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Comparing trial-and-error to errorless learning procedures in training pet dogs a visual discrimination☆

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ABSTRACT

Errorless learning is a stimulus fading procedure that can reduce incorrect responses in a stimulus discrimination task. Errorless learning has been described as a beneficial dog training procedure, although minimal research has been performed with dogs to support its use. The current study compared the effects of using an errorless learning to a trial-and-error learning procedure to train a stimulus discrimination in companion dogs. Eight dogs were trained, four in each group, with concurrent stimuli and either through gradually fading in an incorrect stimulus (errorless learning group) or by differentially reinforcing correct and incorrect responses (trial and error group). Correct responses, incorrect responses, frustration-related responses, and non-responses were measured and compared across the two groups. The results showed the errorless learning dogs were more likely to meet the criteria for learning the discrimination, showed faster speeds of acquisition, and displayed fewer frustration-related behaviours compared to the trial-and-error group. These results are discussed in relation to their benefits for training dogs more effectively and with better welfare during training, suggesting errorless learning could be more greatly utilized for canine training and research.

1. Introduction

In 1963, Terrace proposed a stimulus discrimination procedure, which he named "errorless learning", as an alternative to standard trial-and-error learning. During consecutive stimulus presentations, errors in pigeon key pecks were reduced by presenting the correct key (S+) at full brightness and color (red or green) and gradually fading in the lighted color for a second incorrect key (S-). The S- started as a dark key presented for only 5 secs and was gradually faded in through increased intensity and duration until the light was at the same intensity and duration as the S+. In contrast, the S+ and S- keys were presented consecutively at the same intensity and duration for the trial-and-error group. Thus, errorless learning minimized errors by providing few initial opportunities for incorrect responses to the incorrect stimuli (Byosiere et al., 2017; Catania, 2013; Pierce & Cheney, 2017; Terrace, 1963a; Terrace, 1972).

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Since its inception, errorless learning procedures have successfully allowed individuals to learn to discriminate between stimuli in many species, including humans (Akcin, 2013; Allen et al., 2020; Braga-Kenyon et al., 2017; Robinson & Storm, 1978; Terrace, 1974), pigeons (Arantes & Berg, 2009; Arantes & Machado, 2011; Guillette et al., 2017; Terrace, 1963a; Terrace, 1963b), and dogs (Essler et al., 2021; Vesga et al., 2021). In addition, a number of benefits to errorless over trial-and-error learning have been identified. For instance, Terrace demonstrated that pigeons (Terrace, 1963a; Terrace, 1963b; Terrace, 1971) and humans (Terrace, 1974) made significantly fewer errors and learned a discrimination faster in the errorless learning condition compared to trial-and-error learning. The same effects were also demonstrated in first grade children taught a similar task to the pigeons, using a fading procedure or through verbal instructions compared to trial-and-error learning (Robinson & Storm, 1978). More recent studies have demonstrated the same effects when pigeons were trained a conditional discrimination where the S+ was dependent on how much time had elapsed (Arantes & Machado, 2011), as well as in a transfer from visual to auditory stimuli (Arantes & Berg, 2009).

While the above studies demonstrated some of the benefits of errorless over trial-and-error learning, other studies have shown mixed results. Children with Autism Spectrum Disorder (ASD) showed no difference in the speed of learning acquisition or number of errors produced during the learning process when taught to identify cartoon characters through either a most-to-least errorless learning prompting method or through trial-and-error learning (Leaf et al., 2020). Few differences were also seen when memory-impaired adults were taught to reproduce a sequence to navigate a room, where the errorless learning condition was taught either through following instructions or a combination of following instructions and fading out instructions (Evans et al., 2000). An instruction method of errorless learning was also compared to trial-and-error to train 30 students to navigate their way through a maze on a page (Jones et al., 2010). Although the errorless learning condition resulted in fewer errors during training compared to trial-and-error, when a new maze was presented to the students, the trial-and-error-taught students navigated through the maze significantly faster than the errorless learning group.

Nonetheless, it should be noted that each of these studies used a different method of errorless learning and taught different tasks. Thus, some of the variation in effects may have been a result of the different procedures used. This was seen in a study that compared constant-time delay (i.e., cue fading) versus stimulus fading errorless learning procedures, and found greater speed of acquisition with the constant-time delay procedure (Akcin, 2013). In addition, other studies have demonstrated success with response prompts, some of which occur during errorless training, including through the use of prompt hierarchies (Leaf et al., 2020; Libby et al., 2008), as well as error-correction methods (Carroll et al., 2015; McGhan & Lerman, 2013).

1.1. Errorless learning and frustration-related responses

Aside from speed of acquisition and errors performed, researchers have examined the impact of errorless learning on frustration-related responses. Frustration-related responses (herein occasionally referred to as ‘frustration’) are often a precursor to aggression when expectations are unexpectedly not met (Jeronimus & Laceulle, 2020), and frequent frustration has been shown to cause similar physiological signs to stress responses (Papini et al., 2006). In pigeon research, aggression has been correlated with the occurrence of errors. For instance, pigeons showed more aggressive behaviour (e.g., wing flapping; stamping their feet) in the presence of the S- if a trial-and-error procedure was used compared to an errorless learning procedure (Terrace, 1963a). Similarly, pigeons showed increased aggression to a target pigeon during the S- alone conditions of a consecutive discrimination training procedure (Azrin et al., 1966). Often, frustration is a result of violated expectations such as when a previously reinforced behaviour is then put on extinction (Catania, 2013; Pierce & Cheney, 2017). The observation of behaviours that would help to reduce the aversive emotional state supports these conclusions. However, pigeons were also observed showing aggression when errorless learning was used to train a stimulus discrimination (Rilling & Caplan, 1973). Thus, errors alone were not the only reason for the aggressive behaviours observed in pigeons.

