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### Authors

Ng, Kelly
Narula, Aayush
Powers, Alice S.

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# Stimulus Generalization in Painted Turtles (*Chrysemys picta*)

**Aayush Narula*, Kelly Ng*, and Alice S. Powers**

***Department of Psychology, Stony Brook University, NY***

Stimulus generalization is a phenomenon in which an animal that is trained to respond to one specific stimulus exhibits a similar but not an identical response when presented with a new similar stimulus. It has been widely demonstrated across a variety of vertebrates. This study investigated stimulus generalization in Western painted turtles (*Chrysemys picta*), a phenomenon previously rarely studied in turtles. Three turtles were initially trained to criterion in an automated Skinner box on a discrimination task between vertical and horizontal lines. Reward was beef baby food, pumped from a syringe pump. Analysis of the criterion days showed a significant difference between the latencies to the reinforced and unreinforced stimuli, indicating successful discrimination. Following this training, the turtles were tested for stimulus generalization using lines of seven different orientations (from 0 degrees to 90 degrees in 15 degree increments), involving 20 days of testing. The results revealed that response latency varied with the line's orientation. The fastest latencies were observed for the previously reinforced stimulus and the slowest for the previously unreinforced stimulus, with intermediate response times for the novel intermediate stimuli. This graded pattern formed a generalization gradient, which was best fit by an exponential function ($R^2 = 0.96$). These findings suggest that painted turtles are capable not only of discriminating visual stimuli but also of exhibiting typical stimulus generalization.

*Keywords*: discrimination, generalization gradient, latency, line orientation, reptile

## ニシキガメ(*Chrysemys picta*)における刺激般化

刺激般化とは、ある特定の刺激に反応するようにトレーニングされた動物が、類似した新たな刺激が提示された際に、類似してはいるが同一ではない反応を示す現象である。この現象は、さまざまな脊椎動物において幅広く実証されてきた。本研究は、カメ類ではほとんど研究されてこなかった現象である刺激般化について、ニシニシキガメ(*Chrysemys picta*)を対象に調査した。3 個体のカメは、まず自動スキナー箱を用いた垂直線、水平線の弁別課題において、基準に達するまで訓練された。報酬にはシリンジポンプから供給されるビーフベビーフードを用いた。基準達成日の分析では、強化刺激と非強化刺激に対する反応潜時に有意な差が認められ、弁別に成功したことが示された。このトレーニングに続いて、7 種類の異なる傾きの線（0 度から 90 度まで 15 度刻み）を用いて刺激般化を 20 日間にわたりテストした。その結果、反応潜時は線の傾きによって変化することが明らかになった。最も短い反応潜時は事前に強化された刺激で見られ、最も長い反応潜時は事前に強化されなかった刺激で見られた。新たな中間的な刺激においては中間的な反応時間が見られた。この段階的なパターンは般化勾配を形成し、指数関数（$R^2$=0.96）に最も適合した。これらの知見は、ニシキガメが視覚刺激を弁別できるだけでなく、典型的な刺激般化を示す能力があることを示唆している。

キーワード：弁別、般化勾配、反応潜時、線の傾き、爬虫類

*Both authors contributed equally to this work.

Please send correspondence to Alice S. Powers, Ph.D., Department of Psychology, Stony Brook University, Stony Brook, NY 11794-2500. Email: Alice.powers@stonybrook.edu

