Human Scent Discrimination: Phase 1 and 2

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Phase 1 is a response performance training phase in which dogs learn a targeting response. Phase 2 is a simple human scent discrimination training phase in which dogs learn to attend to the individual-unique discriminative component of human scent. Although training is broken down into phases and Phase 2 only involves *simple discrimination*, the ultimate goal is for dogs to learn a *matching-to-sample (MTS) conditional discrimination* task to accurately and reliably sample a stranger's human scent on a scent sample, then choose from among alternatives the individual-unique information that matches the individual-unique information on the previously presented scent sample.*[1]

Accordingly, human scent must have an individual-unique discriminative component that remains constant over time and is common to all humans, such as genetic information. Genetic cues are analogous to human finger prints being individually unique, staying the same over time, and being common to all humans, which enables accurate and reliable discrimination between people. Furthermore, dogs must be able to detect the individual-unique human scent information from among the array of other information that is less reliably correlated with reinforcement and use the individual-unique information to reliably solve scent matching problems with strangers.

To learn an MTS solution strategy that can transcend training stimuli, dogs must learn about the individual-unique matching relationship holding over trials between the scent sample and matching choice alternative. As dogs learn about the matching relationship, they can learn a domain-specific MTS solution strategy, such as a rule to choose the genetic information that is the same-as the sample. However, in addition to genetic cues, human scent is comprised of a rich array of other olfactory information. Thus, to learn about the matching relationship holding over trials between the genetic information on the scent sample and correct alternative, dogs must attend to genetic information. Therefore, the primary purpose of Phase 2 is to increase attention and associability to the individual-unique discriminative component of human scent while decreasing attention to incidental or irrelevant information. The author argues, by increasing attention and associability to the individual-unique component of human scent prior to MTS conditional discrimination training, the likelihood of dogs learning about the individual-unique matching relationship holding over MTS trials between the scent sample and matching choice alternative will be enhanced.

Scent matching is a far more complex task than the layperson typically imagines, both in training and the solution strategy that dogs must learn to perform accurately and reliably during operations. It is a myth that dogs learn to scent match simply by beginning each trial with the presentation of a scent sample (Hale, 2017). In the absence of knowledge about of the circumstances responsible for successful conditioning, successful conditioning is a happy accident. Furthermore, the more complex the task and/or the appropriate solution strategy, the less likely conditioning will be successful in the absence of knowledge about of the circumstances responsible for successful conditioning.

It's not temporal contiguity, it's the information that the reinforcement contingency provides

Survival often depends on the ability to learn about the predictive relationship between a stimulus and biologically important outcome and use that knowledge to modify behavior in anticipation of the outcome. *Sign-tracking* is an example. In sign-tracking experiments, once animals have learned an association between a stimulus and appetitive reinforcer, that the stimulus predicts the reinforcer, they will typically modify their behavior to come in close physical proximity with the conditioned stimulus. Accordingly, once a wolf pup acquires knowledge about the predictive relationship between the smell of prey and food, the wolf can later use the olfactory information to sign-track its prey. However, at the same time the smell of prey and food are temporally correlated during associative learning, a variety of other stimulus events also occur. Thus, successful conditioning cannot be reduced to a simple process in which animals only register temporally conjoined events. To learn about the predictive relationship between a stimulus and biologically important outcome, animals must have some way to exclude irrelevant information. Survival depends on the ability of animals to differentiate environmental stimuli that signal biologically important outcomes from those that are only incidentally correlated with the same outcome. If animals were not capable of associating selectively, useless associative clutter would circumvent adaptive response and animals could perish.

In the prey-food example, it might seem sufficient that the two events be temporally correlated to establish an association between them. Certainly, that is what behaviorists thought. Central to traditional theories of associative conditioning is the view that temporal contiguity is the primary determinant of successful conditioning. For example, Skinner said, “To say that a reinforcement is contingent upon a response may mean nothing more than that it follows the response….conditioning takes place presumably because of the temporal relation only, expressed in terms of the order and proximity of response and reinforcement” (1948, p.168); “So far as the organism is concerned, the only important property of the contingency is temporal. The reinforcer simply follows the response. How this is brought about does not matter” (1953, p.85). Traditional behavioral psychologists regarded contingencies in terms of the temporal order of events, rather than in terms of the relations that actually control response performance – the conditions responsible for successful conditioning. Thus, for Skinner, a temporally linked antecedent, behavior, and consequence was a contingency, rather than a reinforcement contingency being a cause and effect arrangement, which specifies both when reinforcement will and will not occur. Although behaviorists used the term contingency, for them all successful conditioning was assumed to be an automatic consequence of temporally pairing stimulus-response events with reinforcement.

However, beginning in the late 1960s and early 1970s, empirical evidence began to accumulate that was problematic for this view. So much so, that it prompted in a radical reappraisal of traditional views and ultimately a split from traditional comparative psychology (behaviorism) to contemporary comparative psychology, a subgroup of which is comparative cognition. Numerous experimental preparations showed that temporal contiguity between a to-be-conditioned event and reinforcement is neither sufficient nor necessary for successful conditioning. For example, Revusky & Garcia (1970) and Revusky (1971) showed that under the right circumstances, first trial conditioning between a conditional stimulus (CS) and unconditional stimulus (US) could occur across intervals of several hours, during which time a multitude of other events occur that subjects do not associate with the US. If a representation of a stimulus can be associated with a reinforcer occurring hours later, what prevents the other events occurring between that time from being associated with the reinforcer?

That temporal contiguity is not the primary determinant of successful conditioning has also been shown in *blocking* experiments. Kamin (1968) found that prior conditioning to a stimulus can prevent (block) an added stimulus from gaining control over behavior when it is subsequently presented in compound with the previously conditioned stimulus. In Kamin's blocking experiments, a normally adequate CS temporally paired with a normally adequate reinforcer, showed little evidence of conditioning when it was presented in compound with another CS that was already established as a signal for that reinforcer. Thus, blocking is a function of pretraining with one stimulus component of a subsequent compound.

Kamin (1969) also found that subjects both notice the added stimulus and learn something about it. Rather than blocking being due a failure to notice the added stimulus on subsequent compound trials, Kamin established that when the added stimulus is presented in compound with the previously conditioned stimulus on subsequent trials, subjects do notice the added stimulus. They notice it is redundant, predicting nothing new about the occurrence of the reinforcer. Consequently, subjects learn specifically to ignore the redundant stimulus.

More evidence that blocking is not due to a failure to notice the added stimulus on subsequent compound trials, can be found in *unblocking* experiments. If blocking is the result of a learned predictive relationship between a specific stimulus and specific reinforcer, then if the specific reinforcer is changed on the first compound trial, conditioning to the added stimulus should occur. This is exactly what has been found in unblocking experiments. Unblocking (i.e. conditioning to the added stimulus) occurs not only when the specific reinforcer used in prior conditioning is changed, but also when the intensity of the reinforcer is changed, when another reinforcer is added, and when the predicted reinforcer is omitted on the first compound trial. Thus, unblocking experiments not only show that subjects do notice the added stimulus, they show that blocking is stimulus-reinforcer specific.

Unblocking experiments also show, behaviorists were wrong in supposing the reinforcer is a catalyst to strengthen stimulus-response habits. For instance, the reinforcer is regarded as a catalyst in training advice to sometimes surprise (jackpot) dogs with a much bigger reward than normal (Pryor, 1984). Or to keep motivation high, unpredictably change the reinforcer or reinforce prior to stimulus identification, which actually is a pseudo discrimination/no contingency arrangement. Unblocking experiments show animals learn both about the probable signal (or cause) and about the specific reinforcer (effect) during conditioning. Thus, if the effect (reinforcer) is changed, the change in reinforcement indicates to the learner that there is no causal relationship and thus, attention and response performance can be expected to change to some other potential signal, which could be very bad if training involves land mine detection. Although advice to change the reinforcer may be acceptable to pet dog trainers, it should never be acceptable to working dog trainers.

In another example, finding that temporal contiguity is neither sufficient or necessary for successful conditioning, Rescorla (1966, 1968) showed when there was no reinforcement contingency, little or no conditioning occurred (see also Hammund, 1980). In these *relative validity* experiments, only when there was a true reinforcement contingency, specifying both when reinforcement would and would not be presented, did conditioning occur. Rescorla found that successful conditioning depends on the information the CS provides about the occurrence of the US. Successful conditioning is not an automatic consequence of associating temporally paired events. – More about relative validity experiments will be reviewed below.

These and other experiments, showing that the law of temporal contiguity is not the primary determinant of successful conditioning, led researchers to change their focus from trying to formulate laws of conditioning, to investigating how conditioning is affected by the interaction between multiple environmental events and reinforcement. Since no to-be-conditioned event ever occurs in isolation of other events, the trainer's to-be-conditioned event is only one among many other events that may or may not be the true signal or cause of the reinforcer. Thus, even if the reinforcer follows a to-be-conditioned event immediately after its occurrence, subjects will not necessarily associate the to-be-conditioned event with the reinforcer. Although temporal contiguity generally provides a clue, it is important to the learner only as an indicator that a to-be-conditioned event and reinforcer might be causally related. By now, there is ample evidence that the critical determinate of successful conditioning is not temporal contiguity per say, but rather the to-be-conditioned stimulus and/or response must be a better predictor of the reinforcer than other events. That is, there must a causal relationship between the to-be-conditioned event and reinforcement. Therefore, a true reinforcement contingency, specifying when reinforcement will and will not occur, is more important to successful conditioning than temporal contiguity because the function of a reinforcement contingency, involving differential reinforcement, is to enable subjects to discriminate the better predictor of reinforcement (causal relationships) from events that are only incidentally correlated with the reinforcer.

Cause and effect learning

In nature, where change is common, survival depends on the ability of animals to differentiate stimuli that are better signals of biologically important outcomes from stimuli that are only incidentally correlated with the same outcome. Survival depends on the ability of animals to learn selectively both about signals that better predict events of biological importance (the contemporary view of classical conditioning) and about responses that are instrumental in causing access to resources of benefit and avoidance of harm (contemporary view of instrumental conditioning). It is the ability for selective association that enables animals to control their environment in the service of their needs and desires.

Dickinson (1980) argues that associative learning mechanisms have evolved to enable animals to detect and store information about cause and effect relationships in their environment (see also, Hall, 1990; Testa, 1974). He argues, the conditions under which associative learning takes place are those in which there is a causal relationship between events. Much of what an animal must learn about, so beneficial approach or withdrawal can happen, are the predictive signs of benefit or harm. Therefore, it is important for animals to differentiate environmental stimuli and/or actions that are causally related to biologically important outcomes from events that are only incidentally correlated with the same outcome.

