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EVALUATING FUNCTIONAL CLASS FORMATION THROUGH SIMULTANEOUS SIMPLE DISCRIMINATION TASKS IN DOGS[1]

EVALUACIÓN DE LA FORMACIÓN DE CLASES FUNCIONALES MEDIANTE TAREAS SIMULTÁNEAS DE DISCRIMINACIÓN SIMPLE EN PERROS

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Resumen

El presente estudio tuvo como objetivo investigar la formación de clases funcionales en perros. Para ello, se utilizó un dispositivo automático para presentar estímulos visuales y registrar las respuestas de los sujetos en tareas simultáneas de discriminación simple. La respuesta operante consistió en tocar (con la nariz) estímulos visuales presentados en una pantalla táctil. Se utilizaron tres pares de estímulos (es decir, A1/A2; B1/B2; C1/C2) en cinco fases experimentales. Es decir, en la Fase I se realizaron entrenamientos y reversiones con la pareja A; entrenamiento y reversiones con la pareja B en la Fase II; entrenamiento y reversiones con las parejas A y B presentadas en la misma sesión en la Fase III; entrenamiento y reversiones con la pareja C en la Fase IV; y entrenamiento e inversiones con los pares A, B y C en la Fase V. Después de la adquisición de la discriminación (p. ej., A1/S+ y A2/S-), se invirtieron las funciones discriminativas de los estímulos. Se evaluó si, a partir de la reversión del primer par de estímulos, los sujetos cambiarían su patrón de respuestas al

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par de estímulos restante antes de la exposición directa a las nuevas contingencias. Los resultados muestran que el procedimiento diseñado estableció un repertorio discriminativo complejo y flexible en perros; sin embargo, fue insuficiente para demostrar una respuesta relacional en las sondas de formación de clases funcionales.

Palabras clave: formación de clases funcionales, dispositivo automático, entrenamiento de discriminación simple y reversiones, perros

Abstract

The present study aimed to investigate functional class formation in dogs. For this purpose, an automatic device was used to present visual stimuli and record the subjects' responses in simultaneous simple discrimination tasks. The operant response consisted of touching (with the nose) visual stimuli presented on a touchscreen. Three pairs of stimuli were used (i.e., A1/A2; B1/B2; C1/C2) in five experimental phases. Namely, training and reversals with pair A were carried out in Phase I; training and reversals with pair B in Phase II; training and reversals with pairs A and B presented in the same session in Phase III; training and reversals with pair C in Phase IV; and training and reversals with pairs A, B, and C in Phase V. After the acquisition of discrimination (e.g., A1/S+ and A2/S-), the discriminative functions of the stimuli were reversed. It was evaluated whether, from the reversal of the first pair of stimuli, the subjects would change their pattern of responses to the remaining pair of stimuli before direct exposure to the new contingencies. The results show that the designed procedure established a complex and flexible discriminative repertoire in dogs; however, it was insufficient to demonstrate relational responding in the functional class formation probes.

Keywords: functional class formation, automatic device, simple discrimination training and reversals, dogs

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In psychology, knowledge produced about learning processes and behavior was, and still is, often obtained through studies conducted with non-human animals. According to Lattal and Doepke (2001), the results obtained with non-human animals are relevant to understanding human behavior, given the possibility that basic behavioral processes are shared between species. These authors also argue that the experimenter must reduce the phenomenon of interest to its essential conceptual and experimental components when planning a procedure with non-human animals. For Catania (2007), this reduction contributes to developing techniques and terminologies that can be applied to understand more complex events.

Some of these studies have been conducted with dogs as experimental subjects. Archaeological findings indicate that the first burial dedicated to a dog occurred approximately 14,000 years ago. Therefore, men and dogs have lived together and shared similar environments since the Paleolithic age (Udell & Wynne, 2008).

According to some authors, the canine species' evolution in environments cohabited by humans may have developed communicative and social skills in dogs that favor comparative studies between these two species (Cooper et al., 2003; Miklósi, 2007). Indeed, a prolific area of research is mainly interested in developing animal models for different human cognitive processes based on experiments with dogs (for a discussion of canine cognition, see Lea & Osthaus, 2018). Learning by imitation (e.g., Fugazza et al., 2016; Huber et al., 2020; Pongrácz et al., 2008; Scandurra et al., 2015), human-like language skills (e.g., Ramos & Ades, 2012; Rossi & Ades, 2008), and problem-solving (e.g., Carballo et al., 2020; Marshall-Pescini et al., 2008, 2017) are some examples of the cognitive processes studied over the years.

The experimental results showing emergent repertoire in dogs are particularly important in the context of the present experiment (e.g., Aust et al., 2008; Byosiere et al., 2017; Nagasawa et al., 2011; Range et al., 2008; Zaine et al., 2014). For instance, Byosiere et al. (2017) taught eight *Lagotto Romagnolos* to perform a two-choice visual discrimination task based on the stimulus size. Specifically, the dogs were reinforced by choosing the larger stimulus when two identical circles that varied only in size were presented. In the testing phase, the researchers evaluated whether dogs would respond according to the same control relation (i.e., choosing the larger stimulus) when faced with novel shapes in a similar two-choice discrimination task. The results demonstrated that the subjects achieved percentages of correct responses that differ significantly from chance level performance in five of the eight novel shapes.

Additionally, emergent repertories in dogs were also reported in studies related to vocabulary learning (e.g., Fugazza et al., 2021; Griebel & Oller, 2012; Kaminski et al., 2004; Pilley & Reid, 2011). For instance, Kaminski et al. (2004) demonstrated that an 8-year-old *Border Collie* named Rico could choose a new item presented along with items whose names he had already acquired when an unknown spoken name was pronounced.