1.2. The errorless learning concept

Several researchers have defined errorless learning as a method where errors are prevented from occurring (Bertens et al., 2013; Braga-Kenyon et al., 2017; Leaf et al., 2020; Jones et al., 2010). One of the difficulties with defining errorless learning by its errors is that it emphasizes the result (i.e., minimization of ‘errors’), rather than detail the procedure (Lattal & Fernandez, 2022). In addition, errorless learning presumes errors are detrimental to learning or the learner in some capacity. As Skinner (1984) noted, “the term ‘error’ does not describe behaviour, it passes judgement on it” (p. 583). The more accurate definition would describe errorless learning as a procedure (not an effect) that reduces the chances of errors. A fading procedure is also an important part of the errorless learning method and was used in all studies by Terrace, (1963a; 1963b; 1971; 1972; 1974). However, some researchers have replaced stimulus fading as an instruction-based procedure (Evans et al., 2000; Jones et al., 2010).

Similarly, the field of dog training commonly reports using errorless learning, or ‘training errorlessly’, to emphasize a minimization of errors rather than use of a fading procedure (Friedman, 2016; Jones, 2018; Stremming, 2016). Only two studies have used errorless learning involving a fading procedure with dogs (Essler et al., 2021; Vesga et al., 2021). Both studies successfully trained dogs to detect COVID-19. However, neither of these canine studies directly compared their errorless learning procedure to trial-and-error learning.

1.3. Current study

The purpose of the present study was to compare the effects of using an errorless learning to a trial-and-error learning procedure to train a stimulus discrimination in companion dogs. This was tested by modifying Terrace’s (1963a) original experiment to train dogs to do a visual discrimination task. It was expected that learning would differ between the two groups, particularly through several dependent variables measured, including: (1) the number of correct, incorrect, and non-responses performed, (2) the speed of acquisition, and (3) the frustration-related behaviours observed.

2. Materials and method

2.1. Subjects

A total of 24 pet dogs were recruited through email and word of mouth from the local area. However, only eight dogs met the requirements to move onto the final stage of the study in the allotted time (see below). Therefore, only those eight dogs were included in our analyses. The majority of the dogs recruited came from students and staff at the Roseworthy campus of the University of Adelaide.

Table 1 describes the eight dogs compared in this study. Ages ranged between one and eight years old and breeds consisted of a mixture of pure bred and crossbreeds. Each dog came to the Roseworthy campus of the University of Adelaide for training sessions of two hours and were returned to their owners at the end of the session. To be included in the study, dogs had to be motivated to work for food, however owners were not asked to abstain from feeding their dog. The dogs needed to be capable of working in new environments away from their human. Dogs were excluded if they showed any signs of anxiety-related behaviours (e.g., whining; non-responsiveness) that did not dissipate after 30 min of being in the room and prior to training. They were also excluded if they were easily distracted by outside noises or were not able to learn a nose touch to a target within two days of training. Any excluded dogs were not included in the current analyses.

2.2. Apparatus

Fig. 1 details the three areas involved in testing the dogs. The dog and an assistant stood in the waiting area between each trial (see procedure below) while Researcher 1 (R1) set up the next trial. To move into the testing area for a new trial, the dog was released through a gate into the corridor connecting the waiting and testing areas. The set up for the testing area was modified from Heckler et al. (2014) to prevent the dogs from using human body language to guide them. R1 was situated behind a black plastic sheet with two flaps allowing them to reach through to place or remove stimuli between trials. Treats were dispensed through a Treat & Train® Remote Reward Dog Trainer (Yin et al., 2008) placed at the bottom of the plastic sheet. The treats used were Aussie Pet Treats® chicken and lamb training treats remotely dispensed by R1. A GoPro® HERO4 (Camera 1 in Fig. 1a) was attached to the top of the screen and connected to a laptop that allowed R1 to observe when the dog had touched the stimulus. A Sony® HDR PJ10 video camera (Camera 3 in Fig. 1a) and JVC Everio® camcorder (Camera 2 in Fig. 1a) were set up at the back left and side left of the testing area to record all behaviours displayed by the dogs during the training.

The stimuli used for the study were circles of color (Fig. 1b). These were used to mimic Terrace's (1963a) errorless learning procedure with pigeons, which used red and green stimuli. Since dogs do not see red and green well, blue (wavelength: 464.2 nm) and yellow (wavelength: 570.47 nm) were used (Neitz et al., 1989). The circles were mounted on a wooden stick which fit into wooden cubes on the floor on either side of the feed bowl.

Dogs were quasi-randomized into two training methods: Errorless Learning (EL) or Trial-and-error (TE) groups. The quasi-randomization was balanced based on age and breed across the two groups.

2.3. Procedure

Training and testing occurred over 3-4 days. Each day consisted of a 2-h session, where each dog performed a mean of 6.8 (range: 1 - 15) sessions ranging between 1 and 12 min, depending on the stage of training. In between each session, the dogs received a break which ranged between 2 and 30 min, depending on how much training the dog had already done that day as well as their presumed motivation to enter another session (e.g., short latency to return to the experimenter).

