). Moreover, since no police tracking dogs could reliably respond during the Prussian MTS tests, it stands to reason that prior testing also involved pseudo-MTS arrangements, which resulted in unqualified scent-matching dogs working as detectives.

1.5. Novel human scent MTS transfer tests

The Prussian's novel human scent MTS transfer tests were significant because not only can MTS tests expose dogs that have not learned a scent-matching solution, but even if dogs have learned a scent-matching solution, novel human scent MTS transfer tests can expose dogs that have learned solutions that cannot transcend training stimuli, such as sample-specific associative chains. During scent-matching training, presentation of the scent sample precedes the correct choice/response, which precedes the reinforcer. Thus, during training dogs can learn sample-specific associative chains with training stimuli. The problem with sample-specific associative chains (if-then rules) is that reinforcement history is necessary to learn each associative chain [11]. Sample-specific associative chain solutions are training stimulus bound. Thus, when dogs learn sample-specific associative chains to solve scent-matching problems with training stimuli, they cannot scent match during operations when human scents to be matched and discriminated between are from strangers. Therefore, there can be a significant difference between performance accuracy during training and accuracy during operations.

The goal during training is for dogs to learn about the matching relationship holding over trials between the scent sample and matching comparison. Response performance is released from direct control of stimulus-response-reinforcement history when dogs learn a relational solution strategy; the matching concept. Functionally, the human-scent-matching concept involves a *domain-specific* general rule to choose from among alternatives the individual-unique (discriminative) element of human scent that is the *same-as* the individual-unique information on the previously presented scent sample, such as genetic information. To learn the general rule, dogs must compare the choice alternatives with the memory of the previously presented scent sample, detect the individual-unique information on the scent sample is the *same-as* the individual-unique information on one of the comparisons, and treat the relational concept, *same-as*, as a stimulus. Also, to learn that reinforcement is contingent upon choosing the individual-unique information that is the *same-as* sample, dogs must compare trials with one another. A relational solution permits flexible adaptive behavior when human scent choice alternatives are novel. Thus, dogs that have learned a relational solution strategy can respond as accurately when all choice alternatives are from strangers as they can with training stimuli.

Discovery of whether dogs have learned a general MTS rule depends on transfer performance with novel human scents. In transfer tests, baseline performance is contrasted with transfer

[1] Some additional human-scent MTS tests are designed to also expose an incorrect solution, rather than control against it. For example, some MTS tests involve a nonmatching human scent that is fresher than the matching scent to expose an incorrect solution strategy to respond to the most salient scent regardless of whether it matches the scent sample. Other MTS tests involve the random addition of a nonmatching human scent with prior reinforcement history to expose an incorrect simple discrimination solution to choose the alternative associated with reinforcement, rather than use the scent sample as a signaling cue.

performance. If dogs have learned about the matching relationship common to all MTS problems, that the correct choice is always the *same-as* the individual-unique information on the scent sample, their accuracy rate with novel human scent alternatives on MTS transfer trials should be as high or higher as baseline accuracy rates from training stimuli, and both baseline and transfer accuracy should be well above chance.

Although novel human scent MTS transfer tests are important, aside from a few studies [2,4] scent-matching with novel human scents has not been reported and there have been no studies that explicitly report first trial novel human scent MTS transfer performance. However, Schoon and De Bruin [2] reported that upon performance inspection of a group of dogs tested for the capacity to cross-match human scent, such as hand to elbow, one dog significantly outperformed the others. Closer examination of this dog's records revealed significant differences between test accuracy when the matching alternative was from a person working at the Rotterdam Police Dog Training Center, where the dog was trained, and performance when the matching alternative was from a visitor. Schoon and De Bruin reported that when the dog knew the suspect, 73% of the trials were correct. When the suspect was familiar to the dog and often used during training, 67% of the trials were correct. However, when the suspect was a stranger to the dog and had never been used during training, 25% of the trials were correct. The drop from 73% baseline accuracy to 25%, indicates the outperforming dog had not learned to solve scent-matching problems with a general rule to choose the comparison that matches the sample, or had only partially learned the rule. Following their findings, Schoon and De Bruin advised that for forensic purposes, dogs should be trained with scent from strangers.