If Dickinson is correct, that associative learning mechanisms evolved to detect causal relationships in the world, then sensitivity to true reinforcement contingencies should be readily observed, because to arrange a reinforcement contingency, involving differential reinforcement, is to arrange a cause and effect relationship. This is exactly what Rescorla (1966) found. Dogs were divided into three groups. In the first group, there was a zero-reinforcement contingency, in which the CS and US occurred randomly (analogous to temporally pairing a to-be-conditioned stimulus with reinforcement, but also offering the reinforcer before the CS or presenting the CS or US in the absence of the other). Thus, the reinforcer occurred independently of the CS. Even though the first group received the same number of temporally contiguous CS–US pairings as the second, from a causal perspective, presentation of the CS provided no information about the future occurrence of the US. In the second group, presentation of the US was contingent upon just prior presentation of the CS (CS–>US). Thus, if dogs are sensitive to cause and effect relationships (that an effect never occurs before the cause and never occurs without a cause), they could learn about the CS–US contingent relationship and use the CS (CS+) to reliably predict the occurrence of the US. In the third group, presentation of the CS (CS-) was reliably correlated with (predicted) the absence of the US. Notice there is no temporal contiguity involved in pairing a CS- with the absence of reinforcement. Thus, if conditioning to the CS- occurs, it is not due to temporal contiguity. Instead, successful conditioning indicates it is the information that the CS- provides about the nonoccurrence of the US. That is, successful conditioning is due to the acquisition of knowledge about the predictive relationship between the CS- and the omission of an initially expected reinforcer.

The results of the experiment showed, dogs are indeed finely tuned to learn about contingent relationships; cause and effect relationships. When presentation of the CS+ and CS- enabled dogs to reliably predict when the US would or would not occur, successful conditioning occurred. However, despite the fact that dogs in the zero contingency group received at least as many CS–US temporally contiguous pairings as the second group, no evidence of conditioning to the CS was found. Thus, even if reinforcement follows a to-be-conditioned event immediately after its occurrence, evidence shows subjects will not necessarily associate the to-be-conditioned event with reinforcement. For successful conditioning to occur, the to-be-conditioned event must provide information about the occurrence of the reinforcer better than other events, which is what the CS+ and CS- did in Rescorla's second and third groups.

Effects of reinforcement contingencies on discrimination learning

It is one thing to say that associative learning mechanisms have evolved to enable animals to detect and store information about cause and effect relationships, or animals discriminate events that are causally related to important outcomes from events that are only incidentally correlated with the same outcome, but it is also important to understand how animals go about doing so. What is the process by which animals discriminate causal relationships from noncontingent schedules of reinforcement in which an outcome occurs relatively often but independently of a stimulus or behavior?

In addition to strict laws, such as an effect never occurs without a cause and never occurs before the cause, there are also general laws of cause and effect relationships. For instance, generally an effect contiguously follows its cause, but not always. Due to a general law of temporal contiguity, when events occur contiguously before a motivationally significant outcome, animals are given a clue that the temporally correlated events might be causally related. Temporal contiguity between a to-be-conditioned event and reinforcement is helpful to the learner as an indicator of a possible causal relationship. However, since it is impossible for any event to occur in isolation of other events, the to-be-conditioned event is only one among many other events that may or may not be the true signal or cause of the reinforcer. Therefore, to reliably obtain the motivationally significant outcome, animals are faced with the task of determining which event out of other possibilities is the better predictor or cause. Since reinforcement contingencies, specifying when reinforcement will and will not occur, involve differential reinforcement (two different schedules of reinforcement or outcomes), one way to in which the discrimination could be achieved is by contrasting the probability of an outcome following the possible causal event (P(O/E)) with the probability of the outcome in the absence of the possible event (P(O/–E)). Thus, in situations where P(O/E) is greater than P(O/–E), the event is a good probable cause (or signal; S+) of the outcome. When the P(O/E) is less than P(O/–E), the event is a good probable preventative cause (or signal; S-), predicting the outcome is less likely to occur. Whereas, when the P(O/E) and P(O/–E) are equal, there is no objective contingency between the event and outcome.

For example, if a dog is to be trained to sit on command using a true reinforcement contingency, to learn the associative chain the contingency would be, if the command is given and the dog sits, the response would be followed with the reinforcer. But if the command is given and the dog does not sit, reinforcement would be omitted. Also, if the dog sits when the command has not been given, reinforcement would be omitted. Thus, a novice dog is provided a clue that “sit” signals when the response of sitting will be reinforced the first time the command is given, the dog sits, and the response is followed with the reinforcer. However, the only way to know for certain whether or not it’s a causal relationship would be for the dog to test alternatives by sitting on occasions when the command is not given or fail to sit on occasions when the command is given and then compare the probability of the outcome following the associative chain (Sit–sit–reinforcement) with the probability of the outcome in the absence of the chain. And, observation of novice dogs during acquisition, indicates they do exactly that when conditioning involves a reinforcement contingency. It is both reinforcement following the command and correct response and the omission of reinforcement following incorrect responses that enables dogs to learn for certain the reinforcement contingency – that the command signals when the response of sitting will be reinforced.

Notice, if dogs are reinforced following a correct response but receive an aversive following an incorrect response, although differential reinforcement (different outcomes) would allow the dog to learn the discrimination, use of an aversive is also counterproductive considering dogs must test alternatives to learn the reinforcement contingency. In addition, aversives can produce unforeseen side effects. Another consideration is, if dogs are taught to sit the way behaviorists prescribe, to train the behavior first and then later bring the behavior under stimulus control, learning that the command signals when the response will be reinforced would be retarded. Bringing the behavior under stimulus control of the command would be retarded because the command was absent during the initial behavior training stage. Thus, it must be an incidental stimulus. As far as the dog is concerned, there is no causal relationship between the command, response, and reinforcement. Instead, during the response performance training stage in which there is no command, dogs would likely learn to use some other stimulus to signal when the response will be followed with reinforcement, such as the presence of the reinforcer. Accordingly, dogs may appear as though they have learned to respond on command, when in fact response performance is controlled by some other cue. To find out, transfer trials in which the context is changed can be used to test whether response performance is under control of the command. If dogs do not respond correctly upon command when the context is changed, it indicates response performance is not under stimulus control, rather than old school assumptions that behavior must be generalized to different locations via repetition in those locations. Furthermore, if the response is continually rewarded in the absence of the command – in the absence of a reinforcement contingency – the behavior may never come under stimulus control. Yet, because behaviorists treat reinforcement merely as a catalyst, simplistically assuming that reinforcement following a response strengthens (stamps in) the response, and the omission of reinforcement weakens (extinguishes) the response, behaviorists advise reinforcing the response both after the command and in the absence of the command, rather than training with a true reinforcement contingency so subjects can acquire knowledge about a cause and effect relationship.

Relative validity of cues

For response performance to come under stimulus control, the to-be-conditioned stimulus must be a better predictor of reinforcement than other possible signals. Thus, for a specific command to control a specific response, training must be contingently arranged so the command signals when the response will be reinforced better than competing cues over trials. Similarly, to train say lung cancer detection, training must be contingently arranged so cancer cues are a better predictor of reinforcement than the other olfactory information that is present in compound with the cancer element. Since cancerous cues cannot be presented separately from other information in say human breath, a discrimination procedure between cancerous breath positive (S+) and healthy breath negative (S-) is necessary involving multiple novel cancerous and healthy scent donors over trials to control against genetic cues. The dog's task during lung cancer discrimination training is to determine which stimulus information is most reliably correlated with reinforcement compared to the other stimulus information that is less reliably correlated with the same outcome and assign predictive value relevant to each. If dogs are able to master the task, they can reliably obtain the motivationally significant reinforcer and reliable performance over trials indicates they have learned the discrimination.

Accurate and reliable scent discrimination between similar odors, such as discrimination between healthy and cancerous breath, shows dogs are capable of detecting and selectively controlling the attention they pay to some stimulus information at the expense of other olfactory information that is present in its compound during training. They are capable of learning selectively to attend to stimulus information that is a more valid predictor of an important outcome at the expense of less valid predictors of that outcome. If dogs were not, dogs would not be able to reliably discriminate between similar stimuli.

Our goal is to increase attention and associability to the individual-unique discriminative component of human scent, such as genetic information. Although MTS conditional discrimination is a more explicit procedure with which to inform dogs to attend to and use genetic cues to solve the discrimination problem, it is also a more complex task that is not as readily acquired as simple discrimination. Therefore, to increase attention to the individual-unique discriminative component of human scent and enhance subsequent MTS acquisition, Phase 2 will involve simple discrimination between positive and negative human scents, say between Fred S+ and Mike S-. Here again, to reliably obtain the motivationally significant reinforcer, the dog's task is to determine which stimulus information is most reliably correlated with reinforcement compared to other stimulus information that is less reliably correlated with the same outcome and assign predictive value relevant to each. However, in this arrangement, not only does Fred's genetic information better predict reinforcement than elements common to both S+ and S-, Mike's genetic information predicts the omission of reinforcement better than the common elements. Therefore, with enough discrimination training (overtraining), not only can dogs learn about the absolute predictive values of Fred and Mike's genetic cues, attention and associability can increase to genetic information over all because genetic information predicts a change in reinforcement; better predicts both reinforcement and the omission of reinforcement, two important outcomes (Sutherland & Mackintosh, 1971; Mackintosh, 1975). By increasing attention and associability to the discriminative component (genetic information) of a complex stimulus (human scent), subsequent discrimination between genetic cues will be more readily acquired.

However, relative validity of cues has not been well understood among researchers investigating human scent matching and discrimination by dogs. For example, in a human scent matching task, which involved simultaneous presentation of alternatives (enabling comparison between alternatives), Hepper (1988) transfer tested dogs that were initially trained to scent match with spices, for their ability to discriminate between dizygotic (nonidentical) twins differing only in their genetic relatedness and monozygotic (identical) twins differing only in environmental factors, such as diet.*[2] In experiment 1, involving nonidentical twins, environmental odors were controlled against to determine whether dogs could discriminate between genetic cues only. Controls involved equal presentation of environmental cues in compound with both the correct and incorrect genetic alternatives. Test results indicate genetic differences between nonidentical twins are sufficient to enable dogs to choose correctly the alternative that matches a previously presented scent sample. Experiment 2 involved identical twins who ate different diets. Thus, genetic cues were controlled against, but dietary cues were not. Although dogs appeared to have more difficulty making a choice, spent more time examining the alternatives, and made more errors than experiment 1, all dogs chose the correct alternative at levels significantly greater than chance.