Each training method (TE and EL) had three identical stages: (1) Food Approach (2) Object Approach, and (3) Discrimination Acquisition. In addition, EL had an extra stage, (2.5) Stimulus Fading, between the Object Approach and Discrimination Acquisition stages. During the Stimulus Fading and Discrimination Acquisition stages, three behaviours were recorded: incorrect, correct, and non-

Table 1
Information about the dogs in the study that made it through to the Discrimination Acquisition stage of trials.

Dog	Age (years)	Breed	Sex	Method Allocation	Color Allocation
Riley	5	Australian Shepherd	Female	EL	Y
Millie	8	Labrador x Cocker Spaniel	Female	TE	B
Tilly	6	Whippet x Border Collie	Female	EL	Y
Riley	1	Border Collie	Female	EL	B
Rocky	7	American Staffordshire	Male	TE	Y
Paddington	2	Golden Retriever	Male	EL	Y
Bella	5	Labrador	Female	TE	B
Penny	4	Border Collie	Female	TE	Y

Note. EL = Errorless Learning group, TE = Trial-and-error group, Y = Yellow, B = Blue

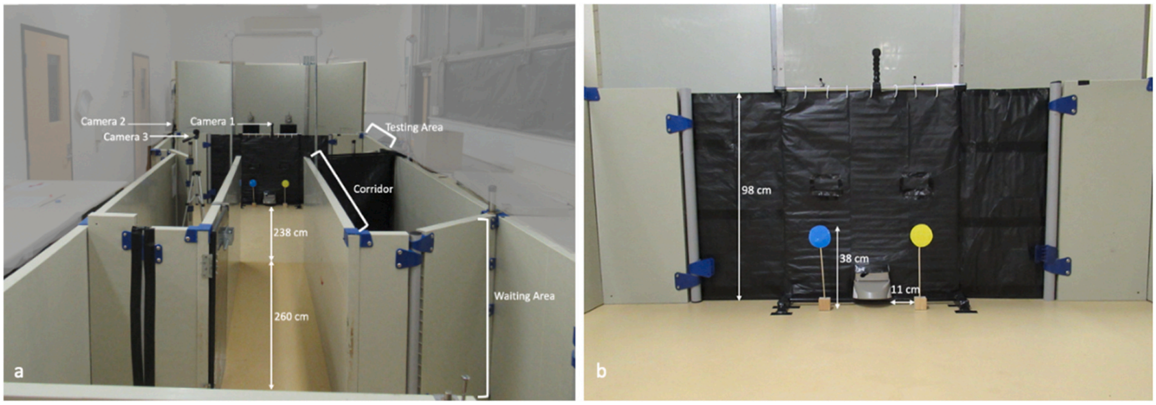

Fig. 1. Photos of the set up. (a) All three areas where the dogs moved to and from. (b) View from what the dogs can see.

responses (described below) and all sessions were recorded for observation of frustration-related behaviours.

2.4. *Food approach*

Each dog was habituated to the treat dispenser, including if necessary to the sound of food being released. Each dog varied in how many sessions they took and what occurred in each session depending on how they reacted to the dispenser and how long they took to be conditioned (range 1 – 6 sessions). However, the general procedure involved the dog entering the testing area while R1 released treats randomly into the bowl for 2 min. Criteria for the dog to move to the next stage was a consistent head turn towards the sound of the feed dispenser, no retreat from the dispenser, and eating the treat each time.

2.5. *Object approach*

Before the dogs could start the Discrimination Acquisition stage, they were taught how to signal a choice. A choice was made when a dog touched its nose to either of the circles and was reinforced via a continuous (fixed-ratio 1; FR-1) reinforcement schedule. During this stage, both colored circles were equally presented, and contacts reinforced to avoid acquiring any stimulus preferences. Only one circle was present during each attempt. During this phase the dogs had to learn to:

1. Touch their nose to the circle to earn a reinforcer (see Fig. 2).
2. Return to the waiting area.
3. Perform the task with no human visible to them.

2.6. *Stimulus fading*

Fig. 3 details the Stimulus Fading stage used for the EL group, which occurred between the Object Approach and Discrimination Acquisition stages. The procedure was modified from Terrace (1963a) and occurred over five sessions of 10 trials each session. Dogs were randomly allocated blue or yellow as their correct stimulus (S+) to limit bias towards one color. In the first session, only the S+ was present. Following this session, the incorrect stimulus (S-) was faded in and simultaneously presented with the S+. From the third to fifth sessions, the S- was gradually faded in from 20 % brightness to equal brightness with the S+. Reinforcement was delivered on a continuous schedule. The stimuli were randomly positioned (left or right) from trial to trial, however the S+ only appeared consecutively on one side a maximum of three times in a row. To prevent dogs from developing a positional bias, the S+ was presented equally on left and right sides within a session.

During the Stimulus Fading stage, the dogs had 3 min to make a response. The number of errors and the latency to decide from when they entered the corridor were recorded.

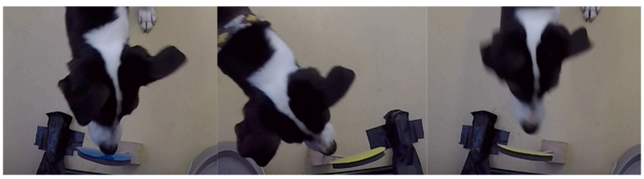

Fig. 2. Images depicting criteria for determining a choice. Images 1 to 3 moving from left to right. 1 and 2 indicate a choice, 3 is no choice.