Interestingly, in Behavior Analysis, complex behavior such as functional class formation is sometimes evaluated by studying emergent repertories (e.g., Canovas et al., 2015, 2019; Goldiamond, 1966; Lionello-DeNolf et al., 2008). Vaughan (1988), for instance, conducted a study to evaluate functional class formation in pigeons using simple successive discrimination training. In that study, 40 pictures containing trees were divided into two sets of 20 pictures each (i.e., sets A and B). First, the pigeons were reinforced to respond in trials that presented any set A stimuli, while responses in trials that presented any set B stimuli were extinguished. Then, after several sessions, the reinforcement contingencies were reversed (i.e., responses to set B stimuli were reinforced, and responses to set A stimuli were extinguished). Further, after several more sessions, contingencies were again reversed, and so on throughout the experiment. Because the stimuli presented in the task sometimes exert the S+ function and sometimes the S- function, the procedure is known as a simple discrimination reversal task.

Therefore, stimuli in the same set shared discriminative functions (i.e., S+ or S-) based on the demand for a common response. In this context, if the stimuli in each set were equivalent, the reversal of the function for one of them would lead to the function reversal for the remaining stimuli in the same set without the need for direct training. Vaughan's results showed such a behavior pattern: after performing a few trials in a reversal session, the pigeons responded accurately to the other stimuli before being directly exposed to the new contingencies.

However, according to Hayes (1989), pigeons' performance in Vaughan's (1988) study would not necessarily reflect a functional class formation process. Hayes argues that, throughout the training procedure, pigeons were directly reinforced to start pecking any set B stimuli if pecks in the set A stimuli were not reinforced or, conversely, to start pecking any set A stimuli if pecks in the set B stimuli were not reinforced. In other words, subjects learned to change their response pattern following the reversal of the discriminative functions of the stimuli throughout the session. Therefore, pigeons’ response pattern in the face of reversed contingencies was explicitly trained instead of an emergent performance.

Some of Hayes's (1989) criticisms were addressed by Dube et al. (1993) in an experiment using successive simple discrimination training for establishing functional classes in rats. Six auditory stimuli were divided into two sets of three stimuli each. Subjects were given 90-trial blocks in which auditory stimuli were presented for up to 5 s. Pressing a lever on the S+ trials ended the stimulus presentation and produced the delivery of the reinforcer. Conversely, S- trials ended after 5 s, regardless of the subjects' behavior. In this context, A1, B1, and C1, as well as A2, B2, and C2, shared the same discriminative functions (i.e., S+ or S-) based on the demand for a common response. Reversals on discriminative functions of the stimuli were scheduled to occur whenever at least 80% of the total responses in a session occurred in S+ trials. For evaluating the functional class formation, only two stimulus pairs were presented in the three subsequent sessions after a reversal (e.g., A1, B1, A2, and B2). Then, in the fourth session, C1 and C2 were reintroduced. The functional class formation would be demonstrated if the responses to this third stimulus pair were consistent with the reversed contingencies even before those responses produced consequences. Only one of the five subjects achieved results compatible with the functional class formation.

In a second experiment from the same study, two rats were given a slightly different training procedure to evaluate the functional class formation. In this procedure, the sessions consisted of 300 trials in the following order: 100 trials presenting A2 and C1 stimuli, 100 trials presenting B2 and A1 stimuli, and 100 trials presenting C2 and B1. The criterion for reversals in the discriminative functions of the stimuli was the same as described in the previous experiment. Thus, it would be possible to observe whether the reversal in the contingencies for the first stimulus pair would cause changes in the response pattern for the remaining pairs. However, only one rat achieved the criterion for scheduled reversals and, after ten reversals, for functional class formation. Together, these experiments indicate that repeated reversals of simple discriminations could sometimes result in functional class formation in non-human subjects; nevertheless, more robust evidence would be critical.

Specifically related to dogs, Domeniconi et al. (2008) conducted a study using simple discrimination training for establishing functional classes. In that experiment, the stimuli were hollow three-dimensional objects into which small food portions could be placed. Then, portions of food were placed inside the S+ on each trial. Correct choices were reinforced by access to the hidden food. First, subjects were given 12-trial blocks in which A1 was arbitrarily defined as S+ and B1 arbitrarily defined as S-. Reversals in the discriminative functions of the stimuli were scheduled to occur whenever the subjects achieved at least 90% of correct choices in a training block. In addition, specific reinforcers (i.e., different foods) were used in that procedure. Little portions of sausage reinforced responses to A1, while little portions of salami reinforced responses to B1. After some reversals using A1 and B1, these stimuli were replaced by A2 and B2. Then, after more reversals using A2 and B2, they were replaced by A3 and B3 stimuli. Finally, after some reversals using these stimuli, the baseline was ended. It warrants noting that responses to all stimuli in set A (i.e., A1, A2, and A3) were reinforced by portions of sausage, and responses to all stimuli in set B (i.e., B1, B2, and B3) were reinforced by portions of salami. In summary, during the establishment of this baseline, only one stimulus pair was presented in each session, their discriminative functions were never reversed within a block, and specific reinforcers for each stimulus set were used.