## Generalización de Estímulos en Tortugas Pintadas (*Chrysemys picta*)

La generalización de estímulos es un fenómeno mediante el cual un animal que ha sido entrenado para responder a un estímulo específico exhibe una respuesta similar, aunque no idéntica, cuando se le presenta un nuevo estímulo similar. Este fenómeno ha sido ampliamente demostrado en una gran variedad de vertebrados. El presente estudio investigó la generalización de estímulos en tortugas pintadas occidentales (*Chrysemys picta*), un fenómeno que ha sido escasamente estudiado en tortugas. Inicialmente, se entrenaron tres tortugas hasta alcanzar un criterio establecido en una caja de Skinner automatizada, utilizando una tarea de discriminación entre líneas verticales y horizontales. La recompensa consistió en alimento infantil de carne de res, administrado mediante una bomba de jeringa. Un análisis durante los días correspondientes al criterio mostró una diferencia significativa entre las latencias de respuesta a los estímulos reforzados y no reforzados, lo que indicó una discriminación exitosa. Tras este entrenamiento, las tortugas fueron evaluadas en una prueba de generalización de estímulos utilizando líneas con siete orientaciones diferentes (desde 0° hasta 90°, en incrementos de 15°), a lo largo de 20 días de evaluación. Los resultados mostraron que la latencia de respuesta varía en función de la orientación de la línea. Las latencias más cortas se observaron para el estímulo previamente reforzado y las más largas para el estímulo previamente no reforzado, mientras que los nuevos estímulos intermedios produjeron tiempos de respuesta también intermedios. Este patrón gradual se relacionó con un gradiente de generalización, que se describe de manera óptima mediante una función exponencial ($R^2 = 0,96$). Estos hallazgos sugieren que las tortugas pintadas no solo son capaces de discriminar estímulos visuales, sino también de exhibir patrones típicos de generalización de estímulos.

*Palabras clave*: discriminación, gradiente de generalización, latencia, orientación de línea, reptil

Stimulus generalization is a phenomenon in which organisms trained to respond to one stimulus respond to similar stimuli in a similar but not identical way (Ghirlanda & Enquist, 2003). This ability is critical for survival in natural environments, as it allows animals to apply learned associations—such as identifying prey or avoiding predators—to novel but related encounters. Their behavior demonstrates not only that they recognize the similarity but also that they recognize a difference. Without the capacity to generalize, an organism would treat every subtle environmental variation as an entirely new learning task, which is inefficient. Furthermore, stimulus generalization is not an isolated skill but serves as a foundational ability that underlies more complex cognitive processes, such as category formation and decision-making. By recognizing that different stimuli belong to a common class, organisms can navigate their environment with greater flexibility, using generalization as a prerequisite for survival-based judgment and behavioral adaptation (Ghirlanda & Enquist, 2003).

Ivan Pavlov first identified the phenomenon of stimulus generalization in dogs (*Canis familiaris*) (Pavlov, 1927), and he measured drops of saliva, an amplitude measure. Subsequent researchers have demonstrated that stimulus generalization occurs in a wide variety of vertebrates in addition to mammals, including fishes (Dailey & Braun, 2011; Fay, 1970; Watanabe, 2024; & Bitterman, 1965) and birds (Hearst et al., 1964; O'Donoghue et al., 2020; Powers et al., 1983; Schneider & Kicliter, 2009; Soto & Wasserman, 2010). These studies have investigated many different stimulus dimensions, including the dimension we used here, line orientation (Hearst et al., 1964; O'Donoghue et al., 2020; Powers et al., 1983). They also studied auditory tempo generalization (Schneider & Kicliter, 2009), wavelength generalization (Yarczower & Bitterman, 1965), and auditory frequency generalization (Fay, 1970), among others. These studies have typically used amplitude measures, such as rate of response.

Stimulus generalization studies are rare in reptiles. In a study of turtles by Leighty et al. (2013), the authors used brightness differences to investigate discrimination and transposition in eastern box turtles (*Terrapene carolina*); they did not report stimulus generalization gradients. A recent study investigated response bias in red-footed tortoises (*Chelonoidis carbonaria*) and used generalization of spatial location as a method (Hoehfurtner et al., 2025). The tortoises were trained in a discrimination between two spatial locations, one reinforced, one not, and then tested on intermediate locations. Clear evidence of generalization was found: the tortoises showed latencies slower than the latency to the positive location and faster than those to the negative location in choosing the intermediate locations. The purpose of this study was to demonstrate individual differences in the intermediate latencies as a function of anxiety (measured by response to novelty).

They found that turtles that were more anxious (more reluctant to approach a novel stimulus or environment) were also slower to respond to some of the intermediate locations.