Hepper argued, the fact that the dogs made slightly more errors in experiment 2 than in experiment 1 and took longer to make a choice may indicate that the dissimilarity between environmental (dietary) information is less than dissimilarity between genetic cues. In other words, discrimination between genetic information may be easier than discrimination between dietary information, which might be true. However, it must not be overlooked that the dogs in experiment 1 were the same dogs used in experiment 2. In experiment 1, genetic cues were relevant and dietary cues were irrelevant. Genetic cues reliably signaled the correct choice, whereas dietary cues were equally present among correct and incorrect alternatives. Therefore, over experiment 1 testing dogs could have learned about the relative validity of cues. Dogs could have learned about the relevance of genetic cues and the irrelevance of dietary cues. Thus, in experiment 2, when the relative validity of cues was reversed, it is predictable that dogs would have more difficulty making a choice, spent more time examining the alternatives, and make more errors than experiment 1, which is exactly what Hepper reported.

Relative validity seems the more plausible account when it is considered that in other studies, researchers reported dogs did not choose based on after-shave (Marciniak, 1999), valerian, soap, processed meat (Dominik, 2000), gender (Schoon, 1997), or smoking habits (Schoon, 1997; Misiewicz, 2000). In both simple human scent discrimination between positive and negative scents and typical human scent conditional discrimination, if dogs respond to any of the afore listed elements that are present in compound with the incorrect genetic cue, reinforcement would be omitted, whereas genetic information can be used to reliably predict both reinforcement and the omission of reinforcement. Thus, although the incidental elements may also be correlated with reinforcement, relatively, genetic cues are better correlated with the important outcomes than the afore listed elements over conditioning. Therefore, the reported findings can be anticipated. Alternatively, it seems unlikely that discrimination between genetic cues would be easier than discrimination between cues from all the afore listed categories. It is also important to notice, it is unlikely that after-shave, valerian, processed meat, or smoking habits were equally present among correct and incorrect alternatives over training and testing. Nevertheless, test results indicate dogs learned they were irrelevant. The point is, evidence indicates that incidental stimuli did not need to be equally present among correct and incorrect alternatives over training and testing. Nor do the need to be neutralized by being equally correlated with reinforcement and the omission of reinforcement, as conditioning-extinction theories have supposed.

Human scent is a complex stimulus. In compound with genetic information, human scent has a wide variety of other information that cannot be isolated from genetic cues during discrimination training, such as gender, diet, hormones, disease, medications, hygiene, hygiene products, tobacco, proteins, microorganisms, saliency, and site of stimulus presentation. Also, in the real-world, as in the laboratory, it is impossible to present a single to-be-conditioned stimulus in isolation of other environmental stimuli. Yet, it is well established that animals can learn to accurately and reliably respond to a specific stimulus at the exclusion of others. If stimuli cannot be presented in isolation of other stimuli, then a problem researchers are face with is to understand why with sufficient exposure to the two sets of stimuli, correlated with different schedules of reinforcement (differential reinforcement), subjects come to respond differently in the presence of one set of stimuli than in the presence of the other set of stimuli. Say for example, discrimination is classically conditioned between Fred's scent positive (S+) and Mike's scent negative (S-) to novice dogs. In classical conditioning, there are no response requirements, so there are no errors. Instead, in this classical conditioning procedure, S+ and S- are presented successively (one at a time over trials) and both S+ and S- discriminative stimuli are presented an equal number of trials. Therefore, reinforcement would occur on 50 percent of the trials, during which reinforcement is contingent upon presentation of S+, and would not occur on 50 percent of trials, when S- is presented. Suppose discrimination training is always conducted in the same place and both Fred and Mike are instructed to wash with the same soap prior to scent collection. Therefore, during discrimination training, all else being equal, gender, soap fragrances, and training context would be paired with reinforcement on 50 percent of the trials and paired with the omission of reinforcement on 50 percent of the trials. The training context would also be present during inter-trial-intervals (ITI). Successful discrimination requires responding on all trials in which S+ is presented and avoidance of S- on all trials in which S- is presented. Suppose all dogs readily learn the discrimination between Fred and Mike's scent; learn to approach Fred's scent and avoid Mike's.

The question is, if over discrimination training, gender, soap fragrances, and training context are paired with reinforcement on 50 percent of the trials, why don't dogs continue to respond when Mike's scent is presented? What is the means by which response to gender, fragrances, and the training context are extinguished. Or to pose the question in contemporary terms, if animals are indeed capable of learning about the irrelevance of incidental stimuli, what is the means by which dogs learn that gender, fragrances, and the training context are irrelevant?

For behaviorists, the answer was simple. Conditioning-extinction theory (Hull, 1952 and Spence, 1956), also called excitatory-inhibitory conditioning theory, accounts for how associative changes are translated into performance by assuming that the probability of a response occurring at a given moment is determined by the net excitatory strength of all stimuli present at that moment. The theory predicts that equal numbers of reinforced and non-reinforced trials will produce equal amounts of excitation and inhibition, leaving gender, soap fragrances, and training context each with a net excitatory strength of zero. Over classical conditioning in which S+ and S- are presented successively an equal number of trials, conditioning-extinction theory assumes, association to gender, soap fragrances, and the training context would be neutralized.

Conditioning-extinction theory also predicts, the presence of stimuli that are better correlated with reinforcement and the omission of reinforcement (such as Fred and Mike's genetic cues) should have no effect on the strength of conditioning to gender, fragrances, or context. According to conditioning-extinction theory, the strength of conditioning to a particular stimulus depends only on its own relationship with the reinforcer. All stimuli present at the moment of reinforcement or the omission of reinforcement will gain or lose associative strength in accordance with their own schedule of reinforcement. Conditioning-extinction theory predicts, it is the absolute relationship between each element and reinforcement that effects the strength of conditioning, not their relative validity with regard to other stimuli that may be better correlated with reinforcement.

On the surface, conditioning-extinction theory sounds plausible. However, if dogs were trained instrumentally, rather than classically with the described procedure, dogs would need to make as many errors over discrimination training as correct responses to neutralize incidental or irrelevant stimuli common to both S+ and S-. In addition, during and after discrimination training, the theory predicts that associative strength would increase to all neutralized stimuli present on subsequent reinforced trials, which would require ongoing neutralization of common elements for accurate and reliable discrimination between similar stimuli. Furthermore, the theory requires incidental stimuli to be equally present among correct and incorrect discriminative stimuli, which does not always occur in the real-world or is not always possible in applied conditions. Conditioning-extinction theory supposes, the probability of choosing Fred's scent rather than Mike's depends not only on the associative strengths of Fred and Mike's genetic cues, but also on the associative strength of incidental elements present at the moment of choice. Thus, if incidental stimuli are not equally present on reinforced and non-reinforced trials, errors may not be due to an inability to discriminate between genetic information, but due to the associative strength of incidental stimuli. Conditioning-extinction theory does not sufficiently explain why dogs would not continue to respond to Mike's scent after discrimination training between Fred positive and Mike negative.

Conditioning-extinction theory predicts that equal numbers of reinforced and non-reinforced trials will produce equal amounts of excitation and inhibition, thus neutralizing incidental stimuli. However, behaviorists knew very well that a 50 percent or partial reinforcement schedule was sufficient to produce and maintain high levels of response performance. Although perhaps slowing down the course of conditioning, a partial reinforcement schedule is often quite sufficient to produce and maintain significant levels of conditioning (see e.g. Skinner & Ferster, 1957). Conditioning-extinction theory failed to explain why during discrimination training, incidental stimuli on a partial reinforcement schedule do not maintain control over response performance that their schedule of reinforcement would permit under other circumstances. Although Hull and Spence were right to question how incidental or irrelevant stimuli and their salience affects the course of conditioning, they omitted an account of the circumstances in which a partial reinforcement schedule will or will not produce and maintain high levels of response performance.

Arguably, the omitted account was because behaviorists sought to expunge cognitive explanations from psychological discourse. Thus, the topic of selective attention or selective association due to the information the environment provides was prohibited during the reign of behaviorism. But, if conditioning accounts do not correctly identify the substance of learning, the circumstances that produce such learning, and the ways in which that learning influences response performance, they fail to inform us how to achieve reproducible results outside the confines of the laboratory and are of little real-world application.

Scientific experiments are conducted in an effort to understand the workings of natural world wonders. Once a variety of empirical evidence has been found, scientific theories are developed in an effort to explain the findings. The theories in turn make certain predictions, which can be tested. If the function of theoretical accounts is to elucidate the true workings of natural wonders, then theoretical predictions must hold true both under further scientific investigation and real-world conditions. If they do not, then the theoretical account is wrong and must be amended or replaced with theories that are better supported. In part, this is how we come to better and better understand nature. But if new discoveries are ignored and old outmoded disproven textbook descriptions of classical and instrumental conditioning are repeatedly taught, then our understanding of nature is severely hindered (see e.g. Rescorla, 1988). When traditional descriptions of conditioning do not transcend the confines of the laboratory, instead of blaming trainers, claiming their timing is off or they do not understand the principles of reinforcement, it might be more profitable to question restrictive views that impede scientific advancement.

Rather than conform to the limitations set by behaviorists, Mackintosh (1965) argued for stimulus selection processes in animals, such that some stimuli are more valid predictors of reinforcement relative to other competing stimuli (see also, Restle, 1955; Sutherland, 1964; Sutherland & Mackintosh, 1971). Based on experimental evidence, Mackintosh argued that part of what animals must learn to solve discrimination problems between similar stimuli is to attend to the relevant dimension. And, learning to attend to a stimulus dimension that signals a change in reinforcement can decrease the amount of attention allocated to other available dimensions that are less reliably correlated with important outcomes. For instance, if discrimination is between green S+ and red S-, each presented on a round disc, subjects must learn to attend to the dimension of color to reliably solve the discrimination problem. In this discrimination, color more reliably predicts both reinforcement and the omission of reinforcement compared to shape. Therefore, with sufficient amounts of discrimination training, attention and associability will increase to color at the expense of shape. Likewise, if discrimination is between a green triangle and a green square, subjects will learn to attend to the dimension of shape and not color. Once attention is increased to a specific stimulus dimension, new discriminations between stimuli from the same dimension (between say, blue and yellow or Jane and Mary's DNA) will be acquired more readily. Mackintosh argued, the overshadowing of stimuli less well correlated with reinforcement by those better correlated with reinforcement is an integral part of discrimination learning.