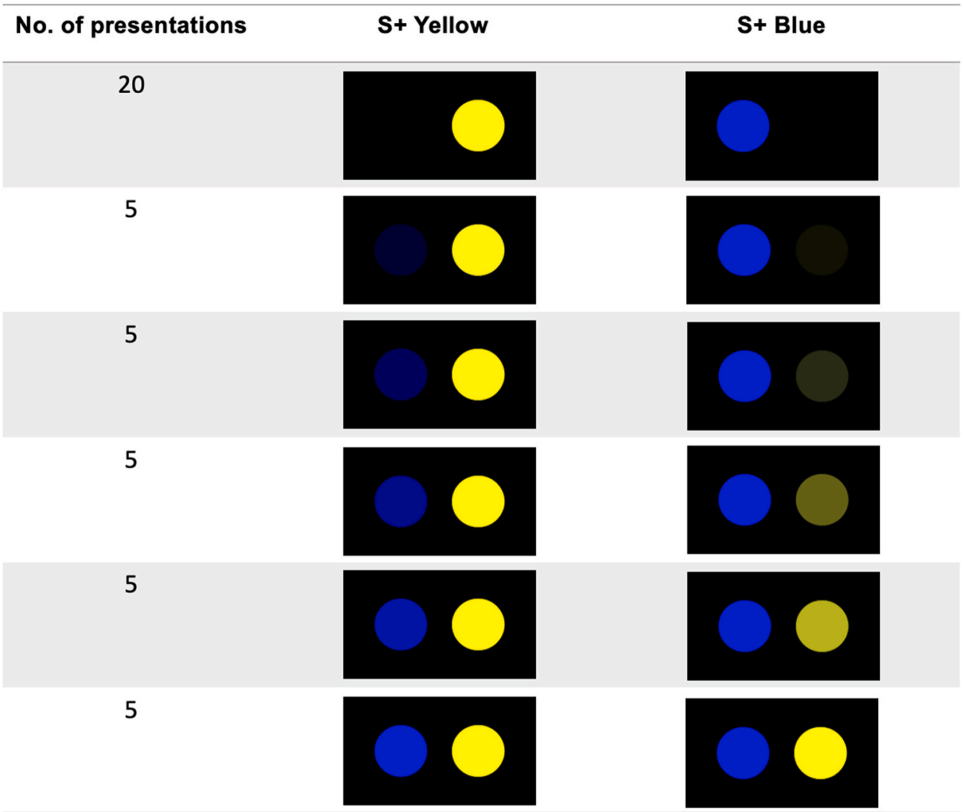

Fig. 3. Stimulus fading progression with either the blue or yellow color as the S+. After the first 20 presentations of the S+ alone, the S- was faded in from 20 % brightness to 100 % brightness over 5 sessions.

2.7. Discrimination acquisition

This stage was the same for both groups and consisted of sessions of 10 trials. The EL group began after they had completed the five Stimulus Fading sessions while the TE group began once they had reached the Object Approach stage criterion. The S+ and S- were presented concurrently at equal brightness and dogs had 30 s from the time they entered the corridor to make a choice. If they chose S+, a treat was dispensed on a continuous reinforcement schedule, and the stimuli removed. If they chose S-, R1 removed the stimuli and signaled an incorrect choice to the assistant before the dogs could make another choice. If the dogs made no response for 30 s, R1 signaled no response to the assistant, the stimuli were removed, and the trial was labeled as 'non-response'. For each situation, the assistant would retrieve the dog and lead them back to the waiting area. Discrimination Acquisition stage sessions continued until one of three of the following events occurred:

1. The dog reached learning criterion, which consisted of choosing S+ 8 out of 10 trials on three consecutive sessions.
2. The dog stopped responding.
3. The dog did not reach learning criterion within a four-day period.

The criterion for not responding was as follows: If a dog gave three non-responses consecutively in a session, the session was terminated, and there was a five-minute break in the study, before commencing the next trial. If this occurred in three consecutive sessions, any further testing for that day was terminated. On the next day, if in the first session, the dog again made three consecutive non-responses, the dog was considered to have stopped responding. However, if the dog completed the first session, three more sessions of three consecutive non-responses was required for the dog to be considered not responding.

In some cases, a dog would refuse to enter the corridor when the gate opened. In this case, R1 would call the dog forward a maximum of three times. If the dog still refused to enter, the session was terminated. As with non-responses, if this occurred in three consecutive sessions, and one session on the next day, the dog was considered to have stopped responding. However, this event was not recorded as a non-response as the dog had not entered the testing area.

2.8. Frustration-related responses

Table 2 details a list of behaviours modified from Hallett (2014), that were considered to be frustration-related responses. Frustration-related responses were operationally defined as any behavior that interfered with a dog making a choice and that lasted less than 30 s (a 30 s break was labeled 'non-response'; see Discrimination Acquisition section above). During each trial, a frustration response was recorded for each occurrence and could occur multiple times in the form of any of the aforementioned behaviours listed in Table 2. All occurrences (events) of frustration-related responses were measured for a given session, in absence of any measurement of the duration (state) of the response or any interval of occurrence (Altmann, 1974; Brereton et al., 2022). Frustration-related behaviors were only measured during a session, and thus counted by total number of occurrences per session.