1.6. Novel human scent MTS transfer test criterion

The criterion to test whether animals have learned a relational solution strategy has been reviewed by numerous investigators [18–21].[2]

The novel human scent MTS transfer test criterion is summarized as follows:

1. Dogs should be double-blind tested with the random control MTS conditional discrimination procedure used for scientific investigation so alternative solutions are controlled against.
2. Human scents in MTS transfer test trials should be novel, not used during any prior training, testing, or familiarization processes. Thus, human scents should not be reused in subsequent test trials.
3. Novel human scent MTS transfer trials should not combine both familiar and novel human scents. All scent samples and both matching and nonmatching comparisons should be novel on all test trials because prior experience with the testing stimuli may confound the results.
4. Results of novel human scent MTS transfer test trials should be limited to the first trial performance.
5. Matching and nonmatching comparisons should be collected at the same time and should be scented for the same period to control against simple discrimination between more and less salient stimuli.
6. Care must be taken that scent samples and comparisons are not cross contaminated with each other or scents form other people.
7. There should be enough novel human scent MTS transfer test trials to determine dogs are not responding by chance. Thus, a large set of novel test stimuli is required to provide sufficient statistics to evaluate transfer performance.
8. During novel human scent MTS transfer testing, correct responses should be reinforced to avoid changing the way dogs have learned to solve the problem.
9. To establish dogs have fully learned a general rule that can transcend training stimuli, MTS transfer performance to novel human scents should be equal or above baseline performance and both baseline performance and novel human scent MTS transfer test performance should be well above chance.

Reliable MTS transfer to novel human scents provides good evidence that dogs have learned a relational solution strategy. Thus, if high baseline accuracy is maintained over novel human scent MTS transfer test trials, it can be assumed that accurate performance is mediated by a general rule. However, when dogs are tested and transfer performance with novel human scents is not equal to baseline training performance, indications are dogs have learned some strategy other than a general rule or have only partially learned a general rule and will not perform reliably during human-scent-matching operations.

1.7. MTS only training and testing

Although reliable novel human scent MTS transfer performance provides good evidence that dogs have learned a relational solution strategy, Premack [18,22], Premack and Premack [23] was the first to argue that there is a simpler novel stimulus MTS solution that does not involve learning the matching concept. In novel stimulus MTS, a trial begins with the presentation of a novel sample stimulus to which subjects are typically required to respond before the novel comparisons are presented. Consequently, the correct choice is more familiar than the incorrect choice. Therefore, to solve novel stimulus MTS only problems, subjects can simply discriminate between familiar and novel stimuli.

Although Premack's familiar/novel discrimination solution can enable dogs to choose correctly during novel human scent MTS trials, the solution strategy limits accurate performance to trials in which there is a matching comparison present. That is, unlike a *same-as* general rule in which dogs could learn an additional *different-from* rule, the familiar/novel discrimination solution strategy is not applicable to an additional rule for trials in which there are no matching comparisons present.

Regardless, evidence indicates that animals do not learn two rules from MTS only training; both a rule to respond to the matching alternative and another rule to suppress response to nonmatching alternatives (e.g., see Refs. [24,25,1,26,4]). In MTS, the reinforcement contingency informs subjects when responses are correct due to differential reinforcement; correct responses are reinforced, incorrect responses are not. However, there is nothing in the MTS procedure to inform subjects when suppression of response is correct. Suppression of response, in the presence of nonmatching alternatives, is not differentially reinforced. Premack [18] argues, a stronger disposition to respond to matching

[2] Studies to determine whether animals learn MTS relational solutions are typically conducted by researchers interested in the capacity of animals to form abstract concepts, rather than domain-specific concepts, However, the reinforcement contingency in canine human scent MTS training is for dogs to scent-match the individual-unique information of human scent, such as the genetic information. That is, due to the MTS reinforcement contingency, the only way dogs can reliably earn reward is to scent-match the individual-unique information of human scent. If dogs respond to some other matching information, but the individual-unique information does not match, reinforcement it omitted. Therefore, the relational solution dogs must learn is domain-specific, rather than abstract. Although the researchers referenced are interested in abstract concept learning, the criterions to test whether animals have learned a MTS relational solution are still applicable to human-scent-matching dogs.

alternatives, than to respond to nonmatching alternatives, is enough to assure successful matching performance.

However, to be used as forensic tools in lineup detection or to be good investigative tools during mantrailing, dogs must be as, or more, reliable at indicating when there is no matching scent present as they are at indicating when there is a matching scent present and accuracy rates should be well above chance for both novel human scent matching and nonmatching trials. Thus, dogs must learn two rules; both a *same-as* general rule for matching trials and a *different-from* general rule for nonmatching trials.