Mackintosh's accounts were a radical departure from the confines of behaviorism, which insisted a complete account of learning did not require mentalistic constructs, such as the acquisition of knowledge about the predictive or causal relationship between events, beliefs, intentions, selective attention, memory, perception, or concept formation. Since behaviorists assumed that environmental events elicited (caused) a change in behavior, not the individual, they believed states of mind could be bypassed in favor of stimulus-response accounts of behavior. Behaviorists thought, all learning, for all animals, under all circumstances involved the direct formation of stimulus-response connections. They thought neurological processes corresponded isomorphically with observable events. If a stimulus and response were contiguously paired with reinforcement, then over conditioning the change in behavior reflected the direct formation of a corresponding stimulus-response neurological connection, which was strengthened through repetition. Subjects did not acquire knowledge that a particular stimulus signaled an increase in the probability of a particular outcome or that a particular response would cause the occurrence of a particular outcome. Since it was a change in behavior that was observed, it was assumed that it was a change in behavior that was learned, either a reflex response or operant behavior, rather than the change in behavior being an index of the acquisition of knowledge about the relationship between events the experimenter (or environment) contingently arranged. Thus, behaviorists believed the sole task of psychology was to study behavior in order to formulate laws of conditioning, rather than to study how animals acquire knowledge about the relationships between events in complex environments and use that knowledge to respond adaptively.

Not only did Mackintosh break with tradition, which ushered in a new school of comparative psychology, he made opposing predictions to those of conditioning-extinction theory. Conditioning-extinction theory assumes irrelevant stimuli gain and lose associative strength as a result of their own schedule of reinforcement, and the presence of stimuli better correlated with reinforcement should have no effect on this process. Old school theory predicts, it is the absolute relationship between stimuli and reinforcement that effects the strength of conditioning, not their relative validity. Conversely, Mackintosh argued it is not the absolute, so much as it is the relative validity of a stimulus or stimulus dimension that effects the strength of conditioning. The strength of conditioning to a particular stimulus or stimulus dimension depends not only on its own relationship with the reinforcer, but also on whether the reinforcer is also signaled by other events, which may be better or worse predictors of the same reinforcer.

In a series of experiments, termed *relative validity* experiments, Wagner, Logan, Haberlandt, and Price (1968) tested the opposing predictions. Subjects were divided into two groups; a correlated group and an uncorrelated group. In these experiments there were two discriminably different auditory stimuli, A_1 and A_2, that were always presented in compound with a light, A_1L and A_2L. In both groups, an auditory-light compound signaled reinforcement on only 50 percent of the trials. In the remaining trials, reinforcement was omitted when an auditory-light compound was presented. Importantly, the only difference between the two groups was that in the correlated condition, A_1L always occurred on reinforced trials and A_2L always occurred on non-reinforced trails (A_1L+, A_2L-). Thus, the correlated condition constitutes a discrimination procedure between positive and negative stimuli, A_1+ and A_2-, with an incidental stimulus, L, common to both positive and negative trials. Whereas, in the uncorrelated condition, A_1L and A_2L each appeared equally often on reinforced and non-reinforced trials ($A_1L+/-$, $A_2L+/-$). Therefore, the uncorrelated condition constitutes a control (pseudo-discrimination/no contingency) procedure in which A_1 and A_2 were no better correlated with reinforcement and non-reinforcement than was the light. Following training, both groups were tested with light in isolation of A_1 and A_2.

Contrary to conditioning-extinction theory, although perhaps slowing down the course of conditioning, a partial reinforcement schedule, such as the partial reinforcement schedule to light in both the correlated and uncorrelated groups, is often quite sufficient to produce significant levels of conditioning. However, though both groups received exactly the same sequence and exactly the same number of A_1L and A_2L trials, the difference between test results of the correlated and uncorrelated groups were quite significant. In the uncorrelated group, test results showed the partial reinforcement schedule associated with the light during training was sufficient to produce and maintain high levels of stimulus control to the light; light was not neutralized. When L no better predicted the outcome of each trial than A_1 and A_2 during training, reliable conditioning to L occurred.

Yet, in the correlated group, light was not the best predictor of the availability of reinforcement. Light was an incidental stimulus that was less well predictive of the availability of reinforcement than A_1+and A_2-, both of which reliably predicted an important outcome, reinforcement and the omission of reinforcement. Test results from the correlated group showed that the presence of a better predictor of the outcome of each trial during training, effectively abolished control by the light (see also, Wagner, 1969 for AL+, L- arrangements). Subjects selectively associated auditory cues with the availability of reinforcement at the expense of light.

Wagner et.al. provided clear evidence of selective association processes in animals; that animals selectively associate events better correlated with reinforcement at the expense of events that are less well correlated with the reinforcer. Although subjects would have continued to respond to light if there was no better signal of reinforcement, by virtue of their better correlation with reinforcement and non-reinforcement, the auditory stimuli prevented the light from gaining the associative value that it would have acquired if A_1+ and A_2- were no better predictors of reinforcement (A_1+) and non-reinforcement (A_2-) than the light. The presence of A_1+and A_2- in the correlated group changed the informative value of the light during conditioning. Wagner et.al. showed, it is not the absolute relationship between events and reinforcement, so much as it is the relative validity of events signaling reinforcement that counts. The strength of conditioning to a particular to-be-conditioned stimulus depends not only on its own relationship with reinforcement, but also on whether the reinforcer is signaled by other events, stimulus or behavioral events, and their relationship with reinforcement.

Relative validity findings are good news for applied science. Under more natural conditions, it is not always possible to arrange incidental stimuli to be equally correlated with reinforcement and non-reinforcement for animals to learn they are irrelevant. The good news is, it is not necessary for incidental stimuli to be equally correlated with reinforcement and the omission of reinforcement for animals to learn which stimuli are better predictors of reinforcement. Although, to enhance learning that incidental stimuli are irrelevant, it may be better to arrange incidental stimuli be equally present during both positive and negative stimulus presentations (and/or during ITIs), incidental stimuli do not need to be equally correlated with both reinforcement and the omission of reinforcement for animals to learn they are irrelevant. Nor do incidental stimuli necessarily need to be equally present among discriminative stimuli. The critical determinate of successful conditioning is that the to-be-detected or discriminated information be a better predictor of the reinforcer than other events.

It is now believed conditioning does involve the acquisition of knowledge and beliefs about the relationship between events in the world, which animals use to adaptively guide their choices in order to gain access to important resources and avoid harm. During associative conditioning, animals are not learning a new behavior; they are learning that a particular stimulus signals an increase in the probability of a particular outcome or that a particular response causes the occurrence of a particular outcome. The response is a manifestation of the knowledge acquired about the causal relationship between the events the trainer or environment contingently arranged. Moreover, the establishment of a causal relationship, successful conditioning, is not simply dependent on the number of times a particular stimulus or response and reinforcer have been temporally paired. Leading authorities in the field of animal learning and conditioning now believe animals register the antecedent events of a valued outcome and then, in an effort to reduce discrepancies, evaluate their predictive relevance compared to the other events that have been temporally correlated with that outcome and select the event that better predicts the valued outcome. Animals attribute events of consequence to their most probable causes by associating selectively the better predictors of an outcome at the expense of poorer predictors. Selective associations, comprising a broad range of environmental relations, is thought to be one of the main ways animals represent the structure of the world (Dickinson, 1980; Mackintosh, 1983; Rescorla, 1988).

Know your training procedures and what they produce

The function of a reinforcement contingency, involving differential reinforcement, is to enable subjects to learn selectively about events that better predict a sought-after outcome at the exclusion of others. However, a to-be-conditioned stimulus or stimulus dimension is not always better correlated with reinforcement than other stimuli from reinforcement contingencies alone. Successful conditioning also depends on stimulus selection processes, such as *latent inhibition*, *stimulus generalization*, *overshadowing*, *blocking*, *unblocking*, *relative validity*, and *learned irrelevance,* as well as training arrangements. Not all procedures (training arrangements) are as explicit as others. Therefore, if it is the dog's task is to determine, from past and present experiences, which stimulus information most reliably predicts reinforcement, it is the trainer or experimenter's task to know about reinforcement contingencies, stimulus selection processes in animals, the various procedures used during conditioning involving reinforcement contingencies, and what they produce under complex conditions.*[3] For something as complex as scent matching training, it is the trainer's task to know about the substance of learning, the circumstances that produce learning, the ways in which learning influences response performance, and how to conduct controlled training and testing.

For example, in the absence of knowledge about true reinforcement contingencies, stimulus selection processes in animals, discrimination procedures, and what they produce, many people believe mantrailing (and tracking) training should proceed in stages, from the easiest to the more difficult. Accordingly, training typically begins with single, freshly laid tracks, over grassy surfaces, which is termed a *single stimulus conditioning* procedure involving discrimination between the presence and absence of a single track. Single stimulus conditioning procedures are not very explicit. In arrangements requiring discrimination between the presence and absence of single track, there is nothing to inform dogs to use the human scent component of the track to solve the problem. Moreover, there is nothing in the arrangement to inform dogs of the task to attend to and discriminate between the individual-unique component of human scent at choice points. As far as their correlation with reinforcement is concerned, all elements of a track are as relevant as the individual-unique human scent information that would enable reliable discrimination between tracks. Additionally, if trials begin with the presentation of a scent sample, the arrangement is a *systematic pseudo matching-to-sample (pseudo-MTS) procedure* because the alternative solution to simply discriminate between the presence and absence of a single track is not controlled against. Pseudo-MTS arrangements are not conditional discrimination procedures in which simple discrimination solutions are controlled against to ensure subjects use the conditional cue (sample stimulus) to signal which alternative is correct from one trial to the next (Hale, 2017). There is nothing in single track pseudo-MTS arrangements to inform dogs of the task to use the scent sample as a signaling cue or to ensure dogs learn to use the scent sample to solve the problem. Furthermore, going back as far as the 1700s, there is no objective evidence I have found that animals learn to use the sample stimulus from pseudo-MTS procedures. Yet, mantrailing dogs are often tested and certified with single track pseudo-MTS arrangements. Tests involving pseudo-MTS arrangements, yield high false-positive results, indicating dogs have learned to scent match when in fact they have not. Regardless of whether single track pseudo-MTS certification tests are double-blind, they do not inform us whether dogs have learned to use the scent sample as a signaling cue or have learned to discriminate between human scent trails, or tracks. Single stimulus conditioning typically produces stimulus generalization and overshadowing, not discrimination between similar stimuli.

Stimulus generalization

Stimulus generalization refers to the tendency of animals conditioned to respond in a certain way to one stimulus, to respond in the same way, but to a lesser extent, to other similar stimuli. Stimulus generalization depends on the strength of conditioning to the common elements that similar stimuli share (see e.g. Bennett, Wills, Wells, and Mackintosh, 1994). Therefore, if novice dogs are trained on single tracks laid by Fred and are later tested to see if they will follow Fred's trail at the exclusion of Mike's trail, whether dogs show stimulus generalization over test trials depends on the strength of conditioning to common elements, such as crushed vegetation, disturbed soil, or olfactory information that Fred and Mike share. During single stimulus training, as far as their correlation with reinforcement is concerned, common elements are as relevant as the stimulus information that would enable reliable discrimination. Thus, to the extent that a test stimulus has elements in common with a conditioned stimulus, subjects may respond to it similarly after single stimulus conditioning. Furthermore, when similar stimuli are complex, consisting of many elements, the common elements are typically in greater abundance than the discriminative elements. And, of the common elements, some are more salient than the discriminative elements. Consequently, when animals are trained one way (to generalize) and are then tested another way (to discriminate) they typically show stimulus generalization; that is, chance performance during discrimination test trials between similar stimuli.