2.9. Statistical analysis and interobserver agreement

Statistical analysis was performed using IBM SPSS® Statistics 27. All behavioural response data were compared across groups (EL versus TE), with the number of individuals multiplied by the number of sessions providing the sample size per group. Statistical analyses were conducted for the first eight Discrimination Acquisition stage sessions, since only one dog between both groups remained beyond eight sessions. The variables included in analyses were correct, incorrect, non-responses, and frustration-related responses, which were compared across groups.

Since there were differences between sample size for individuals, an independent samples *t*-test was used for comparison between treatment groups. All tests were analyzed for homogeneity of variance (Levine's test) and normality (Shapiro-Wilk test). Only one comparison, the correct responses measure, passed both tests. All other comparisons (incorrect, frustration, and non-responses) were made using the nonparametric version of a *t*-test, a Mann-Whitney *U* test. Four comparisons were run simultaneously; therefore, a Bonferroni correction was performed to reduce the chance of Type I errors, with the significance level set as $p < 0.0125$ (.05/4).

Interobserver agreement (IOA) between two independent observers was calculated based on total agreement (Poling et al., 1995) of 16 (31 %) of all sessions. Total agreement of all measures was 88.5 % (12 sessions above 90 %).

3. Results

Of the eight dogs that made it to the Discrimination Acquisition stage of the study, three dogs from the EL group and one dog from the TE group reached the learning criterion with a mean of 10.8 sessions (range: 4 to 23 sessions). Of the four dogs that did not reach learning criterion, two dogs stopped responding and two dogs did not reach learning criterion within four days. Sixteen dogs were not able to reach the final Discrimination Acquisition stage. Reasons for not reaching the final stage included dogs refusing to take or consume treats, showing signs of fear- or anxiety-related behaviours (e.g., panting; trying to leave the testing area) that interrupted performance, and not learning the object approach response within the allotted time.

3.1. Group comparison

Within the first 8 Discrimination Acquisition stage sessions, the EL group completed a total of 279 trials while the TE group completed a total of 197 trials. This difference was due to when dogs stopped responding or when they had already met the learning criterion.

Fig. 4 describes the comparison between groups for mean correct and incorrect responses per session, including the overall number of responses (Fig. 4b). Within each group the correct and incorrect responses were not direct inversions of each other as non-responses were also considered later in the results. Dogs in the EL group made significantly more correct responses per session ($M = 5.704$, $SE = 0.455$) compared to the TE group ($M = 3.375$, $SE = 0.570$) ($t_{49} = 3.222$, $p = 0.003$). While the difference between incorrect responses per session for the EL ($M = 4.296$, $SE = 0.420$) and TE ($M = 2.958$, $SE = 0.448$) groups did not reach significance ($U = 216.00$, $n_{EL} = 27$,

Table 2
Behavioural ethogram for frustration-related responses.

Behaviour	Definition
Yawn	When the dog stretched open its mouth in a prolonged inhalation of air.
Whine	A high-pitched cry or series of cries made when the dog's mouth is closed.
Bark	An abrupt, explosive cry or series of cries made by the dog.
Moving away/distracted	Retreats to the back of the testing area or into the corridor and/or performs irrelevant activities continuously.
Sniff	When the dog places its snout onto a surface other than the target stimuli for at least 2 s.
Sit	When sitting on its hind leg quarters and legs.
Lip lick	When the tongue extends outside the mouth onto lip or nose, but not after having food.
Scratch	Use of the back legs to scratch the body.
Lying down	Dog moves from a sitting/standing position into a horizontal position.
Frozen	When the dog remains in the same location for a period longer than 2 secs with very little movement, so appears frozen.
Scratch at feed dispenser	When dog moves to feed dispenser when no food has been dispensed and uses paws to scratch at dispenser.

Note. Detailed list of behaviours the dogs could present as a frustration-related response, including the operational definitions for each behaviour used for coding.

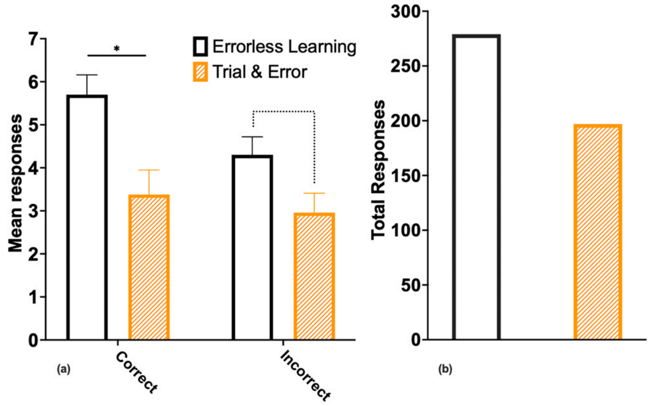

Fig. 4. (a) Comparison of the mean correct and incorrect responses per session seen between dogs in the errorless (EL) and trial & error (TE) groups. (b) Comparison of the total responses each group gave. The solid line and * indicates a statistically significant result (p < 0.0125). Error bars represents the standard error of the mean. The ··· line indicates an effect that approaches significance (p < 0.05).

$n_{TE} = 24$, $p = 0.039$), it did approach significance as it was below $p < 0.05$ before the Bonferroni correction.