For evaluating functional class formation, subjects were given six 12-trial testing blocks in which all three pairs of stimuli were presented in a semi-random order. In the first three test blocks, the dogs were reinforced to respond to stimuli from set A (i.e., A1, A2, and A3), while responses to stimuli from set B were extinguished. Reinforcement contingencies were reversed in the last three test blocks. In general terms, the performances of all subjects were above 90% correct responses in all six testing blocks. Indeed, two of the three subjects achieved 100% correct choice in the block where the reversal occurred. While considering the possibility of functional class formation by dogs, some concerns related to the Domeniconi et al. (2008) results must be addressed. Importantly, in a simple discrimination situation, the reversal in contingencies is perceived through errors in choice responses. In other words, after a reversal, most responses would be emitted to the stimulus that exerted the S+ function in the previous block. The absence of reinforcement to respond to that stimulus would control the change in the pattern of responses in the following blocks. This error pattern did not occur in Domeniconi et al.'s experiment. Considering the testing block results, it was possible to argue that dogs' responses exemplified conditional discrimination in the experimental procedure. Specifically, the reinforcer smell used in each block could serve as a cue to indicate the S+ stimulus in each trial. If it is true, it would not be necessary to suppose the formation of a functional class between the visual stimuli to explain the participants' performances described in that experiment.

In summary, considering the experimental findings describing some complex processes presented by dogs that seem to be analogous to complex processes of humans in various domains, such as problem-solving and learning by imitation (e.g., Carballo et al., 2020; Fugazza et al., 2016; Huber et al., 2020; Marshall-Pescini et al., 2008, 2017; Pongrácz et al., 2008; Scandurra et al., 2015 – for a review see Lea & Osthaus, 2018), and describing that previous learning impacts performance on untrained tasks (e.g., Aust et al., 2008; Byosiere et al., 2017; Fugazza et al., 2021; Griebel & Oller, 2012; Kaminski et al., 2004; Nagasawa et al., 2011; Pilley & Reid, 2011; Range et al., 2008; Zaine et al., 2014), research on complex behavior with dogs as experimental subjects seems a promising path to be followed. Some authors have supported using dogs as experimental subjects in behavior analysis research (see Udel & Wyne, 2008), which seems to have significantly increased such research in recent decades (Hall et al., 2023). Indeed, a recent special issue of a behavior analytic journal was dedicated to canine behavior and cognition (Hall et al., 2023). Such experiments evaluated, for instance, methods for evaluating dogs’ preferences and the reinforcing effectiveness of stimuli (Payne et al., 2023), concept learning (Bulla et al., 2023), and learning and retention (Messina et al., 2023).

Furthermore, considering the need for more substantial evidence of the functional class formation established through repeated reversals of simple discriminations in non-human subjects and the concerns related to the experimental procedure employed by Domeniconi et al. (2008), the present study aimed to conduct a systematic replication of Dube et al. (1993) using dogs as subjects. In the present experiment, simple discrimination training between pairs of visual stimuli was followed by successive reversals and probes to evaluate the functional class formation. An automatic device was used to present visual stimuli and record operant responses.

Method

Subjects

Three experimentally naïve domestic dogs (Canis familiares) participated in the study: a 3-year-old female Dachshund (S1), a 5-year-old male Dachshund (S2), and a 3-year-old male medium-sized crossbred dog (S3). The subjects resided in a veterinary clinic and belonged to the clinic owners. The present experiment was approved by the Ethics Committee on Animal Experimentation (Process No. 007/2010).

Experimental Setting

Data collection was performed three to five times weekly at the clinic where the animals lived. The activities were carried out in a 5-square-meter room in the morning before feeding the dogs, which allowed taking advantage of the natural condition of deprivation to ensure the reinforcing value of the food. The sessions were performed individually and lasted approximately 15 minutes.

Equipment and materials

A wooden apparatus measuring 50.5 cm x 50.5 cm x 50.5 cm was built for data collection. A screen with a 19-inch touchscreen monitor (model 1939L LCD Open-Frame Touchmonitor, brand Elo Touchsystems) was attached to the front wall of the apparatus, on which the subjects should emit the responses. All subjects responded, poking the screen with their nose. The touchscreen was connected to a Sony Vaio notebook (Model VPCEA25FX) equipped with the Stimulus Control 1002 software (Velasco & Picorone, 2008), specifically designed to conduct experiments with non-human subjects. This software managed the presentation of stimuli, recording responses, and releasing a differential sound consequence for correct and incorrect responses. The sound was presented in two computer 5w sound boxes on the floor, one on each apparatus side.

Figure 1

Picture of the Apparatus in Each of the Possible Height Levels

Level 1 Level 2 Level 3

A manual food dispenser was located behind the touchscreen and consisted of two PVC pipes, measuring 20 cm and 8 cm, connected by a PVC curve with an angle of 135°. The food was deposited at the end of the most extended pipe, ran through the entire pipe, and dropped into a plastic container accessible to the animal below the screen. The food dispenser and the handling and release of the food unit were not visible to the dog. Only the dispenser outlet, the plastic container, and the touchscreen remained visible to the animal during the session. Furthermore, the height of the apparatus was adjustable, and the screen could be displayed on three different levels, depending on the dog's height, as shown in Figure 1. Height level 1 was used with S1 and S2, and height level 3 was used with S3.

Table 1

Visual Stimulus Sets Employed on Experimental Tasks

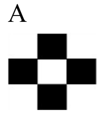
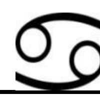
		Sets			
		X	A	B	C
Classes	1				
	2				

Table 1 presents the visual stimuli used in the procedure. These stimuli, measuring 9.9 cm x 9.1 cm, were presented horizontally in pairs on the computer screen in two different positions (left and right), maintaining approximately 8 cm from each other. As seen in Table 1, different stimuli with identical dimensions were used to establish the operant response and the simple discrimination training.