Dogs trained on single tracks are no exception. Following single track training with initially novice dogs, accuracy rate typically reverts to chance over discrimination test trials between the training target and added decoys. Chance performance indicates, during single track training response performance came to be controlled by some element or elements common to both target and decoy test tracks. Also, likely there is a common track element that is more salient than human scent or its discriminative dimension, which can come to control response performance over single track training with novice dogs. In other words, during single track training, a more salient cue can overshadow learning about the less salient human scent information that is present in compound with the more noticeable cue.

Overshadowing

Overshadowing is a robust stimulus selection phenomenon. Overshadowing occurs when two or more stimuli (or stimulus elements) are presented in compound and one is more salient than the other. With sufficient conditioning in which both are equally correlated with reinforcement (without non-reinforced trials involving the stronger stimulus alone), the stronger stimulus comes to overshadow learning about the less salient stimulus. Thus, after compound conditioning, when the stimuli are tested in isolation of one another, subjects respond to the more salient stimulus, but very little or not at all to the less noticeable stimulus.

Overshadowing experiments have revealed that a stronger stimulus will overshadow conditioning to an otherwise conditionable weaker stimulus when the two stimuli are conditioned in compound. However, response to the weaker stimulus can be conditioned if the weaker stimulus is conditioned in isolation of the more salient stimulus; that is, when the weaker stimulus is better correlated with reinforcement. Successful conditioning to the weaker stimulus requires either that the weaker stimulus be better correlated with reinforcement over trials or that there be no stronger stimulus to overshadow conditioning to the weaker stimulus.

Moreover, some overshadowing experiments have revealed that during compound conditioning with a more and less salient stimulus, subjects selectively learn to ignore the less salient cue while learning to attend to the more salient information, which in turn retards subsequent conditioning to the less salient stimulus (see e.g. Seraganian, 1979). These experiments have revealed that subjects do not simply fail to notice the less salient stimulus. Instead, subjects do notice the less salient information and specifically learn to ignore the weaker cues.

From easy to more difficult tracking training

Problems arising from an insufficient understanding of animal learning and stimulus selection processes, which result in inappropriate training arrangements, are as old as tracking and mantrailing training itself. For example, on the heels of growing controversy, during 1913 and 1914 the Prussian Minister of Interior officially ordered police tracking dogs from all parts of the country be tested to determine whether they could be used as detectives for suspect identification. That is, to determine whether dogs scent matched; used a previously sampled human scent as a cue to signal which choice alternative was correct at choice points, would bark at the person who laid the target track at the exclusion of others, or select from among alternatives an object bearing the human scent that matched the previously presented human scent sample. Thus, after letting dogs take in a novel person’s scent, dogs were required to remain on that stranger’s track when they encountered competing stranger laid tracks of the same age. Testing also included lineup detection and aged trails.

In the 1913-1914 tests, all dogs failed to follow only the target track when given a choice between equal saliency target and decoy tracks laid by strangers. All dogs tended to avoid a change in direction at choice points. After sniffing a person, no dogs could reliably choose from among human scented objects, the object that had been handled by the previously sniffed person. All dogs failed to follow a track older than two hours. And, no dogs would follow a trail laid on dry stone streets or dry sandy ground without undergrowth.

Assuming dogs performed reliably prior to the well-controlled [MTS] official Prussian tests, based on what we now know about various training arrangements and stimulus selection phenomenon, there are a few assumptions that can be made about the dogs' training: 1) Because the dogs did not scent match during testing, training involved pseudo-MTS arrangements in which solutions alternative to scent matching (using the previously sniffed human scent as a signaling cue) were not controlled against. 2) Because a scent matching solution strategy did not transfer to the well-controlled Prussian tests in which solutions alternative to scent matching were controlled against, dogs did not learn to scent match from pseudo-MTS training arrangements. 3) Because dogs would not follow a track older than two hours and no dogs would follow a trail laid on dry stone streets or dry sandy ground without undergrowth, dogs learned to ignore the human scent component of tracks during soft-surface tracking training. This could occur during both soft-surface single track training, in which some track element, such as crushed vegetation, came to overshadow the human scent component due to greater saliency, and during later discrimination training between soft surface tracks, in which discrimination between track saliency cues were not controlled against, such as discrimination between fresher tracks positive (S+) and older tracks negative (S-). According to training guidelines of the time, those are among the initial stages of training (see e.g., Most, 1954).

Based on easiest to more difficult training guidelines, the first stage of training involved single, freshly laid tracks over soft surfaces. Therefore, contrary to assumptions that tracking dogs learn to attend to both crushed vegetation and human scent, by not controlling against overshadowing stimuli, dogs were taught to ignore human scent during soft-surface single track training; single stimulus conditioning involving simple discrimination between the presence and absence of a track. In other words, during the first stage, dogs were taught to ignore the discriminative information that would enable them to most reliably select the correct alternative at choice points during real-world operations. 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 holding over trials between the scent sample and matching alternative can be retarded during subsequent human scent MTS conditional discrimination training.

Next, a subsequent stage involved a more explicit simple discrimination arrangement; discrimination between the freshest track positive (S+) and less salient tracks negative (S-). Rather than control against a solution to discriminate between track saliencies, either by randomly varying relative saliencies of target and decoy tracks over trials or by arranging for target and decoy tracks to equal in saliency, simple discrimination between track saliencies was explicitly arranged by holding constant the greater relative saliency of the target track over trials. Because track saliencies reliably predicted both reinforcement and the omission of reinforcement, all else being equal, attention and associability can be expected to increase to track saliency. During this later stage, while attention was increased to track saliency information, dogs could continue to ignore human scent.

Furthermore, it must not be overlooked that learning to use a sample stimulus as a signaling cue is a more complex task than simple discrimination. Animals acquire simple discrimination solutions more readily than conditional discrimination solutions in which the signaling significance of a conditional cue must be learned about to reliably solve conditional discrimination problems. Also, when trials begin with the presentation of a sample stimulus, but simple discriminations solutions are not controlled against (pseudo-MTS arrangements), there is no objective evidence I have found that animals learn about the signaling significance of a sample stimulus. Dogs do not learn to scent match from pseudo-MTS arrangements. Instead, the author argues that the more readily acquired simple discrimination solutions, not controlled against in pseudo-MTS arrangements, overshadows learning about the signaling significance of the scent sample. Moreover, because the scent sample does not predict anything new, which is not already perfectly predicted by the more readily acquired simple discrimination solution, dogs can learn to ignore the scent sample over pseudo-MTS training. Thus, subsequent MTS acquisition will be retarded. Based on much experimental evidence, the author argues, it is only when simple discrimination solutions are controlled against that objective evidence shows animals learn to use the sample stimulus (initial cue) to signal the correct alternative at choice points. Contrary to layman's assumptions that dogs readily learn to use the initial information from a scent sample or along a track as a cue to signal the correct alternative at choice points, failure to control against simple discrimination solutions (i.e. failure to use the appropriate training procedure) is a primary reason why the capacity of mantrailing dogs learning to scent match has remained controversial since large scale use of police tracking dogs began over one hundred years ago (see e.g. Gerritsen & Haak, 2010). Failure to distinguish between simple discrimination, random control MTS conditional discrimination, and systematic pseudo-MTS has been a major drawback to the success of scent matching operations, the advancement of scent matching dogs, and is a contributing factor to the continued controversy surrounding their use and reliability (Hale, 2017).

Track saliency matching

The 1913-1914 test findings did nothing to quell the controversy over the use of police dogs as detectives for suspect identification or the use of police tracking dogs in general. Consequently, the Berlin police did not try to achieve suspect identification during training. Nor did they officially recognize its possibility. However, even without using dogs as detectives, to be a good investigative tool, tracking dogs still needed to stay on the track in which they were put. During operations, often target tracks were not the only track present or the freshest track. Therefore, training investigators continued to experiment with different training methods.

From 1927 to 1929, Berlin police dogs were tested under similar, but varying conditions as the 1913-1914 tests. Although most dogs failed, some dogs did succeed in discriminating between target and decoy stranger laid tracks at choice points regardless of whether the target track was fresher or older than competing decoy tracks. This occurred when the dogs were given an opportunity to become familiar with the target track before encountering decoy cross tracks that differed in laying times. To familiarize dogs with the target track, the track layer created a scent pad by trampling for three minutes a half square meter surface at the start of the track where dogs were induced to sniff, and cross tracks were kept some distance away from the start (Böttger, 1936). However, response performance was at chance when target and decoy test tracks equaled in saliency; were laid at the same time. Thus, dogs were using saliency cues to solve discrimination problems at choice points, rather than individual-unique human scent information.

The significance of dogs learning how to reliably choose between alternatives the target track, regardless of whether it was fresher or older than decoy tracks, should not be overlooked. To be able to do so, dogs had to learn to use initial track saliency information, from the scent pad or along the target track, as a cue to signal the correct alternative at choice points. Dogs learned a conditional discrimination solution strategy. After attention and associability was increased to track saliency during an initial stage involving simple discrimination between positive and negative track saliencies, dogs learned to use saliency as a conditional cue signaling the correct alternative at choice points when simple discrimination was controlled against in a subsequent stage. During training stages, dogs were first taught ignore human scent. Then they were taught to attend to saliency cues during simple discrimination between track saliencies, in which the freshest track was positive and older tracks were negative. Finally, simple discrimination solutions were controlled against by randomly varying the greater and less saliency of the target track relative to decoy tracks over training and test trials. Once, simple discrimination solutions were controlled against, such as simple discrimination between the presence and absence of a single track or simple discrimination between track saliencies, experimental evidence showed dogs learned to use initial saliency as a signaling cue. By first decreasing attention to human scent and increasing attention and associability to saliency cues, the likelihood of dogs learning in a subsequent stage about the matching relationship holding over trials between initial track saliency and the correct alternative at choice points was enhanced.

The achievement of track saliency matching was quite significant. However, tracking, discrimination between tracks, and track saliency matching was at the expense of mantrailing (following human scent), discrimination between human scents, and human scent matching. Also, track saliency matching is limited to tracking over soft surfaces, during which competing tracks must differ in laying times.

Moreover, other than to report training methods analogous to a recipe, early investigators did not know the circumstances responsible for successful saliency matching training, such as reinforcement contingencies, increasing attention and associability to track saliency cues through overtraining simple discrimination between more and less track saliency cues, and then later controlling against simple discrimination solutions during a track saliency MTS stage.*[4] They did not know how to achieve reproducible results. Therefore, although some dogs succeeded in learning a track saliency conditional discrimination solution strategy, early investigators found that acquisition was hit and miss, with more miss than hit.