Table 3 describes the comparison between groups for incorrect, non-response, correct and total responses. The EL group had a higher response total (279) than the TE group (197). While the percentage of incorrect responses was higher in the EL group (41.6 %) compared to the TE group (36.0 %), when incorrect and non-responses percentage was added together, the TE group had a higher combined percentage (58.8 %) than the EL group (44.8 %).

Fig. 5 describes the mean frustration responses and non-responses per session of the EL and TE groups. The EL group produced significantly fewer frustration responses ($M = 1.630$, $SE = 0.385$) ($U = 543.500$, $n_{EL} = 27$, $n_{TE} = 23$, $p < 0.001$) and non-responses ($M = 0.333$, $SE = 0.131$) ($U = 507.000$, $n_{EL} = 27$, $n_{TE} = 24$, $p < 0.001$) compared to the TE group ($M = 8.783$, $SE = 1.076$; $M = 1.875$, $SE = 0.342$, respectively).

Fig. 6 details the changes in mean correct and frustration-related responses over the first 8 discrimination sessions compared between EL and TE. The EL group increased in the number of correct responses over the eight sessions while the TE group maintained correct responses at around four per 10 trials with little change over sessions. Frustration-related responses were lower and decreased for the EL group over the sessions whereas the TE group have a higher frequency of frustration-related responses, and this increased from session 5.

3.2. Individual comparison

Fig. 7 describes the unique pathway of each dog over a maximum of 8 discrimination sessions. Within the eight sessions one dog from each group met learning criterion (Riley_AJ and Penny), with two dogs from the EL group (Riley_HM and Tilly) meeting learning criterion at more than 8 sessions. The dogs in the EL group mostly produced five or more correct responses whereas the dogs in the TE group mostly produced five or less correct responses. In both groups there was one dog that stopped responding: Paddington in the EL and Milly in the TE group. In both cases the dogs stopped responding in four sessions. Paddington started to refuse to enter the testing area after he made several errors and was not receiving a high rate of food. Milly never gave a correct response and was considered non-responsive after three consecutive sessions.

For the overall number of sessions, Tilly took 23 sessions before reaching criterion. During these sessions, on two occasions she made 8 out of 10 correct responses on two consecutive sessions but then failed to meet this on the third attempt. Rocky in the TE group also went through 20 sessions. However, he started with low correct responses and almost reached the criterion for terminating the study based on non-responses but began to make many more correct responses from session 9 to 16. From session 17 his correct responses began to decline to below 5 correct.

Table 3
Comparison of responses from the errorless learning (EL) and trial-and-error (TE) groups. Percentage of total responses are in brackets.

	Incorrect responses	Non-responses	Correct responses	Total responses
Errorless learning	116 (41.6 %)	9 (3.2 %)	154 (55.2 %)	279
Trial-and-error	71 (36.0 %)	45 (22.8 %)	81 (41.2 %)	197

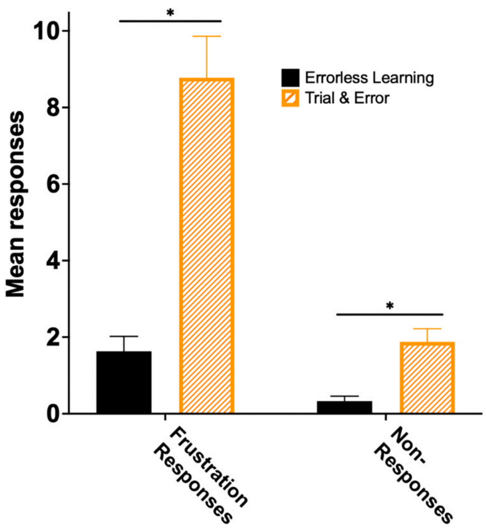

Fig. 5. Comparison of mean frustration responses and non-responses per session between dogs from errorless learning (EL) and trial & error (TE) groups. The solid line and * indicates statistically significant results ($p < 0.0125$) and error bars represent the standard error of the mean.

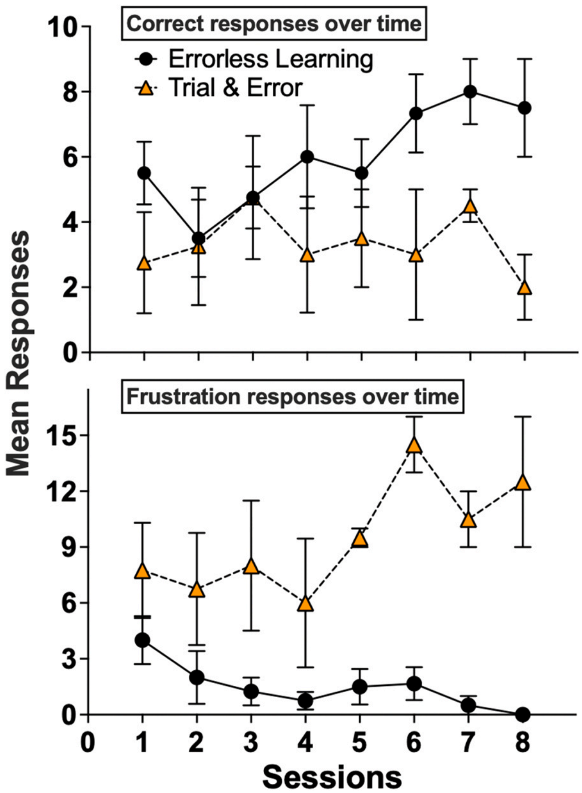

Fig. 6. Comparison of mean correct responses (top) and frustration responses (bottom) over the first 8 Discrimination Acquisition stage sessions. Error bars represent the standard errors of the mean.