The reinforcers were dry dog food units (Pedigree Expert Super Premium - Adult Medium Breed). For S3, social reinforcement and physical contact were contingently presented for each correct response in addition to food.

Procedure

Establishment of the operant response

The necessary target behaviors directed toward the experimental apparatus were shaped in this phase. Firstly, the screen was turned on, and a 25 cm x 24 cm smiling face filled almost the entire screen. In addition, one food unit was placed in the dispenser outlet before bringing the dogs into the data collection room. Once inside the room, the dogs explored the environment and eventually found the food. Some more food units were given to the dogs while consuming the first one. The sound associated with correct responses had consistently been presented with the reinforcer since the very first reinforcement occurrence.

The first reinforced response in this shaping process was the dogs' natural head-lifting movement after eating each food unit. Over time, larger head-lifting movements were required, which caused the dogs to bring their noses closer to the computer screen. After some reinforcement occurrences, the criterion was changed, and the dogs needed to nose-poke the screen, even if their responses did not automatically trigger the touch-screen system. Finally, the subject had to present responses detected by the touch-screen system and registered by the software to be reinforced.

Establishing the session parameters

Since the smiling face filled almost the entire screen, virtually all nose-poking responses occurred on the visual stimulus during the shaping process. However, it is noteworthy to consider that the poking response should continue to occur on the visual stimulus even when smaller visual stimuli are presented. Because of this, a sequence of 20 sessions was designed to decrease the size of the visual stimulus on the screen. Then, the visual stimulus was presented as measuring 20 cm x 19 cm in the first five sessions. Next, it was presented as measuring 16 cm x 15 cm for another five sessions. The smiling face measured 12 cm x 11 cm for five additional sessions. It was finally presented in the size used in the experimental procedure during the last five sessions.

In addition, this same sequence of 20 sessions was used to establish the number of trials per session. The first five sessions ended after ten trials. Then, the number increased to 20 trials in the next five sessions. It increased to 40 trials for another five sessions and 50 trials per session in the last five sessions.

Finally, after this 20-session sequence, there was a 15-session sequence in which the S- presentation was introduced. Specifically, 36 out of 50 trials in the first five sessions contained only the S+ and the remaining 14 trials presented both S+ and S-. During the establishment of the session parameters, responses to X1 produced reinforcement delivery and the release of the sound associated with correct responses. Responses to S- (i.e., X2), when available, produced 4s of timeout and the release of the sound associated with incorrect responses. In other words, incorrect responses produced a dimming of the screen and the suspension of programmed consequences for any poking on the touchscreen during this period. In the last ten sessions, both S+ and S- stimuli were presented in all trials, and this phase was finished after 15 sessions, regardless of the subjects' performance.

Simultaneous simple discrimination training and reversals

In each experimental session, 72 trials were performed, in which the subject's task was to nose-poke one of two stimuli presented on the computer screen. An intertrial interval (ITI) of 2s followed each trial. After a correct response, a specific sound was presented, and the food unit was delivered to the dispenser. If the subject touched the stimulus designated as incorrect, a different sound was presented, followed by the timeout. After the timeout, the ITI started. Incorrect responses also produced the repetition of the trial. If, in the trial repetition, the subject selected the S+, the sound, and the food unit were presented; if the subject selected the S- after the ITI, the trial was restarted, but only the S+ was presented and remained on the screen until the dog selected it (i.e., forced choice trial). Responses in any other area of the screen had no consequences. Repeated and forced-choice trials were not considered for the data analysis.

The procedure took place in five phases. Initially, discrimination between the stimuli of each pair was taught and reversed in isolation: training and three consecutive reversals with stimuli from set A were performed first (Phase I); then, training and three consecutive reversals with stimuli from set B (Phase II). It is important to note that the two stimuli of the set were always presented simultaneously, one with the

Table 2

Phase, Step, and Discriminative Function Through the Experimental Procedure

Phase	Step		Discriminative Function
I	1	Training	A1+/A2–
	2	Reversal 1	A1–/A2+
	3	Reversal 2	A1+/A2–
	4	Reversal 3	A1–/A2+
II	1	Training	B1+/B2–
	2	Reversal 1	B1–/B2+
	3	Reversal 2	B1+/B2–
	4	Reversal 3	B1–/B2+
III	1	Simultaneous Reversal	A1+/A2–; B1+/B2–
	2	Reversal 1	A1–/A2+
	3	Simultaneous Reversal	A1–/A2+; **B1–/B2+**
	4	Reversal 2	B1+/B2–
	5	Simultaneous Reversal	**A1+/A2–**; B1+/B2–
IV	1	Training	C1+/C2–
	2	Reversal 1	C1–/C2+
	3	Reversal 2	C1+/C2–
	4	Reversal 3	C1–/C2+
V	1	Simultaneous Reversal	A1+/A2–; B1+/B2–; C1+/C2–
	2	Reversal 1	B1–/B2+; C1–/C2+
	3	Simultaneous Reversal	**A1–/A2+**; B1–/B2+; C1–/C2+
	4	Reversal 2	A1+/A2–; C1+/C2–
	5	Simultaneous Reversal	A1+/A2–; **B1+/B2–**; C1+/C2–

Note. Underlined stimulus pairs indicate when functional class formation probes were performed.

S+ function and the other with the S- function. For example, in every trial where A1 was present, A2 would also be present. Furthermore, when A1 is related to reinforcement (S+), A2 is related to extinction (S-).