Yet, training comprising both matching and nonmatching trials, typically involves go/no-go procedures in which response is differentially reinforced on go (matching) trials, but suppression of response is not differentially reinforced on no-go (nonmatching) trials. On nonmatching trials in which there is no matching alternative present, reinforcement is omitted regardless of whether dogs respond correctly or incorrectly. Like MTS only training, there is nothing in the go/no-go training arrangement to inform dogs when suppression of response is correct. Furthermore, because go trials are differentially reinforced and no-go trials are not, the likelihood of a response on no-go trials is increased. Response on matching trials and suppression of response on nonmatching trials are unequal response measures. Evidence shows when animals are trained with either go/no-go procedures or MTS only and then tested with go/no-go procedures, they do not completely suppress response on no-go trials [24,25,1,26,4]. Both arrangements have the disadvantage of increasing a tendency to respond.

Alternatively, by differentially reinforcing not just matching trials, but also nonmatching trials, and requiring dogs to respond in the same manner but to different stimuli, rather than mixing requirements to respond and suppress response, the problem of unequal response measure can be avoided. Moreover, high accuracy rates from both randomly distributed novel human scent nonmatching and MTS transfer trials indicates dogs have not only learned a domain-specific *different-from* general rule for trials when all comparisons are different from the individual-unique information on the scent sample, but also a domain-specific *same-as* general rule, rather than a familiar/novel discrimination solution strategy that is limited to MTS alone.

2. Methods

2.1. Simple discrimination

Simple discrimination can be conditioned classically or instrumentally. During classical conditioning, subjects are not required to make a response, whereas in instrumental conditioning, responses are required. In addition, over trials the discriminative stimuli may be presented either successively or simultaneously. When the discriminative stimuli are presented one at a time over trials, the classical conditioning procedure is termed a *successive discrimination procedure* and the instrumental procedure is termed a *successive go/no-go procedure*. Alternatively, when the discriminative stimuli are presented at the same time during each trial, the procedure is termed a *simultaneous discrimination procedure*. However, due to their rapid learning effect, discrimination procedures involving random presentation of positive and negative stimuli over trials have come to be known as *simple discrimination learning procedures*.

In simple discrimination procedures, there are two or more discriminative stimuli that are systematically correlated with different schedules of reinforcement over trials. One stimulus is designated the positive stimulus (S+) and the other is designated the negative stimulus (S−). Over trials, S+ is always the same stimulus; S+ is not alternated from positive to negative. The reinforcement contingency is, following presentation of or response in the presence of S+, subjects are reinforced and following presentation of or response in the presence of S−, reinforcement is omitted.

To control against subjects learning a systematic stimulus presentation solution, S+ and S− are presented in random order over trials. Thus, over trials reinforcement does not reliably follow a predictable order during simple successive discrimination. And response to a particular stimulus presentation position is not reliably correlated with reinforcement during simple simultaneous discrimination. Whereas, S+ is reliably correlated with reinforcement and S− is reliably correlated with the omission of reinforcement. Therefore, during conditioning subjects can learn that S+ predicts reinforcement and S− predicts the omission of reinforcement. And, successful conditioning requires subjects respond differently to S+ than to S− [27].

2.2. Matching-to-sample

Discrimination procedures in which reinforcement is contingent upon the use of a conditional cue to signal which alternative is correct on a given trial, are termed *conditional discrimination procedures*. Conditional discrimination is more complex than simple discrimination. Unlike simple discrimination procedures in which one discriminative stimulus is systematically correct over trials, in conditional discrimination a cue is required to signal which of the discriminative stimuli is correct on any given trial. To ensure subjects use the conditional cue and control against alternative solutions, random controls are specified in the procedural description. MTS is an example of a conditional discrimination procedure.

Prior to MTS training, there is an initial response training phase in which subjects are trained responses that are to be performed during subsequent MTS training. Initial response training phases never involve the presentation of a sample stimulus at the beginning of each trial. It is not until after response training that subsequent MTS training involves presentation of a sample stimulus.

In the standard MTS procedure, a trial begins with the presentation of a conditional cue (the sample stimulus). After presentation of a single sample stimulus, two or more alternative stimuli are presented, one of which is the same as the sample, while the other differs from the sample. The subject's task is to choose from among alternatives, the comparison that matches the sample.

Although each MTS trial begins with the presentation of a sample stimulus, to ensure subjects learn to use the sample stimulus as a signaling cue and control against simple discrimination solutions, over consecutive trials there is never just one sample stimulus involved. If just one sample stimulus is systematically used over trials, subjects can ignore the sample stimulus and simply learn to solve the problem by choosing the alternative that has come to predict reinforcement from prior reinforcement history. Thus, the constraint involving more than one sample stimulus to be used over consecutive trials, helps control against a simple discrimination solution strategy between alternatives, rather than a conditional discrimination solution strategy.