In 1931 the Prussian Government banned the use of police dogs as detectives to identify criminal suspects. After decades of training investigation involving hundreds of thousands of training trials and thousands of test trials involving thousands of dogs, no evidence of tracking dogs learning to follow, discriminate between, or scent match human scents was found. However, the author argues that the failures were not due to an inability of the police dogs to perform any of the tasks. Rather, training was not appropriately arranged to inform dogs of the tasks to discriminated between the individual-unique component of human scents, attend to and follow human scent trails, and to sample the odor on a scent sample, then choose between alternatives the individual-unique discriminative information that matched the previously presented scent sample. Instead, a mistake that early investigators made, and a mistake that persists today, is dogs were inadvertently taught to ignore human scent, rather than to attend to the individual-unique discriminative component of human scents.

Selective attention is an important determinant of successful discrimination training. When animals learn to discriminate between stimuli that signal important outcomes from those that do not, they are learning to attend selectively to certain environmental stimuli at the execution of others. Experimental evidence has shown, animals learn to attend selectively to stimuli that inform them of future events of importance and ignore less informative, redundant, or uninformative stimuli. They learn both about the environmental stimuli that better inform them of valued outcomes and about stimuli that are uninformative to those outcomes.

Notes:

*1. Simple discrimination involves discrimination between positive (S+) and negative (S-) discriminative stimuli that are held constant over conditioning. Thus, trials do not begin with the presentation of a sample stimulus. Instead, subjects learn an associative solution based on reinforcement history; that S+ predicts reinforcement and S- predicts the omission of reinforcement. The instrumental reinforcement contingency is, following response to S+, subjects are reinforced, but following response to S-, reinforcement is omitted. When the discriminative stimuli are presented simultaneously, S+ is presented randomly to the left and right of S- over trials to control against subjects learning to predict reinforcement based on some systematic stimulus presentation position. Successful conditioning requires subjects respond differently to S+ than to S-. 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.

Alternatively, MTS is a conditional discrimination procedure in which trials do begin with the presentation of a sample stimulus; a conditional cue. In the standard MTS procedure, a trial begins with the presentation of a 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 previously presented sample.

In conditional discrimination training and testing procedures, reinforcement is contingent upon use of the conditional cue to signal the correct choice alternative from one trial to the next. Thus, MTS conditional discrimination is a more complex task than simple discrimination in which positive and negative discriminative stimuli are held constant over trials. To ensure the sample stimulus is a conditional cue (i.e. to ensure subjects use the sample stimulus to signal the correct alternative on any given trial), simple discrimination solutions are controlled against, which requires specified constraints. Therefore, during training, involving numerous MTS trials within each training session and several sessions, one constraint is that there is never just one sample/comparison correct stimulus. Instead, unless all stimuli are novel on every MTS trial, there is a set of stimuli used during training that serve as both sample/correct and incorrect alternatives. Another constraint is that over trials the set of training stimuli are never presented in some systematic sequence. Rather, the set of training stimuli are randomly presented over trials, so all stimuli are unpredictably both sample/comparison correct and incorrect as training proceeds. Also, the presentation positions of the comparison stimuli relative one another are random over trials.

The reinforcement contingency in the random control MTS conditional discrimination procedure is, if subjects choose the alternative that matches the sample, they are rewarded, but if subjects choose a nonmatching alternative, the trial is terminated without reward. Therefore, to solve the MTS problem and reliably earn reward, animals must learn to use the sample stimulus to signal which discriminative stimulus is correct on any given trial.

However, in pseudo-MTS procedures, in which trials begin with the presentation of a sample stimulus, but simple discrimination solutions are not controlled against, animals do not need use the sample stimulus to signal the correct choice from one trial to the next. Due to a lack of controls against simple discrimination solutions, pseudo-MTS arrangements are not conditional discrimination procedures; the sample stimulus is not a conditional cue. Unlike MTS, in pseudo-MTS procedures, reinforcement is not contingent upon use of the sample stimulus to signal the correct discriminative stimulus from one trial to the next. Hence, there is nothing to inform dogs of the task requirements to sample the odor on the scent sample, compare the memory of the sample to the alternatives, and then choose the comparison that matches the sample. Instead, dogs can simply solve pseudo-MTS problems with the more readily acquired simple discrimination solutions left open to them and learn nothing about the signaling significance of the scent sample. Therefore, there can be significant differences between MTS and pseudo-MTS the solution strategies. Although dogs can reliably solve pseudo-MTS lineup detection, mantrailing, or tracking problems with the simple discrimination solutions left open to them, tests involving pseudo-MTS arrangements can produce high false-positive results, indicating dogs have learned to use the scent sample as a signaling cue when in fact they have not. Yet, during subsequent MTS testing, accuracy scores will drop to chance if dogs have not learned to use the scent sample as a signaling cue.

Therefore, pseudo-MTS scent matching tests do not meet scientific standards of objectivity. To objectively determine whether dogs have learned to use the scent sample as a signaling cue, dogs must be tested with a random control MTS conditional discrimination procedure in which alternative solutions are controlled against.

*2. Although Hepper did not report first trial transfer performance or appear to regard the experimental tests as transfer tests, since dogs were initially trained to scent match with spices and later transferred to human scent matching, better than chance human scent matching transfer performance indicates dogs learned the matching concept during initial training with spices, such as a rule to choose the comparison that is the *same-as* the previously presented scent sample. Same-as is a concept. And successful scent matching transfer from spices to human scents (a different stimulus) indicates dogs learned an abstract concept, as opposed to a domain-specific concept, such as a rule to choose the DNA that is the same-as the DNA on the previously presented scent sample. Abstract concepts are regarded as more difficult to acquire than domain-specific concepts. As far as the author is aware, Hepper's study is the only study to indicate dogs are capable of learning abstract concepts. Therefore, although the study has been criticized for initial training with spices, the report is very significant, despite the omission of method and transfer information necessary to rule out alternative solutions.

*3. To review all stimulus selection phenomenon and conditioning procedures is beyond the scope of this paper. Readers are encouraged to learn about the various stimulus selection phenomenon and under which conditions they do and do not occur, such as latent inhibition, stimulus generalization, overshadowing, blocking, unblocking, relative validity, and learned irrelevance (see Mackintosh, 1983 for a review of stimulus selection phenomenon). Also, in addition to arrangements reviewed here, readers can benefit from learning about other procedures used for experimental investigation and what they produce, such as simultaneous discrimination, successive discrimination, successive go/no-go discrimination, pseudo discrimination, MTS conditional discrimination, systematic pseudo-MTS conditional discrimination, symbolic MTS conditional discrimination, and same-as/different-from discrimination procedures. Also, two arrangements that have not received much scientific investigation are MTS go/no-go conditional discrimination and the matching/nonmatching relational learning procedure.

*4. Because during a previous stage, discrimination was between the target track more salient (S+) and decoy tracks less salient (S-), readers may think violation of the learned predictive relationships during later saliency matching training (in which greater and less salient target tracks are randomly varied as alternative correct and incorrect tracks) would increase errors. This is exactly what can be expected. Following simple discrimination training in which greater relative saliency came to predict reinforcement and less relative saliency came to predict the omission of reinforcement, errors can be expected to increase during initial trials of subsequent track saliency matching conditional discrimination training. However, track scent is a complex stimulus, having many elements. In overtraining reversal experiments, Mackintosh (1963, 1969) found when discrimination is difficult, involving either a decrease in the discriminability of discriminative stimuli or an increase in the number of irrelevant elements, overtraining past accuracy criterion increases the probability that subjects will continue to attend to the relevant discriminative dimension upon reversal of positive and negative stimuli [or upon transfer to a new discrimination involving different discriminative stimuli from the same relevant dimension], provided the reinforcer is motivationally significant (see also, overtraining reversal effect, Sutherland & Mackintosh, 1971). Whereas, for non-overtrained subjects, reversal learning was retarded because the likelihood of shifting attention to irrelevant cues was increased upon reversal [or transfer]. And the more irrelevant cues there are, the more learning can be expected to be retarded. Even though overtraining initially increases the number of errors upon reversal, it also decreases the probability that attention will shift from the relevant dimension to irrelevant cues upon reversal or transfer, which in the long run increases the rate of acquisition compared to non-overtrained subjects.

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Human Scent Discrimination: Phase 1 and 2

By Ellen Hale

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Necessary items for phase 1 and 2

1) Two visually identical glass jars with openings large enough for the dog to poke its nose in but not so large that the dog can remove the scent sample from the jar (about 1 1/2" diameter). The lid should not be plastic because plastic can absorb odors and cannot be sterilized for reuse with another scent article. I use 8 once apothecary jars with glass stoppers.
2) Small sticker labels to place on the jars and their lids to identify the positive and negative scents.
3) A clicker to bridge time interval between a correct nose-poke and food reward.
4) A bowl to put the small motivationally significant pieces of food rewards in. I use real meat, such as liver or kidneys, rather than dry dog food or packaged dog treats. However, liver is high in vitamin A, which is not water soluble and can accumulate in the system, causing problems if the accumulation gets too high. Therefore, do not reward with large pieces of liver.
5) A small plate for the individual pieces of food that will be presented to the dog at the end of each correct training trial.
6) Small tongs for handling the food, in order to keep your fingers free of the food smell.
7) A log book and pen for documenting responses and notes at the end of each training trial.
8) A counter top or work station for all your training items. Truck tailgates can be used.
9) For Phase 2, scent articles from two different people that are from strangers to the dog and who will not interact with the dog during intertrial intervals. The articles should be sterile prior to the collection of human scent, such as gauze pads or new cotton clothing that has been freshly laundered in unscented detergent. Note, the S+ and S- scent donors used in phase 2 will not be used in subsequent training.
10) Small pieces of food cut approximately into 1" square portions.
11) A food deprived dog. Do not train after the dog is satiated, has been fed a meal, because it can produce low baseline goal-directed response performance even when later conditioning involves hunger (see e.g. Dickinson & Balleine, 1994).

Human Scent Discrimination: Phase 1 and 2

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Phase 1: Target Training Procedure

Phase 1 is a preliminary response performance training phase in which dogs learn to target the mouth of a jar with their nose.*[5] Dogs learn to nose-poke the jar in order to earn a click from the clicker followed by a piece of the motivationally significant food. Reinforcement (the click and food) following a correct response completes one trial. Over training trials, the jar is held randomly in the left and right hands. Reinforcement is contingent upon a nose-poke to the jar. Thus, reinforcement is omitted following incorrect responses.