Then, in Phase III, trials with the stimulus sets (A1/A2 and B1/B2) were mixed in the same session, and the stimulus functions were reversed a few times. When more than one set of stimuli was presented in the same session, class 1 stimuli (i.e., A1 and B1) were always presented with the same function (S+ or S-), while class 2 stimuli (i.e., A2 and B2) were always presented with the inverse function. In Phase IV, discrimination between stimuli from set C was taught, and three successive reversals were carried out. In the last phase, the three sets of stimuli were presented in the same session (Phase V). Each phase was further subdivided into steps detailed below and summarized in Table 2. Underlined stimulus pairs indicate the moments in which the probes for establishing functional classes were performed.

Phase I - A1/A2 stimuli

In Step 1 of Phase I, stimulus A1 exerted the discriminative function of S+, and A2 exerted the discriminative function of S-. The criterion for the occurrence of reversal was 93% of correct responses in three of four consecutive sessions. However, with the beginning of the reversals, the dogs began to respond periodically to the S- throughout the session. These errors were not enough to question the learning of the new contingency in force, but they made it difficult for them to reach the proposed criterion. For this reason, beginning with Step 2 and on the following steps and phases, the learning criterion became two consecutive sessions with a minimum of 85% correct responses.

In Step 2, stimulus A1 was the S-, and stimulus A2 was the S+. All other session parameters were maintained except for the timeout duration. When the functions of the stimuli were reversed, the animals were expected to miss many trials until they learned the new contingency. Due to the possibility of many incorrect responses in these sessions, the timeout was reduced to 2s. This timeout value was used until the subject achieved 50% in one session. Once this correct response percentage was achieved, the next session reinstated the 4s timeout. This strategy was used in all reversal steps. Subsequently, Steps 3 and 4 consisted of replications of what was described for Steps 1 and 2, respectively.

Phase II - B1/B2 stimuli

After all the reversals programmed with set A had occurred, training with stimuli from set B started using the same parameters described above. In Step 1 of Phase II, stimulus B1 was the S+, and stimulus B2 was the S-. After achieving the learning criterion, the discriminative functions were reversed, and the sessions continued until the learning criterion was achieved again (Step 2). Again, Steps 3 and 4 consisted of replications of Steps 1 and 2, respectively.

Phase III - A1/B1/A2/B2 stimuli

The occurrence of reversals in this phase was used to perform the first functional class formation test. Therefore, in Step 1 of Phase III, class 1 stimuli (i.e., A1 and B1) were the S+, and class 2 stimuli (i.e., A2 and B2) were the S-. This simultaneous presentation of pairs A and B continued until reaching the learning criterion.

In Step 2, only stimuli from set A were presented with their functions reversed, that is, A1 as S- and A2 as S+. This contingency was maintained until the learning criterion was obtained. Finally, during Step 3, stimuli from set B were reintroduced with the functions also reversed (B1-/B2+), and the session resumed trials with two sets of stimuli (i.e., A and B). In this context, the formation of classes would be demonstrated if the subject emitted a pattern of responses to stimuli from set B according to the new contingency taught with stimuli from set A.

Steps 4 and 5 of Phase III carried out, respectively, the reversal of the functions of stimuli from set B and tests of functional class formation with stimuli from set A. Therefore, Steps 4 and 5 replicated what was described for Steps 2 and 3.

For subject S2, an alternative approach was used in Phase III due to the high number of sessions needed to achieve the learning criteria in Phases I and II. More specifically, different from what was initially planned, the contingencies were reversed for S2 every three sessions regardless of its performance in the task.

Phase IV - C1/C2 stimuli

After all the reversals programmed in Phase III occurred, training with stimuli from set C began, using the same sequence of events described in the steps of Phases I and II.

Phase V - A1/A2/B1/B2/C1/C2 stimuli

In the last phase, the three sets of stimuli were presented in the same session. Each session consisted of 72 trials equally divided between the three sets of stimuli. The sets of stimuli were presented semi-randomly, with the only restriction being the maximum number of three consecutive trials with the same set of stimuli. In Step 1, class 1 stimuli (i.e., A1, B1, and C1) were the S+, and class 2 stimuli (A2, B2, and C2) were the S-. Upon reaching the learning criterion for Step 1, Step 2 began, in which the discriminative function of sets B and C were reversed (i.e., B1–/B2+; C1–/C2+), and set A was removed from the session. In this case, the session consisted of 36 trials with stimuli from set B and 36 trials with stimuli from set C presented in a semi-random order. In Step 3, set A stimuli were reintroduced in the session with reversed functions (i.e., A1–/A2+) and started to be presented together with stimuli from sets B and C. Therefore, the formation of classes would be demonstrated if the subjects emitted a pattern of responses to stimuli from set A consistent with the new contingency taught with stimuli from sets B and C.

In Step 4, discriminative functions were reversed for stimuli from sets A and C (i.e., A1+/A2–; C1+/C2–) and the withdrawal of stimuli from set B. In Step 5, stimuli from set B occurred with their functions reversed (i.e., B1+/B2–).