Another MTS constraint involves random or unpredictable presentation of the sample stimuli over consecutive trials. Random presentation over trials of the sample stimuli used during MTS training and testing, controls against subjects predicting reinforcement based on some systematic order, rather than learning to use the sample stimulus as a conditional cue.

Similarly, a third constraint in the standard MTS conditional discrimination procedure involves randomly varying the set of stimuli used, so that over trials all stimuli unpredictably serve both as sample/comparison correct and incorrect comparisons.

A fourth constraint involves randomly varying presentation positions of the choice alternatives over consecutive trials. Otherwise, if over trials the correct alternative is always presented in the same location relative to the nonmatching alternative, or if it is presented in a systematic pattern over trials, subjects can learn a stimulus presentation position solution, rather use the sample stimulus to signal which discriminative stimulus is correct on each given trial.

The MTS reinforcement contingency is, if subjects choose the alternative that matches the sample, they are rewarded, if subjects choose a nonmatching alternative, the trial is terminated without reward. Thus, due to the constraints that control against alternative solutions, as well as the reinforcement contingency, to reliably solve MTS conditional discrimination problems and earn reward subjects must use the conditional cue to signal which discriminative stimulus is correct on any given trial.

Controls against simple discrimination solutions enable the random control MTS conditional discrimination procedure to meet scientific standards of objectivity.

2.3. Systematic pseudo matching-to-sample

Systematic pseudo-MTS procedures have sometimes been termed MTS in canine human-scent-matching literature. However, there is a significant difference between MTS and systematic pseudo-MTS procedures. Unlike MTS, pseudo-MTS arrangements are not conditional discrimination procedures in which reinforcement is contingent upon use of a conditional cue, the sample stimulus, to signal the correct discriminative stimulus on any given trial.

In systematic pseudo-MTS, a trial begins with the presentation of a sample stimulus. After presentation of the sample stimulus, the subject's task is to choose, from among alternatives, the stimulus that matches the previously presented sample. Yet, constraints to control against simple discrimination solutions are lacking. Thus, subjects do not need to use the sample stimulus to signal which alternative is correct on a given trial and they do not need to learn about the matching relationship holding over trials between the sample stimulus and matching alternative to reliably solve systematic pseudo-MTS problems and earn reward. There is nothing in the arrangement of pseudo-MTS training to inform subjects of the task to attend to the sample stimulus, compare the memory of the previously presented sample stimulus to alternatives, and then choose the comparison that matches the sample.

For example, in some canine human scent systematic pseudo-MTS arrangements, controls against simple discrimination solutions are omitted over consecutive trials when, following scent sample presentation:

1.) The correct choice is systematically something (such as an item or track) comprising human scent and the incorrect choice is the absence of human scent.
2.) The correct choice is systematically from the same person.
3.) The incorrect choices are systematically from the same people.
4.) The correct choice is systematically more salient than the incorrect choice.
5.) The correct choice is systematically from people with prior reinforcement history and the incorrect choice is from people with no reinforcement history.
6.) The correct choice is systematically signaled by stimuli other than the individual unique information on the scent sample, such as cues from the handler or food presented in compound only with the correct alternative.
7.) The scent samples and/or alternatives are presented in a systematic order. For instance, Bowling [28] advised that during human-scent-matching training, scent samples from two different people (A & B) should be presented in the order of A, B, A, B over consecutive trials and alternative A should always be presented to the left of alternative B.[3]
8.) And, following presentation of scent sample A (SA), comparison A (CA) correct and CB incorrect are presented in random presentation position order over trials and following presentation of SC, CC correct and CD incorrect are presented in random order over trials.

In all examples, high accuracy rate may appear as though subjects have learned to use the sample stimulus to signal which alternative is correct on a given trial, when in fact the strategy learned during systematic pseudo-MTS training only involves simple discrimination solutions not controlled against.

Because systematic pseudo-MTS procedures do not control against alternative solutions, stimulus matching tests involving systematic pseudo-MTS arrangements do not meet scientific standards of objectivity.

Note: systematic pseudo-MTS procedures are not the same as pseudo discrimination procedures in which there is no way subjects can reliably predict reinforcement. In systematic pseudo-MTS procedures, there is always more than one way to reliably predict reinforcement.