The purpose of target training prior to Phase 2 human scent discrimination is to teach dogs that a nose-poke to the jar, and not some other response, causes the occurrence of a click and food reinforcer. During Phase 1, due to random presentation of the jar held in the left and right hands over trials, dogs can also learn that stimulus presentation position is irrelevant. Therefore, the likelihood of position preference errors during subsequent Phase 2 discrimination training will be reduced when S+ and S- jars are randomly held in the left and right hands over trials. Typically, during discrimination training involving simultaneous presentation of discriminative stimuli, it is not until position errors begin to diminish (indicating that subjects are starting to learn that stimulus presentation positions are irrelevant) that records indicate subjects also begin to learn the stimulus discrimination task. Thus, by learning that presentation position is irrelevant in Phase 1, Phase 2 human scent discrimination learning can be enhanced, rather than retarded due to position errors. Due to Phase 1, when the dog responds to the negative human scent (S-) and reinforcement is omitted, the likelihood of dogs learning to switch to the other side and nose-poke the S+ jar for reinforcement is increased.

Training should take place in a location that is well ventilated and provides minimal distractions.

Note:

*5. Originally, a scent article containing a positive human scent from a stranger was in the nose-poke jar throughout Phase 1 training. However, due to the possibility that some more salient stimulus could come to overshadow individual-unique human scent information during Phase 1, it was considered that discrimination learning between individual-unique human scent information could be retard during Phase 2. In addition, it was supposed that an increase in attention to both S+ and S- due to novelty, would enhance acquisition of Phase 2 discrimination. Therefore, there is no longer an S+ human scent article in the jar during Phase 1 training. Alternatively, during the first few trials of Phase 1, the mouth of the jar may be put to the dog's nose, followed with a click and food reinforcer or food may be placed in the jar to initially elicit a nose-poke.

Training

Step 1 Using the tongs, remove a piece of food from the bowl (which has enough pieces of food for each trial in the training session) and put it onto the plate for reinforcement after a correct response (a nose-poke to the jar). Set the plate aside on a work station until after the dog makes a correct response.

Note: Training trials in Phase 1 involve random order presentation of the jar held in one hand and the clicker in the other. An 8 oz., wide mouth, glass apothecary jar with a glass stopper is good; not a plastic jar, stopper, or lid because plastic absorbs odor. A nose-poke to the mouth of the jar followed by a click and piece of food completes one trial. There are a number of training trials in one training session. The number of trials in each daily session is determined by the dog's continued interest to work and its level of satiation. Several trials within each daily training session are necessary for dogs to learn for certain the causal relationship between the nose-poke to the jar–the click–and food reward.

Step 2 While holding the clicker in the left or right hand and the jar in the other hand, turn and face the dog. Simultaneously lower both hands to your side, which should be nose height for the dog. Wait for the dog to poke its nose to the mouth of the jar, then click once and reward the dog with the piece of food on the plate. This will conclude the first trial.

Over trials, the jar and clicker should be held randomly in each hand, so the dog can learn that stimulus presentation position is irrelevant. If the jar was not held randomly in each hand over trials, the dog could learn to always respond to just one side (develop a position habit). Consequently, during Phase 2, when S+ and S- jars are presented simultaneously, but randomly to the left and right of each other over trials, the dog may continue to respond to just one side and discrimination learning could be retarded.

Note: Initially if the dog does not nose-poke the jar, you may put the mouth of that jar to the dog's nose, then click and reward with food. During the first 1 to 3 trials of Phase 1 training, food may also be placed in the jar.

The clicker is a useful tool for bridging the time interval between the nose-poke and food presentation, which can help dogs to learn the associative relationship between the nose-poke–click–and food. However, some dogs are distracted by the click, which can interfere with learning about the associative relationship. Therefore, in those cases it's fine not to use the clicker.

Step 3 Continue training until all the food has been used or the dog starts to show signs of reduced interest. If the dog does lose interest during a session, reduce the number of trials in the next session. Also, if the dog initially has little interest in learning the task, the dog may be satiated, or the food reinforcer used may be motivationally insignificant. Do not train dogs when satiated, only hungry dogs, and use real meat, not kibble or packaged dog treats.

An average of 120 training trials are required to complete Phase 1. The mean optimum number of training trials per daily training session is around 30, depending on the dog. If there are too many training trials in each daily session, the dog may become satiated and lose interest. Additionally, if the number of trials within each session is too small, acquisition of the associative (causal) relationship between the nose-poke, the click, and food reward can be slower. In other words, to learn for certain that the relationship between events is causal, rather than just correlative, dogs need enough trials to learn both about the probability of reinforcement occurring given the to-be-conditioned response and the probability of reinforcement occurring given the absence of the to-be-conditioned response. When dogs stop testing alternative responses, it is a measure that they have learned about the causal relationship between the nose-poke to the jar–the click–and food reward.

Procedural Constraints

1) Each training session must begin with a hungry dog. When a food reinforcer is used, the dog must never be satiated prior to training.
2) During discrimination training, the food reinforcer used must be motivationally significant and must not be changed, increased, or decreased.
3) The motivationally significant food reinforcer must only be used to reinforce a nose-poke to the jar. The dog must earn the reinforcer for a correct response to the jar and not be given the food during intertrial intervals or be fed the food during other training.
4) Successful conditioning requires the to-be-conditioned event be a better predictor of reinforcement than other events, such as cues from the trainer. Therefore, layman's training advice to help (cue) the dog so each trial ends on a positive note must not be followed. Only during the first one to three trials may the trainer assist a nose-poke by putting the jar to the dog's nose. In all remaining trials, the trainer must wait for the dog to respond correctly without cues from the trainer.
5) The jar and lid must be sterilized and kept free of odors other than the dog or trainer, such as scent from other people.
6) To control against a position habit to the trainer's left or right side, the jar should be held equally often, but randomly, in the left and right hand over each daily session and should never be held in the same hand for more than three consecutive trials.
7) Because in Phase 2 reinforcement will be omitted following a nose-poke to S-, Phase 1 is important for the dog to learn that presentation position is irrelevant and to reduce the likelihood that the dog will respond in some other way when reinforcement is omitted after a nose-poke to S- in Phase 2. Therefore, Phase 1 must not be bypassed.

Human Scent Discrimination: Phase 1 and 2

By Ellen Hale

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Phase 2: Human Scent Discrimination Procedure

To begin, choose two (to six) strangers to the dog who will donate scent for Phase 2 human scent discrimination training and who will also lay some simple discrimination trails after Phase 2 discrimination training with the jars, prior to MTS training. Over Phase 2 training, there will be three pairs of positive and negative human scents, all from different people. Each pair must be the same gender, but one pair must be a different gender than the other two. In choosing scent donors, there are a few parameters: 1) Because a goal during Phase 2 is for dogs to learn that the individual-unique discriminative component of human scent reliably predicts both reinforcement and the omission of reinforcement (that S+ and S- both predict an important outcome) and thus, increase attention to the individual-unique discriminative information, dogs should not have interaction with the scent donors during intertrial intervals. Therefore, scent donors should not be people the dog lives with, has had interaction with in the past, or that the dog will be involved with other than discrimination training. 2) Because Phase 2 involves simple discrimination, in which the positive and negative discriminative stimuli are held constant over training trials, dogs can learn that S+ predicts reinforcement and S- predicts the omission of reinforcement. However, during subsequent MTS training, a constraint to control against dogs learning to solve the problem without using the scent sample as a signaling cue, requires that the set of stimuli used during MTS training are never held constant or presented in some systematic order over trials. Therefore, if the set of Phase 1 simple discrimination scent donors were used during MTS training, prior learning about S+ and S- predictive relationships can cause errors during subsequent MTS training and retard MTS acquisition. Thus, the scent donors should not be people who will be used during later scent matching training. 3) The scent donors should be the same gender and have similar proclivities, such as smoking. Scent from unrelated people living in an institution would be good because, while their DNA is individually-unique, they typically eat the same diet, wash with the same brand of soap, use the same brand of deodorant, launder with the same detergent, and so on. 4) The scent donors should not be related and most certainly should not be identical twins.

The mistakes dogs make in discrimination tasks can be regarded as response errors and discrimination errors. To avoid response errors during human scent discrimination learning, Phase 2 involves classical conditioning, in that an identification response to S+ is not required. The omission of an identification response requirement to S+ during acquisition of the task to discriminate between human scents, is to prevent indiscriminate persistent response performance that can retard human scent discrimination acquisition. For example, if an identification response was required prior to dogs learning the discrimination between human scents, then the identification response would sometimes be followed with reinforcement, after a correct response to S+, and would sometimes be followed with the omission of reinforcement, after an incorrect response to S-. In other words, reinforcement following an identification response would be on a variable ratio reinforcement schedule. Variable ratio reinforcement schedules typically produce steady state or persistent rapid response rates. Some researchers have argued that rapid response rates can serve as a discriminative cue predicting reinforcement, which can in turn retard learning about the predictive relationships between discriminative stimuli and reinforcement (see e.g. Thomas and Switalski, 1966). The author has found, if dogs are trained human scent discrimination instrumentally (requiring an identification response), rather than classically (not requiring an identification response), dogs learn the instrumental response before they learn about the predictive relationships between the positive and negative discriminative stimuli and reinforcement. When dogs first learn the identification response, which is on a variable ratio reinforcement schedule, dogs tend to rapidly and persistently switch indiscriminately from jar to jar, identifying each one, without learning the discrimination. Learning that the S+ individual-unique component of human scent predicts reinforcement and that the S- individual-unique component of human scent predicts the omission of reinforcement is retarded. Therefore, prior to acquisition, Phase 2 involves classical conditioning in which an identification response is not required. Once dogs learn the discrimination, an identification response can be incorporated.

In Phase 2, there are two visually identical jars. One jar must hold an article scented by the person designated S+ and the other jar must hold an article scented by the person designated S-. Throughout Phase 2 training, both the S+ and S- human scents must be held constant; not changed from positive to negative and vice versa.

Begin each training session with presentation of the S+ jar only, by holding it down at your side with the mouth of the jar accessible to the dog's nose. When the dog nose-pokes mouth of the jar, give the dog a click and then food reinforcement, as in Phase 1.

In all the remaining trials within the session, both S+ and S- should be presented simultaneously in the right and left hands; one jar held in each hand.