Results

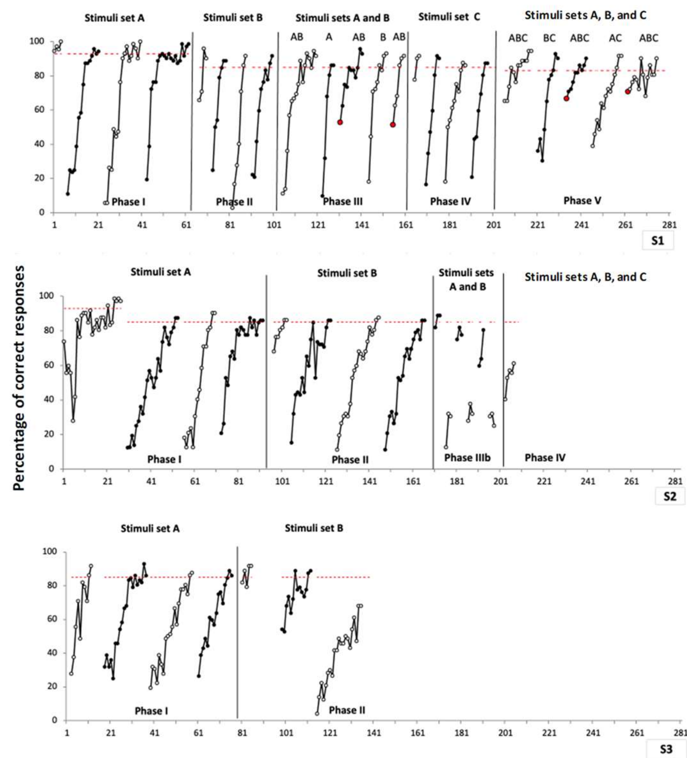
In general terms, S1 was exposed to the five programmed experimental phases, S2 to the first three experimental phases, and S3 achieved the learning criterion for Phase I but did not complete Phase II. Figure 2 presents the percentage of correct responses throughout all experimental phases for each subject. Empty circles represent the percentage of correct responses when class 1 stimuli (i.e., A1, B1, and C1) were the S+, and filled circles represent the percentage of correct responses when class 2 stimuli (i.e., A2, B2, and C2) were the S+. Continuous vertical, black lines separated phases throughout the experiment, and dotted horizontal, red lines indicate the learning criteria. As mentioned, the analysis did not consider repeated or forced choice trials presented after incorrect responses.

Regarding the S1 performance in the simple discrimination training, fewer sessions were necessary to achieve the learning criterion during the initial training of each stimulus pair (Phases I, II, and IV) than during the reversals that occurred within each Phase. In addition, a decrease in the total number of sessions required to complete the phases throughout the experiment was observed. Specifically, Phase I was completed after 56 sessions, while Phases II and IV were finished after only 28 sessions. It is worth noting that S1 demonstrated typical reversal performance during the procedure: an abrupt drop in the percentage of correct responses in the first session of each reversal followed by a steady increase in the percentage of correct responses until the criterion was achieved after a few sessions.

Regarding functional class formation performance, S1 did not achieve the learning criterion in any of the four probes carried out during the procedure (i.e., filled red circles in Figure 2). For instance, in the first probe (Phase III), the class formation would be demonstrated if S1 emitted a pattern of responses to stimuli from set B consistent with the new contingency taught to stimuli from set A. Unfortunately, the drop in the percentage of correct responses in the probe session compared to the immediately previous session (in which only stimuli from set A were presented) indicated that functional class had yet to be established. However, there appears to be an improvement in probe results, considering that the percentage of correct responses was about 60% in the two first probes and about 75% in the latter two.

Figure 2

Subjects' Performance Through the Experimental Phases



Note. Empty circles show the subject's performance in sessions where stimuli from Set 1 were used as the S+. Filled circles when stimuli from Set 2 were used as the S+. Filled red circles comprise the results of functional class probes.

The S2 performance in Phase I differed from the pattern presented by S1: initial discrimination training occurred in a more extensive number of sessions compared to reversals. Despite many correct responses in the first session, the percentage dropped in the second session and only resumed after five sessions with the presentation of remedial procedures to change the preference for one of the positions. After that, the performance reached asymptotic values of around 80% of correct responses for 18 sessions, but the stipulated learning criterion was only achieved after the adoption of physical restraint of the animal in all trials in the 24th session. Regarding performance during reversals, the pattern was compatible with that of S1: the percentage of correct responses in the first reversal session dropped abruptly, gradually rising again in the following sessions. However, S2 required ten sessions more than S1 on average within each step to achieve the learning criterion. Even so, this criterion was only achieved after the adoption of several sessions with the presentation of correcting procedures. Furthermore, comparing the number of sessions required to conclude Phases I and II, it is noted that learning the initial discrimination of pairs A and B took an approximate number of sessions to complete.

In Phase IIIb, pairs of stimuli were presented simultaneously, and the functions of the stimuli were reversed every three sessions. The performance concerning the stimuli from class 2 (i.e., filled circles in Phase IIIb) was always superior to the performance of the stimuli from class 1. However, throughout the reversals presented, it was possible to observe an increase in the percentage of correct responses in sessions in which the stimuli from set 1 had an S+ function (second and fourth curves) and a decrease in this percentage when the stimuli from set 2 returned to have a discriminative function.

Analyzing the performance of S3 in Figure 2, it is possible to observe a pattern like that observed in S1: The subject needed fewer sessions to achieve the learning criterion in the initial discrimination than in the reversals. The abrupt drop in performance in the reversals followed by a gradual increase in correct responses until the acquisition was also observed for S3. The number of sessions needed to complete each step of Phase I was more extensive than that of S1, but the values were close to those presented by S2. In Phase II, the learning criterion for the first and second steps was achieved in five and 14 sessions, respectively. However, the performance dropped to 4.0% for correct responses in the first reversal session of the third step, and S3 did not achieve the criterion for this step even after 21 sessions. In addition, the percentage of correct responses in this step randomly varied from one session to the next, sometimes increasing and now decreasing compared to the previous session.