3. Results

The goal in canine human-scent-matching training is for dogs to learn about the individual-unique matching relationship common to all trials between the scent sample and matching comparison. However, when dogs are trained with systematic pseudo-MTS arrangements, they can learn to solve problems with the simple discrimination solutions left open to them. In simple discrimination, discriminative stimuli are associated with some representation of the consequences they are reliably paired with; such as, S+ predicts reinforcement and S− predicts the omission of reinforcement. When dogs learn a discriminative stimulus predicts reinforcement in pseudo-MTS arrangements, they do not need to use the scent sample to signal which discriminative stimulus is correct on a given trial. Thus, rather than learn about the matching relationship, dogs can learn to ignore the scent sample as pseudo-MTS training proceeds.

A clue that dogs have learned a simple discrimination solution during pseudo-MTS training, at the expense of learning about the matching relationship, involves avoidance of the scent sample when it is presented. Although novice dogs actively sniff the scent sample, a common observation among dogs trained with pseudo-MTS arrangements is resistance to scent sample presentation. Some speculation of why dogs resist scent sample presentation, assumes the scent sample is offensive when it is held under a dog's nose. However, an alternative explanation of the change in behavior, from initial attention to subsequent resistance, is that dogs initially notice the scent sample but during pseudo-MTS

[3] In the introduction of his book, Bowling acknowledges his techniques (acquired through trial-and-error) lack scientific method. However, he argues in favor of scientific research, which can empower law-enforcement canine trainers to train toward higher levels of proficiency. Bowling contends that without more research, trainers will continue to base their training largely on trial-and-error.

training, more readily acquired simple discrimination solutions overshadow learning about the matching relationship between the scent sample and matching comparison. That is, during pseudo-MTS training, dogs learn the scent sample is redundant. They learn the scent sample does not signal anything that is not already perfectly predicted by the simple discrimination solutions not controlled against. Thus, dogs learn to ignore the scent sample, which retards learning about the matching relationship.

The later account predicts that as dogs learn the more readily acquired simple discrimination solutions not controlled against during initial pseudo-MTS training, not only do the more salient solutions overshadow the more complex matching solution, but as dogs learn to ignore the scent sample, the likelihood of learning about the matching relationship is attenuated. Furthermore, when dogs learn to ignore the scent sample, acquisition of subsequent MTS conditional discrimination will also be retarded. Therefore, pseudo-MTS training arrangements, during which dogs learn to ignore the scent sample, are counterproductive.

Another way to determine whether dogs have learned a relational solution strategy from systematic pseudo-MTS arrangements involves contrasting baseline performance from a previous training phase with transfer performance to a new phase to see whether the solution learned during the prior phase generalizes to the new phase. For example, if during an initial scent-matching phase, dogs learn about the matching relationship between the scent sample and matching comparison, a solution learned to use the sample as a signaling cue would enable dogs to perform accurately during initial trials in the new phase. Thus, transfer performance should be as high as baseline performance when response requirements remain the same. Alternatively, if response requirements are changed in a subsequent phase, acquisition to criterion rate should be faster than the previous phase if dogs learned a general scent-matching solution. That is, the error rate may initially increase due to the change in response requirements, but acquisition rate in the new phase should be faster than during the previous phase because dogs do not need to learn both about what responses to make and about the matching relationship.

Conversely, if transfer performance is not equal to baseline performance when response requirements remain the same, poor transfer performance indicates dogs have learned some other solution not controlled against during prior pseudo-MTS training, even though each trial began with the presentation of a scent sample and baseline accuracy was high. Additionally, if the solutions learned in each successive training phase are progressively more difficult, such as simple discrimination between the presence and absence of a stimulus, to simple discrimination between similar stimuli, to conditional discrimination, transfer trials can be expected to show a progressive increase in the number of errors in each subsequent phase and the number of training trials required to reach criterion from one phase to the next would likely increase.

3.1. Stimulus generalization

Pavlov [29] was the first to report that when he trained dogs to discriminate between the presence and absence of a single stimulus (*single stimulus conditioning*) and then tested them, not between the presence and absence of the conditioned stimulus (CS), but between the CS and similar test stimuli, his dogs responded to both the CS and similar test stimuli, even after over a thousand training trials prior to testing. Eventually, Pavlov discovered that if he exposed his dogs to two or more similar stimuli and correlated them with different schedules of reinforcement, his dogs rapidly learned the task to discriminate between the similar stimuli.