4. Discussion

4.1. Correct responses and speed of acquisition

Overall, the dogs from the Errorless Learning (EL) group produced significantly more correct responses compared to the Trial-and-

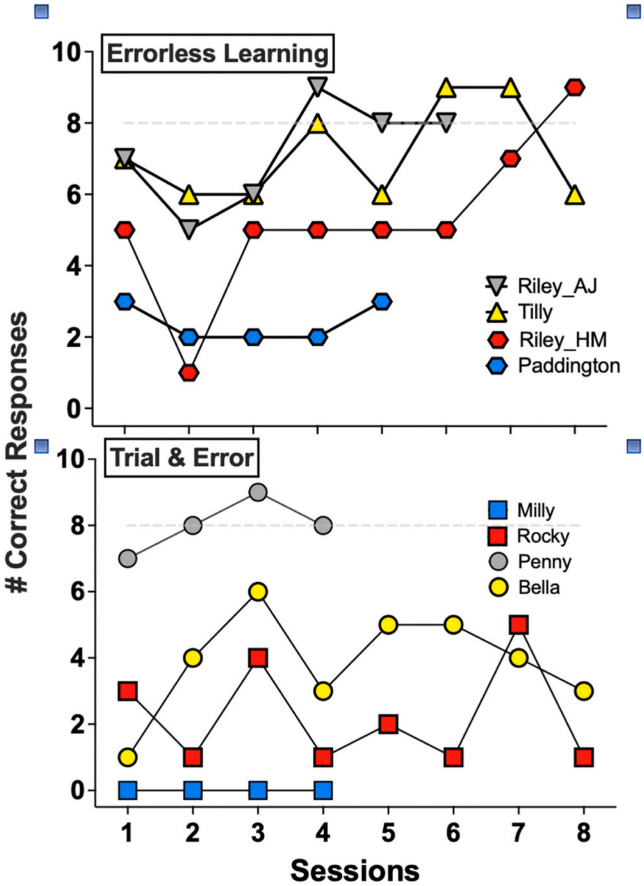

Fig. 7. Individual correct responses for errorless learning (EL, top) and trial & error (TE, bottom) groups over the first 8 Discrimination Acquisition stage sessions. The faded dotted lines represented 8 out of 10 correct which was the learning criterion.

Error (TE) group. The EL dogs also increased the number of correct responses produced over the first eight Discrimination Acquisition stage sessions while the TE group plateaued at a low level of correct responses through the same sessions, suggesting that EL allows for faster acquisition of the discrimination. Both these results indicate that as with pigeons (Terrace, 1972), the use of an errorless learning fading procedure may be more effective in training dogs stimulus discriminations.

4.2. Individual differences

A number of individual differences for the correct responses and speed of acquisition were observed for the dogs in both groups (see Fig. 7). For instance, in the TE group, Penny showed both a higher total number of correct responses, as well as a faster speed of acquisition, while in the EL group, Paddington showed a lower total number of correct responses and no change in their number of corrects over time. While it is possible that the individual differences observed could be related to age, sex, or breed, such assessments are beyond the scope of our design. However, future assessments of errorless learning procedures could focus on potential individual differences and their correlation with subject characteristics, particularly if they were assessed using between-subject methodology (i.e., larger sample size studies).

4.3. Frustration-related responses

There was a significant difference in the number of frustration-related responses displayed between groups, with the dogs in the EL group producing significantly fewer responses than the dogs in the TE group. This suggests that the TE group may have resulted in poorer welfare during training compared to the EL group, as frustration is an indication of a negative affective state (Jeronimus & Laceulle, 2020). Non-responses were also seen significantly more in the TE group compared to the EL group. Animals may perform fewer responses, such as not responding to discriminative stimuli, in order to reduce negative affective states (Chance, 2013). As the TE group showed more frustration responses, the observation of greater non-responses further supports the idea that the TE group had a more negative affective state than the EL group. Thus, the reduction in frustration-related responses may be one of the most important outcomes of this comparison, particularly as it relates to dog training methods.

4.4. Errorless learning reduces but does not remove frustration

As discussed in the introduction, previous research showed variation in what caused frustration-related responses while learning a discrimination. Some researchers have suggested that it is the errors themselves that produce the frustration-related responses (Azrin et al., 1966; Terrace, 1972), and thus errorless learning produces fewer errors and fewer frustration-related responses. However, more recent research has defined frustration as a negative emotional state experienced when an expectation is not met (McPeake et al., 2019), such as when an animal is prevented from obtaining a resource, or when a previously reinforced behaviour is then put on extinction. This explains why in the current study and Rilling and Caplan (1973) frustration-related responses were seen when an errorless learning procedure was used, as any incorrect response made by the animals could be a violated expectation. However, Rilling and Caplan failed to conduct a direct comparison of frustration-related responses during an errorless learning procedure to a trial-and-error method. The current study showed lower frustration-related responses in the dogs in the EL group, so although the frustration was not completely removed, it was significantly reduced. As noted above, this reduction may be one of the most critical findings of this study, as it suggests that the use of errorless learning may reduce negative affective states during training.