Discussion

The present study investigated whether repeated reversals of simultaneous simple discriminations would facilitate functional class formation in dogs. Only S1 performed all five phases, while S2 and S3 performed three and two phases, respectively. Unfortunately, the many sessions needed to achieve the learning criteria in some phases prevented S2 and S3 from completing all the experimental procedures. For instance, S2 needed approximately 90 sessions to achieve all Phase 1 learning criteria, and about five months of data collection (considering four sessions per week on average) were spent in this phase. Similarly, S3 needed approximately 80 sessions to finish Phase 1.

Two of the three subjects did not perform all the experimental phases, indicating that the learning criteria were demanding. However, considering that the functional class formation was the main interest of the present experiment, the learning criterion tried to ensure strong evidence for the establishment of the needed behavioral prerequisites (i.e., well-established simple discriminations and reversals; e.g., Dube et al., 1993; Canovas et al., 2015; 2019; Vaughan, 1988). The initial criterion was at least 67 correct responses in 72 trials in three out of four consecutive sessions. Using a learning criterion based on results in consecutive sessions was to avoid exceptional performance in a single session that could be confused with regular performance or with evidence of learning. After observing S1 and S2 performances in Phase 1 first step, however, the criterion was changed to at least 62 correct responses in 72 trials in two consecutive sessions. Unfortunately, even this second criterion seemed demanding for S2 and S3.

In addition, comparing the current learning criterion with previous experiments that taught simple discrimination for dogs can be complicated by the significant difference in the number of trials used in the training blocks. For instance, the maximum number of trials used was in Aust et al. (2008) study, which was 32 trials per block. This number corresponds to only approximately 45% of the trials used in the present experiment. Even so, the learning criterion used in the present experiment was 85% of correct responses. Previous studies varied between 80% and 90% of correct responses for the learning criterion (e.g., Byosiere et al., 2017; Zaine et al., 2014), except for the Nagasawa et al. (2011) study that required 70% of correct responses in some training phases. Furthermore, in most previous studies, subjects were required to achieve this criterion in a single session. In contrast, the subjects were required to achieve it in two consecutive sessions in the present experiment. Perhaps, if used in isolation, these aspects would not have caused problems; however, the sum of a large number of trials per block and the high percentage of correct responses required for two consecutive sessions made the criterion demanding for the subjects of this experiment. Therefore, future experiments could consider using less demanding criteria to evaluate subjects' performance to allow faster progress through the phases. For example, throughout the procedure, it is possible to observe many sessions in which subjects S2 and S3 achieved percentages of correct responses that were very close to but lower than the established learning criterion. Using a learning criterion of 75% instead of 85% of correct responses would possibly reduce the number of sessions performed at each step.

It is also important to emphasize that, despite teaching simultaneous simple discriminations, none of the previous studies performed reversals of the taught discriminations. Only Domeniconi et al. (2008) conducted an experiment in which simultaneous simple discriminations and reversals were taught to dogs. The learning criterion they used was 11 correct responses in 12 trial blocks. Interestingly, all subjects achieved the learning criteria in a maximum of seven sessions. The result may indicate that the task aligns with the dogs' natural behavior. For example, dogs were asked to choose between two three-dimensional objects in a retrieval task instead of the nose-poking response. On the other hand, as mentioned before, the smell of specific reinforcers used in the training procedure could serve as a cue to indicate the correct responses in each trial block. If it is true, the subjects' performance would be under the control of conditional discrimination rather than simple discrimination, which raises some concerns when comparing the results of both experiments. Importantly, the apparatus in the present experiment did not control access to the reinforcer's smell. However, the same reinforcer was employed in all trials. Thus, the reinforcer's smell could not be used as a cue to control the subjects' responses in each step of the present experiment.

The many sessions required to achieve the learning criterion caused a high rate of reinforcement for specific choices in the training phase before the reversal phase took place. For example, in Phase 1, S2 was reinforced by choosing A1 in 27 72-trial sessions before changing this pattern (i.e., choosing A2 instead of A1) in the reversal phase. Nevin and colleagues (e.g., 1992; 2016; 2017) proposed a metaphor for the physical concept of momentum to account for resistance to change in situations where organisms are asked to vary some pre-established behavioral pattern. In this metaphor, the response rate controlled by a discriminative stimulus is understood to be analogous to the speed of a moving body. According to the Behavioral Momentum Theory (BMT – Nevin, 1992; Nevin et al., 2013; 2016; 2017), resistance to change in a pre-established behavioral pattern would directly depend on the rate of reinforcement used to teach it.

For example, Dube and McIlvane (2002) conducted a study with nine adults with intellectual and developmental disabilities to evaluate the occurrence of BMT. In this experiment, a series of simple discriminations using two visual stimuli were trained. Additionally, there were two experimental conditions. In the condition named "High", each correct response in the initial simple discrimination training (e.g., A1+ and A2–) and the reversal (i.e., A1– and A2+) was followed by continuous reinforcement (CRF). In the condition named "Low", correct responses in the initial simple discrimination training (e.g., B1+

and B2–) were reinforced in variable ratio schedules (i.e., VR2 or VR4) and, during the reversal (i.e., B1– and B2+), reinforcers were presented in CRF schedule. As a result, the errors in the reversals were more frequent in the "High" condition than in the "Low" condition for eight of the nine participants. Thus, as predicted by the BMT (Nevin, 1992; Nevin et al., 2016; 2017), the high rate of reinforcement before the reversal may have produced a more persistent stimulus control, making the subsequent behavioral change more difficult (i.e., to choose A2 instead of A1 in "High" condition and to choose B2 instead of B1 in "Low" condition).