Although in simple discrimination procedures, subjects are typically exposed to similar stimuli that are correlated with different schedules of reinforcement, single stimulus conditioning, in which a single stimulus is reliably paired with reinforcement, can also be regarded as a form of simple discrimination. For example, during simple classical and instrumental conditioning, subjects are exposed to two different sets of stimuli that signal different schedules of reinforcement; one comprising the context plus the CS or S^D (C_xS+) and the other comprising the context alone (C_X-). In the presence of C_xS+, subjects are reinforced, whereas reinforcement is omitted in the presence of C_X- alone. Thus, discrimination is between the presence and absence of S+ and successful conditioning requires subjects respond differently in the presence of both C_xS+ and C_X- [27].

The product of single stimulus conditioning is *stimulus generalization*. Stimulus generalization refers to the tendency of an animal conditioned to respond in the presence of one stimulus, to respond in the same way, but to a lesser extent, to other similar stimuli. The phenomenon of stimulus generalization can be understood by considering that a stimulus (a term of convince) is comprised of a set of common elements that make stimuli similar and unique elements that enable discrimination between similar stimuli. After single stimulus conditioning, the greater the proportion of unchanged common elements controlling behavior, the less will variations in test stimuli (unique elements) bring about a change in behavior during subsequent discrimination testing between similar stimuli.

An example of stimulus generalization in tracking or mantrailing involves initial training on freshly laid single-tracks over soft surfaces. That is, discrimination between the presence and absence of a single-track over trials. Dogs, including puppies, very readily learn this simple discrimination. However, when dogs are subsequently transferred to trials involving two tracks, each laid by a different person, dogs initially show stimulus generalization. Moreover, dogs respond indiscriminately regardless of whether initial single-track training involves scent sample presentation at the start of every trial (e.g., see Refs. [30,31]). High baseline performance reverts to chance upon transfer to a new phase.

Although during single-track pseudo-MTS training, each trial begins with the presentation of a scent sample and the dog's task is to choose the human scent that matches the sample, transfer trials to a subsequent phase, involving two or more tracks, show dogs do not learn to use the scent sample as a signaling cue and do not learn about the matching relationship between the scent sample and matching scent along the track. Chance performance during initial transfer trials indicates that during single-track pseudo-MTS training, dogs learn the simple discrimination solution strategy not controlled against; to discriminate between the presence and absence of a track, at the exclusion of the more complex scent-matching solution. Not only do single-stimulus pseudo-MTS arrangements fail to inform dogs of the task to discriminate between human scents, they fail to inform dogs of the task to sample the odor on the scent sample, compare it to alternatives, and then choose the individual-unique human scent information that matches the sample.

3.2. Overshadowing

Furthermore, elements from soft surface laid tracks, such as crushed vegetation and disturbed soil, can overshadow human scent during soft surface pseudo-MTS mantrailing training.[4] Pavlov [29] was also the first to report that when two or more stimuli are presented in compound and one is more salient then the other, the more salient stimulus will *overshadow* learning about the less salient stimulus. Later, Seraganian [32] reported that after compound conditioning, in which a more salient stimulus overshadows a less salient stimulus, acquisition of control by the less salient stimulus can be significantly retarded during subsequent conditioning to the less salient stimulus presented in isolation of the more salient stimulus. The significance of Seraganian's findings is they indicate that during initial compound conditioning, subjects do not simply fail to notice the less salient stimulus. Rather, subjects initially attend to both stimuli and then preferentially select the more salient stimulus over the less salient. Not only do subjects notice the less salient stimulus, they also notice it is a less reliable predictor of reinforcement, and selectively learn to ignore it, which retards subsequent conditioning to the less salient stimulus.

A long-standing tradition in dog training maintains that "*training should proceed in stages from the easiest to the more difficult*", typically with little regard to what dogs learn in each stage. Accordingly, mantrailing training typically begins with single, freshly laid tracks, over soft surfaces. Yet, because response rates over soft surfaces are greater than those obtained over asphalt surfaces, a reasonable assumption is that elements of soft surface tracks (not present on hard surfaces) are more salient than the human scent component present in its compound. Thus, when dogs are initially trained with pseudo-MTS arrangements to follow single laid tracks over soft surfaces, elements from the trodden surfaces can overshadow human scent. That is, dogs can learn to ignore human scent during such initial pseudo-MTS training. Once dogs learn to ignore human scent, not only can subsequent training to trail human scent over hard surfaces be retarded, but moreover, acquisition of the individual-unique matching relationship between the scent sample and matching comparison can be retarded during subsequent human scent MTS conditional discrimination training.