However, to control against dogs learning a presentation position discrimination at the expense of learning human scent discrimination, during every session S+ and S- should be held equally often in the left and right hands, but in random order over trials. Also, S+ and S- should never be presented from the same hand for more than three consecutive trials. Furthermore, if the dog nose-pokes the S- jar, the trainer must wait patiently for the dog to move over to the S+ jar, rather than switching the S+ jar to the other hand or cueing the dog with the S+ jar. If trainers did switch the jars to their other hands following a nose-poke to S-, over trials dogs could be reinforced only on one side. Consequently, dogs could learn a position discrimination, that response to a particular side predicts reinforcement, rather than learn the task to discriminate between the human scents. In addition, successful conditioning requires the to-be-conditioned stimulus information (individual-unique information) be a better predictor of reinforcement than other events, such as cues from the trainer. If a trainer develops a bad habit of deliberately or inadvertently cueing the dog, cues from the trainer can be a better predictor of reinforcement than the individual-unique discriminative information. Thus, while attention is increased to the handler, dogs can learn to ignore human scent, which can significantly retard or prevent human scent discrimination learning.*[6]

In addition to holding both jars, one hand should also hold the clicker in such a way that a correct nose-poke can immediately be followed with a click from the clicker.

After presenting both jars, if the dog nose-pokes the S+ jar, the correct nose-poke response should be followed with a click and then food reward, thus ending the trial. If the dog nose-pokes the S- jar, wait until the dog moves to your other side and pokes the S+ jar. Then click and reward, thus ending the trial.

Each click and food reward completes one training trial. There should be 10 to 30 training trials in each daily training session, depending on the dog's level of interest and food satiation.

Document the number of training trials in each session and the date of training, as well as any other points of interest.

Puppies and adult dogs learn human scent discrimination at different rates. Novice adult dogs tend to learn human scent discrimination more readily than puppies. However, acquisition can be significantly retarded if dogs have had inappropriate training prior to the procedures here.

Since in Phase 2 there is no identification response requirement, with which discrimination learning can be easily measured, an arbitrary number of 30 trials to learn the human scent discrimination problem is recommended.*[7] Next, dogs should be overtrained an additional 150 trials. When discrimination is difficult, or the discriminative stimuli are complex, involving either a decrease in the discriminability of discriminative stimuli or an increase in the number of irrelevant elements, overtraining past accuracy criterion increases the probability that subjects will continue to attend to the relevant discriminative dimension (Mackintosh, 1963, 1969). When attention is increased to the relevant dimension, acquisition of a new discrimination involving discriminative stimuli from the same dimension, such as genetic information, should be enhanced, provided the reinforcement constrains below are followed.

Once the 180 trials with the first pair of (S_1+ and S_1-) scent donors has been completed, dogs can be trained an identification response to scent articles from S_1+. When dogs have learned the identification response, S_1+ and S_1- articles can be placed near one another and dogs can be required to identify the correct alternatives. Unless dogs are going to be used for lineup detection, pairs of S_1+ and S_1- articles (e.g. 8 pairs) can be placed in locations where the dog must hunt for the article pairs. With this arrangement, response errors are reduced compared to line training, and dogs more readily learn the task.

Additionally, before Phase 2 discrimination training with S_2+ and S_2- human scents begins, dogs can be required to discriminate between short hard surface trails laid by S_1+ and S_1-. Prior to mantrailing, dogs must be trained to identify S_1+, the target trail layer. And to enhance response rate, the first two or three trails should begin with fire trails in which the dog is teased with the food reinforcer by the trail layer before they run off and lay the trail. To control against dogs using visual cues to solve fire trail problems, the dog should be restrained behind a visual barrier while the trail layer teases the dog. Throughout this stage of trailing training, S_1+ and S_1- must never be revered so S_1- is the target. Because S_1+ will be the target trail layer throughout this stage, a scent sample must not be presented. If during this stage, trials did begin with the presentation of a scent sample, it would be a pseudo-MTS arrangement, during which dogs could learn to ignore the scent sample that predicts nothing that is not already perfectly predicted by prior reinforcement history. Instead, trailing trials may begin with a few reinforced discrimination trials between the S_1+ and S_1- jars just prior to trailing.

After discrimination training with the first pair of positive and negative human scents, Phase 2 discrimination training between a new pair of novel human scents can begin. An arbitrary number of 30 trials to learn the human scent discrimination between S_2+ and S_2- is recommended, followed with an additional 90 overtraining trials. Upon completion of Phase 2 with S_2+ and S_2-, dogs can be required to discriminated between S_2+ and S_2- articles and trails, as they were with S_1+ and S_1-.

The same process of training should be conducted with S_3+ and S_3-. However, following the first 30 Phase 2 discrimination trials, only 60 overtraining trials are required to complete Phase 2.

Following simple human scent discrimination training with the three pairs of positive and negative human scents, training should involve MTS (not pseudo-MTS), preferably with novel human scents or a large training set.

For dogs to learn about the matching relationship between the individual-unique cue on the scent sample and correct alternative, which is common to all human scent MTS trials, dogs must not only compare the alternatives with the memory of the previously presented scent sample, they must also compare trials. Therefore, in addition to increased attention to the individual-unique dimension of human scent, several MTS trials within each training session can enhance acquisition of the matching relationship.

However, if 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. If a small set of training stimuli were not randomly alternated as sample/comparison correct and incorrect over trials, the arrangement would be not be MTS; it would be a pseudo-MTS arrangement. But, MTS is a memory game. A problem subjects are faced with during MTS, is remembering which stimulus sample/comparison is correct on a current trial (see e.g. Wright, Urcuioli, and Sands, 1986). Dogs must remember the olfactory information from the scent sample long enough to choose between alternatives the matching scent. But memory is taxed when MTS involves a small set of training stimuli, such as scent from just two people, and trials are massed together within sessions. When a small set of MTS training stimuli is used, errors are increased due to *proactive interference*. That is, associative memory from earlier trials interferes with memory of the correct alternative on a current trial and dogs choose the wrong alternative, which retards learning about the matching relationship.

To avoid proactive interference errors and enhance acquisition of the matching relationship holding over MTS trials, the solution is to increase the training set size, the number of people who to donate scent, or train with all strangers. 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 (see e.g. Overman & Doty, 1980; Sands & Wright, 1980a, 1980b; Wright, Cook, Rivera, Sands, & Delius, 1988; Peña, Pitts, & Galizio, 2006). Also, to reduce retroactive interference errors during MTS acquisition, the number of alternatives in each trial should be limited to two, one matching alternative and one nonmatching alternative, as opposed to six alternatives, one matching and five nonmatching.

Notes:

*6. Because the methods here are designed to be users friendly as much as possible, without omitting important controls, and because there will be handler involvement during subsequent mantrailing training and real world mantrailing operations, explicit controls against handler cues are not included in the method. However, the author cannot emphasize enough how detrimental cueing the dog can be, which includes following the leach length law during subsequent mantrailing training. Rather than subscribing to the rule to anchor the line if the dogs goes more than a leach length and a half off the trail layers actual line of travel, our goal is to train and test scent matching dogs prior to maintrailing. After the dog has learned to scent match and discriminate between human scents, while working trails the handler can watch the dog's attention to environmental stimuli. When the dog encounters a choice point (a juncture in which dogs must discriminate between alternatives), the handler is provided a clue that the dog is still working by either change in attention (such as, a head dip to the left or right) or by passing alternatives with little response to them. Also, following a head dip, if the dog indicates it has lost the trail, the handler will know where the trail layer turned and where to back up to. Thus, head dips to the left or right as the dog moves forward do not necessarily indicate the dog cleared the area; they are not negative indications.

*7. Although discrimination learning is not easily measured in Phase 2, a way to determine whether dogs have learned the discrimination is to compare how readily the dog moves to the trainer's other side after a nose-poke to the S- jar, versus persistent nose-pokes to the S+ jar. When dogs have learned about both the predictive relationship between S+ and reinforcement and S- and the omission of reinforcement, they will approach S+ and avoid S-. Yet, before dogs can learn that S- predicts the omission of reinforcement, dogs must first learn that S+ predicts reinforcement. Therefore, another measure of discrimination learning is avoidance of S-.

Procedural Constraints

1) Scent articles should consist of the same material, so the dog cannot learn a discrimination based on differing material odors at the expense of learning to discriminate between individual-unique human scent information.
2) The jars that the scent articles are presented in should be identical.
3) The jars and their lids must be sterilized prior to use and kept free of extraneous odors, other than the dog or handler.
4) The scent articles must be sterilized and not touched by people other than the trainer or have human scent from anyone other than S+ or S-.
5) S+ and S- human scents used for discrimination training must be novel (from strangers) prior to phase 1 and 2 during conditioning.

6) The trainer must not use their own scent for discrimination training. During human scent discrimination training, the trainer's scent will be present during both reinforced and non-reinforced trials. Consequently, the dog can learn that the trainer's scent is irrelevant and come to ignore it. Whereas, S+ will be reliably correlated with reinforcement and S- will be reliably correlated with the omission of reinforcement. Thus, both S+ and S- will be relevant stimuli.
7) When collecting human scents, care should be taken as much as possible that elements other than genetic cues are equally present among discriminative stimuli. For example, while the dog is learning the discrimination, both S+ and S- should be the same gender and ideally should wash with the same soap, eat the same diet, both either smoke or not, etc.
8) During human scent discrimination acquisition, both S+ and S- scent articles should be collected at the same time and be scented for the same duration. Do not arrange for S- to be systematically less salient than S+.
9) During human scent discrimination acquisition, both S+ and S- should be collected from the same parts of the body.
10) Do not use identical twins as S+ and S- discriminative stimuli.
11) During human scent discrimination acquisition, S+ and S- scent articles should not have been collected any longer than four days prior to use.
12) Scent articles must be individually stored in glass, air tight, dark, and cool environments when not in use.
13) During phase 2, S+ and S- must not be reversed. S+ must remain positive and S- must remain negative throughout phase 2 human scent discrimination training.
14) To control against dogs learning a position discrimination, at the expense of learning human scent discrimination, S+ and S- must be presented in the trainer's right and left hands in a semi random order. Over trials within each session, S+ and S- should be presented equally often from the right and left hands and S+ must never be presented from the same hand for more the three consecutive trials.
15) If the dog nose-pokes S-, the trainer must not switch the jar to the other hand. Instead, the trainer must omit the click and reward until the dog switches sides and nose-pokes S+. This constraint controls against the development of a position habit. If trainers were to switch jars to their other hands whenever dogs respond to S-, then dogs could ultimately be reinforced only on one side and consequently develop a position habit at the expense of learning the discrimination between human scents.
16) The clicker should be held in either the left or the right hand throughout all Phase 2 training.
17) Each training session must begin with a hungry dog. When a food reinforcer is used, the dog should never be satiated prior to training.
18) During discrimination training, the reinforcer used must be motivationally significant (no dry or packaged dog treats) and must not be changed, increased, or decreased.
19) The reinforcer used during phase 2 training must only be used to reinforce correct responses to S+. Dogs must not receive the same reinforcer during other occasions not involving in human scent discrimination.
20) Dogs must have zero interaction with the S+ and S- scent donors during intertrial intervals.