In the present study, the rate of reinforcement for selecting each stimulus (e.g., to choose A1 in Phase 1 first step) was high due to the number of repetitions required to achieve the learning criterion. According to the BMT, a high rate of reinforcement would result in a high resistance to change (Nevin, 1992; Nevin et al., 2016; 2017). In other words, many errors would be expected when the subjects were asked to choose A2 instead of A1 – the reversal steps. Indeed, the number of sessions in the reversal steps was higher than in the initial discrimination when considering the subjects' performance. However, this is a speculative analysis because different contexts with differing reinforcement rates were not used in the present study, and high resistance to change predicted by the BMT could indirectly produce additional difficulties for subjects achieving the learning criteria and completing all experimental phases. The S2 learning criterion used in Phase III was an attempt to speed up changes in the choice pattern during the reversal phases while somehow balancing the rate of reinforcement. Unfortunately, the low percentages of correct responses in the blocks where responses to Class 1 stimuli were reinforced caused the difference in the rate of reinforcement to remain an unsolved problem.

Regarding the functional class formation probes, the S1's data were inconclusive. S1 did not reach the planned criterion in any of the four probes, even though this subject showed correct responses in half of these probes. For evaluating functional class formation in the present experiment, we used the percentage of correct responses in an entire block, although previous studies also used correct responses on the first trial presenting stimuli with reversed discriminative functions (e.g., Canovas, 2010; Domeniconi et al., 2008; Goulart et al., 2003; Kastak et al., 2001). In the present experiment, the access to food and social play with experimenters between sessions could have impacted the subjects' performance at the beginning of sessions. Then, using responses from the first trial to evaluate functional class formation was not indicated in the present experiment because impulsive or “inattentive” responses to the stimuli were frequent at the beginning of the sessions.

Another critical issue to be solved in future experiments is the limited number of sessions with different stimulus pairs presented in the same trial block. For example, subjects in Vaughan's (1988) study were given about 800 40-trial blocks in which different stimuli shared the same function until functional class formation was documented. In the present study, S1 performed only about 90 72-trial blocks with concurrent discriminations. Such a simultaneous presentation may be necessary to establish the sharing of discriminative functions between stimuli from different pairs. If this is true, the number of blocks with simultaneous display of different stimulus pairs can be important for the formation of functional classes. Future studies could present more sessions with concurrent discriminations and verify whether the results on class formation would differ from those obtained in the present experiment.

Although inconclusive results related to functional class formation were obtained, it is possible to highlight some positive aspects of the proposed procedure. For instance, the operant response allowed for effective data collection over a long period. S1, for example, was given 281 blocks of simple discriminations in approximately 18 consecutive months with no indication of avoidance in performing the experimental sessions. These results indicate that the experimental procedure developed for the present study can be used to investigate behavioral processes requiring prerequisites involving teaching many stimulus relationships or a long data collection period.

Also, these results confirm previous studies showing that nose-poking responses on computer screens constitute a viable dependent variable when working with dogs (e.g., Aust et al., 2008; Byosiere et al., 2017; Nagasawa et al., 2011; Range et al., 2008). In addition, such an experimental task also allowed sessions with a higher number of trials when compared to the previous experiments with dogs. For instance, each session consisted of a 72-trial training block in the present experiment, while Domeniconi et al. (2008) and Zaine et al. (2014) used 12-trial training blocks. Using this specific type of response and stimulus presentation on computer screens makes it possible to teach not only relations between stimuli based on simple discriminations but also conditional discriminations in matching-to-sample tasks (Cumming & Berryman, 1961; 1965). Teaching conditional discrimination in MTS preparations would be fundamental to allow the evaluation of equivalence class formation (Sidman, 1994) in this population.

Finally, the stimulus presentation on the screen and the automatic response register could be used to control the dog's high sensitivity to detect and react to human social cues. More specifically, studies indicate that dogs have high sensitivity to understanding and use human cooperative communication cues, such as pointing and gazing (e.g., Bray et al., 2021; Hare et al., 2002; Salomons et al., 2021; Virányi et al., 2008). Therefore, using a primarily automated apparatus prevents the subjects' behavior from being somehow controlled by inadvertent cues that can be provided when tasks are arranged manually.

In summary, the results did not allow the evaluation of the functional class formation in dogs; however, a relevant result is the development of an apparatus and an experimental setup suitable for conducting discrimination research with dogs, experimental subjects that do not yet have a long experimental history when compared to other non-human subjects used in research in this area (e.g., pigeons, rats, monkeys; Udell & Wynne, 2008). It is worth noting that using software to present the stimuli and register responses in teaching simple discrimination solves some of the problems found in studies conducted with dogs due to their high sensitivity to detect and react to human social cues (e.g., Junttila et al., 2022). The development of new apparatus and technologies for studying behavioral processes and evaluating dogs' cognitive abilities seems to attract more and more interest over the years.

Secondly, the procedures employed managed to establish in the subjects a considerably extensive behavioral chain that consisted of (i) remaining in front of the screen during the entire session without the need to use equipment to restrict their movements, (ii) tracking the screen in search of a visual stimulus that could be presented in different places, (iii) nuzzling the screen in the places where the stimuli were presented and (iv) obtaining food when choosing specific stimuli. The knowledge resulting from the performance of these experiments will certainly be useful in other research that requires these repertoires as requirements for other behaviors. Such advances could give rise to several experimental procedures for studying symbolic behavior and processes such as memory and perception.

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