Although dogs can learn to reliably trail over hard surfaces in contaminated urban environments with competing trails of the same age, fresher, and older (e.g., see Refs. [9,10]), Bowling [28] reported that when dogs are initially trained to track, prior to human scent discrimination training, they often have much difficulty learning human scent discrimination. In addition, he reported that if tracking performance comes to be controlled by ground-disturbance, dogs never achieve track reliability over hard surfaces. Moreover, Bowling found that dogs never achieve track reliability over hard surfaces even though each trial began with the presentation of a scent sample (pp. 117). The significance of Bowling's findings is they indicate that during initial soft surface pseudo-MTS training, in which simple discrimination between the presence and absence of ground disturbance is not controlled against, not only do the more salient elements from trodden soft surfaces overshadow the less salient human scent component, but moreover, with enough initial soft surface pseudo-MTS training, dogs can learn to ignore the human scent component both on the scent sample and along the track. Yet, the goal in human-scent-matching training is for dogs to learn about the individual-unique matching relationship holding over trials between the scent sample and matching comparison. Because of his findings, Bowling advocated that human scent discrimination [human-scent-matching] should be trained prior to tracking (pp. 116).

Mantrailing over hard surfaces can also involve pseudo-MTS arrangements. A frequent practice is to train using a trail layer with prior reinforcement history as the correct choice and strangers (members of the public) as the incorrect alternatives. Thus, simple discrimination between a human scent that has come to predict reinforcement from prior reinforcement history and novel human scents is not controlled against. From my own research (unpublished), I have found that when the set of trail layers used for training is small and training does not involve trials in which matching and nonmatching alternatives are either both familiar or both novel (MTS), high baseline accuracy reverts to chance during novel human scent MTS transfer tests. That is, novel human scent MTS transfer tests show dogs do not learn to use the scent sample as a signaling cue and do not learn a relational solution strategy from the pseudo-MTS arrangement.

3.3. Lineup detection training involving pseudo-MTS

Pseudo-MTS is not limited to mantrailing. In methods used to train lineup detection police dogs, initial response training phases typically involve pseudo-MTS arrangements, during which trials begin with the presentation of a scent sample but simpler solutions are not controlled against. For example, rather than reinforcement being contingent upon use of the scent sample, reinforcement may be contingent upon simple discrimination between the presence and absence of food, followed by a reinforcement contingency to discriminate between the presence and absence of human scent in the next phase, and then simple discrimination between human scents in a later pseudo-MTS phase (e.g., see Refs. [33,34,8,35,36]). Although lineup detection training methods vary, baseline performance from an earlier phase can be contrasted with transfer performance to a subsequent phase to see if dogs learn to use the scent sample as a signaling cue and learn about the matching relationship from any of the pseudo-MTS training phases. That is, if during pseudo-MTS training, response performance comes to be controlled by a rule to *choose the comparison that matches the sample,* transfer of the general rule to the next phase would enable accurate performance.

Jezierski et al. [35] evaluated the progress made over three [pseudo-MTS] training phases and reported the percent of correct responses decreased significantly over consecutive training phases, the percent of false alarms increased significantly over consecutive training phases, and the percent of misses increased significantly in training phase three. Similarly, in a study to provide a description of the training phases used by the French Division of the Technical and Scientific Police, Marchal et al. [36] reported that the mean number of trials required to reach criterion in the various [pseudo-MTS] phases increased significantly over each successive phase.

[4] Tracking is a general term. However, researchers have found dogs can solve tracking problems by discriminating between the presence and absence of a track or by discriminating between differences in track saliency at the exclusion of human scent information. Therefore, the function of the term mantrailing is to specify that response performance is controlled by human scent information. However, although problems may begin with the presentation of a scent sample, due to training arrangements mantrailing dogs may not learn to use the scent sample as a signaling cue. Non-scent-matching mantrailing dogs may simply discriminate between the presence and absence of some human scent information, discriminate between saliencies, or discriminate between a human scent that has come to predict reinforcement from prior reinforcement history and other human scents that either predict the omission of reinforcement or have no reinforcement history. Additionally, scent-matching mantrailing dogs may learn sample-specific associative chains, which are training stimulus bound. Yet, to accurately and reliably perform during operations when human scent alternatives are novel, mantrailing dogs must learn a general solution strategy that can transcend training stimuli, such as a rule to choose the comparison that is the *same-as* the sample. Therefore, alternative solutions must be controlled against, both during training and testing.