4.5. Study differences in incorrect responses

As mentioned above, dogs in the EL group made significantly more correct responses than the TE group, and this reflects results seen in pigeon and human studies comparing errorless learning and trial-and-error discrimination procedures (Arantes & Berg, 2009; Robinson & Storm, 1978; Terrace, 1963a). However, the number of incorrect responses made by the EL group in the current study differed from these studies. Pigeons produced on average 0 % to 3 % incorrect responses (Arantes & Berg, 2009; Terrace, 1963a) while children produced on average 3 % incorrect (Robinson & Storm, 1978). In comparison, the current study found the dogs in EL group averaged 40 % incorrect responses and made more incorrect responses than the TE group. A possible explanation for why the dogs appeared to make more errors than the TE group is because the total number of responses for the EL group was higher than the TE group (see Fig. 4b and Table 3 for comparison), and therefore the EL group simply had more attempts where an error could be made. Also, the percentage of incorrect and non-responses when combined was higher in the TE group compared to the EL group (see Results and Table 3). As for the larger number of incorrect responses compared to other research, the potential reason for this difference is the lack of a correction procedure through the Stimulus Fading stage, which was used in all the previous research. Therefore, the dogs in this study had fewer presentations at each fading stage before beginning stimulus discriminations. Terrace (1963a) also had 13 steps to introduce the brightness of the S- whereas this study only had five steps for the same fading procedure. Thus, smaller fading steps may have increased overall performance and reduced incorrect and non-responses observed in both groups.

4.6. Effectiveness of errorless learning

Despite the larger number of incorrect responses observed in the EL group of this study, the dogs still learned the discrimination faster than the dogs of the TE group (see Fig. 6). In pigeon errorless learning studies (Arantes & Machado, 2011; Terrace, 1963a), similar results were seen as pigeons trained with a fading procedure learned significantly faster than the trial-and-error trained pigeons. There were differences between the errorless learning groups of each study as the dogs from the EL group of the current study took less time than both EL groups in the pigeon studies. These differences may reflect the learning abilities of distinct species and the difficulty of the task, as one of the pigeon studies required the pigeons to learn a potentially more difficult conditional temporal discrimination (a context- and time-based stimulus discrimination; Arantes & Machado, 2011). Thus, both task and species involved in such experimental procedures should be taken into consideration. However, as in all studies, the errorless learning groups learned faster, and therefore the fading procedure can be suggested as a more effective method.

4.7. Limitations in design

As mentioned in the Method, only eight of 24 dogs (33 %) reached the final Discrimination Acquisition stage of the study. Of the 16 dogs that did not reach the final stage, as well as some of the eight dogs that did not complete this stage, some were not motivated by the food option that was used. While several different treats were evaluated in preliminary food deliveries prior to the study, the automated dispenser used for the research was limited to dry kibble. Future research could use a more quantitative process for selecting treats, such as systematic preference assessments (e.g., paired-choice presentations), which have been effective in selecting potential reinforcers for applied animal behavior research and practice purposes with canines (Feuerbacher et al., 2022; Payne et al., 2023; Protopopova et al., 2016; Vicars et al., 2014; Waite & Kodak, 2023), as well as in other applied animal settings, such as zoos (Fernandez et al., 2004; Fernandez & Timberlake, 2019; Slocum & Morris, 2022; Woods et al., 2020). Other research has shown that providing multiple types of rewards over time will maintain motivation in dogs (Bremhorst et al., 2018) and incorporating this into the process could have potentially kept the dogs responding for longer periods.

The study was also limited by time availability to train each dog, which meant that dogs that were slower to learn the Food and Object Approach stages could not reach the Discrimination Acquisition stage. To improve this for future research, ensuring that the dogs already had an adequate level of training through pre-training or excluding dogs that did not have a specific level of training could improve performance and the number of dogs that could be tested (Marshall-Pescini et al., 2016). In addition, increasing the potential reinforcing/enriching properties of the training tasks (e.g., involving scent work for the stimulus discrimination) could increase the number of individuals that complete the task, as well as provide an improved assessment of canine welfare (Fernandez, 2022).

Finally, previous studies using pigeons (Arantes & Machado, 2011; Rilling & Caplan, 1973; Terrace, 1963a; Terrace, 1963b) were completed in laboratory settings, which itself provides greater control over external variables, such as competing reinforcers or external stimuli. For instance, some of the testing setup we used included screen fasteners that were similarly colored to the stimuli used in the study (see Fig. 1), and could have distracted the dogs from the test stimuli themselves. While testing dogs outside of laboratory settings may limit the experimental control achieved, it also provides greater generality by evaluating a new species under more natural conditions. Examinations of errorless learning in less contrived, more applied conditions should be considered a valuable method for testing learning procedures, particularly as they relate to modern training practices.

5. Conclusion

The overall results of this study suggested that an errorless learning procedure has a positive impact on the welfare of dogs during the learning process of a discrimination acquisition, as well as allowing dogs to learn more effectively. The benefits of these findings include providing dog trainers with a clearer protocol for implementing errorless learning procedures, including how to properly define such procedures, as well as demonstrating potential benefits of using the method. There is little previous research using a fading procedure for training dogs and no studies compared errorless learning with other training methods. Therefore, these results provide a foundation for future research in dogs. For instance, studying how fading procedures can be implemented with other types of stimuli, such as scent or sound, or with different tasks. Training is a key part of any relationship with an animal that lives and works with humans, so the benefits of continuing research in this area will help improve the effectiveness of training for dogs and other species as well.

Data availability

Data will be made available on request.

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