In both studies, poor transfer performance indicates the dogs learned the simple discrimination that reinforcement was contingent upon in each pseudo-MTS phase at the exclusion of a scent-matching solution strategy. As each new discrimination became progressively more difficult from the previous phase, the percent of correct responses decreased and the number of trials required to reach criterion increased. Although throughout training phases, each trial began with the presentation of a scent sample and accordingly, the dogs' task was to sample the odor on the scent sample and then choose the comparison that matched the sample, transfer trials showed dogs did not learn to use the scent sample as a signaling cue and did not learn about the matching relationship holding over trials between the scent sample and matching comparison from any of the pseudo-MTS arrangements.

3.4. Enhancement of novel stimulus transfer performance

Canine human-scent-matching training frequently involves a limited amount of scent donors. However, when dogs are trained MTS with just a few helpers, acquisition of a MTS solution can seem almost impossible. Wright et al. [37] argued, when the set of MTS training stimuli is small and trials are massed together within a session, training stimuli must be randomly but repeatedly alternated, so all training stimuli are both sample/comparison correct and incorrect over trials. The problem animals are faced with, is remembering which stimulus is sample/comparison correct on a current trial, which is a problem of *proactive interference*. Wright et al. found, errors were increased when a nonmatching comparison in a current trial was sample/comparison correct in a previous trial. They reported, the limited stimulus reversal method of training MTS seldom produces evidence that animals learn the matching concept; the sample stimulus is always the *same-as* the matching comparison [Also, the number of comparison stimuli within trials can interfere with memory of the sample, which involves *retroactive interference*.].

Researchers have found that acquisition of a general MTS solution strategy, can be significantly enhanced when trial-unique stimuli are used during training and testing [38–40]. For example, Wright et al. [41] trained two groups of pigeons MTS. In the experimental group, there were 152 trial-unique training stimuli presented just once in each daily session of 76 trials. In the control group, there were only two stimuli in the training set, which were presented randomly over 76 trials in each daily session. Once both groups reached a criterion of 75% correct, they were transfer tested with novel stimuli. The researchers found that although acquisition of the task was slow in the trial-unique group, requiring 360 training sessions to reach the 75% criterion, versus 16 sessions for the control group, the trial-unique group showed excellent transfer of 80% correct, whereas the control group showed no evidence of transfer.[5]

Similarly, Peña et al. [42] found when the set of olfactory training stimuli was progressively increased over MTS training, the solution learned by rats transferred to novel test stimuli. Although, some species (e.g., *humans* [43,44],*chimpanzees* [45], and *dolphins* [46]) have been found to spontaneously attend to the physical similarity between stimuli when training involves a small set size, other species require a larger set size to learn about the matching relationship.

To learn about the matching relationship common to all MTS trials, dogs must not only compare the alternatives with the memory of the previously presented scent sample, they must also compare trials. Thus, multiple trials within a session can enhance learning about the matching relationship. Yet, errors are increased when MTS involves a small set of stimuli and trials are massed together within sessions. The solution to enhance acquisition of the matching relationship and reduce proactive interference errors is not to limit the number of trials within a session, but to increase the training set size or train with novel stimuli. Also, to reduce retroactive interference errors during MTS acquisition, the number of alternatives in each trial can be limited to two.

[5] Experimental evidence indicates species differ in their ability to learn about the matching relationship common to all MTS trials and transfer such learning to completely novel stimuli. Primates and dolphins have shown good evidence of transfer, whereas pigeons show limited evidence of transfer when conditioning involves the standard MTS procedure. Consequently, pigeon studies finding good transfer following modifications of the standard MTS procedure can be useful, considering there are very few studies involving novel stimulus transfer tests with dogs (but see Ref. [1]).

4. Conclusion

The assumption that dogs readily learn to scent-match simply by beginning each trial with the presentation of a scent sample is a myth. The misconception arises from systematic pseudo-MTS training and testing procedures in which high accuracy rates alone, without appropriate controls, give the illusion dogs have learned to use the scent sample to signal the correct choice. Although a matching solution exists in all systematic pseudo-MTS procedures, evidence indicates when dogs are trained with systematic pseudo-MTS procedures, they do not learn to use the scent sample as a signaling cue and do not learn about the matching relationship common to all trials between the scent sample and matching comparison.

Human-scent-matching dogs can be a valuable tool both to law enforcement and search and rescue. However, the limitations inherent in pseudo-MTS procedures, which persist as popular initial or sole training and testing methods, gravely impedes their application and advancement. Unless evidence is provided that a dog in question has been transfer tested with the random control MTS conditional discrimination procedure in which alternative solutions are controlled against, it must be supposed that the dog does not scent-match and alternative solutions are responsible for reports of high accuracy.

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