Turtles occupy a unique phylogenetic position, having diverged early within the amniote lineage. As a sister group to the archosaurs (crocodilians and birds) (Crawford et al., 2012; Rieppel, 1999), they provide a vital model for understanding the evolutionary origins of cognitive traits shared by reptiles, birds, and mammals. However, the reptilian class remains largely underrepresented in the comparative literature. Based on documented neophilic tendencies in fish (Bensky & Bell, 2020; Fior et al., 2018; Franks et al., 2023) and birds (Damphousse et al., 2024, 2025; Lendvai et al., 2011**)**, we predict that turtles will likewise exhibit a systemic, graded pattern of response to novel orientations. Such a finding would suggest that the pressure to recognize commonalities across varied environmental stimuli is a universal requirement for vertebrate fitness.

In the present study, we extended the investigation of stimulus generalization to painted turtles (*Chrysemys picta*) and obtained generalization gradients on a line orientation task for 3 turtles. Line orientation has been used to study stimulus generalization in pigeons (e.g., Hearst, et al., 1964; Powers, et al., 1983). In addition, we used a unique measure: latency to respond. This measure is rarely used but has been shown to be comparable to a measure of rate of response in goldfish (Yarczower & Bitterman, 1965). We trained turtles on a discrimination between a vertical and a horizontal line and then tested them on their latency to respond to lines of different orientations. Our hypothesis was that response latency would form a "generalization gradient," where the fastest responses occur for the training stimulus and progressively slow as the test stimuli become less similar.

In earlier learning theories (e.g., Hull, 1943; Spence, 1937), a great deal of discussion took place over the shape of generalization gradients. Whether the gradient fit an exponential or Gaussian function affected theorists' predictions about generalization behavior (Ghirlanda & Enquist, 2003). We investigated which distribution better fit our findings and found that they fit an exponential function.

## Method

### Ethical Statement

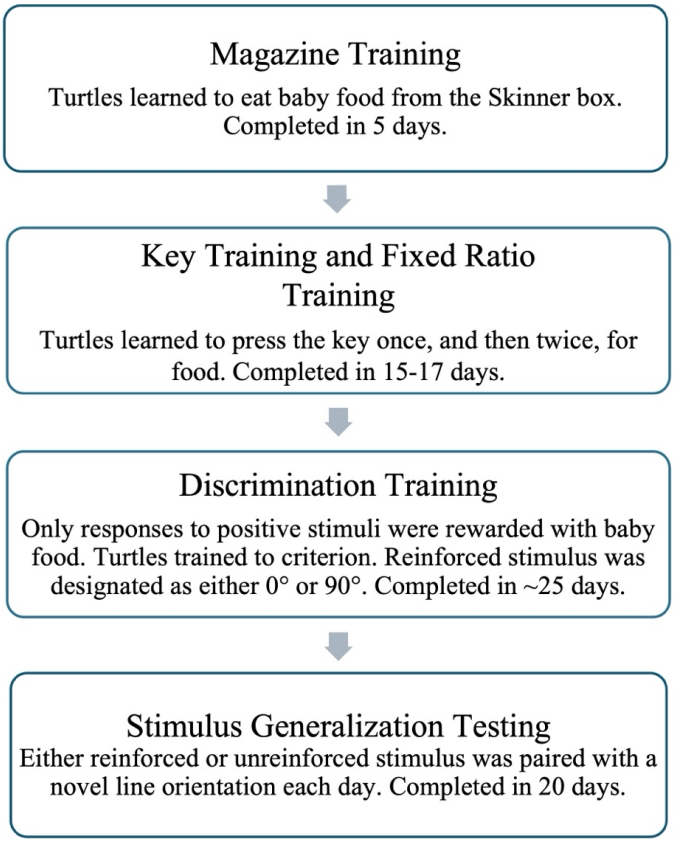
This study was approved by the Institutional Animal Care and Use Committee of Stony Brook University (protocol #335685) and complied with all Federal, State, and University regulations regarding the use of animals in research.

### Subjects

Three western painted turtles (*Chrysemys picta*) were run in the experiment. Turtles were wild-caught and acquired from Marc Cantos Reptiles in Fort Myers, FL; age was unknown, but all were adults. Although sex of the individual animals used here was not recorded, we obtain turtles of both sexes in each shipment. They were housed individually in white plastic tanks (45 × 37 × 19 cm) with a gray slatted plastic platform (15 × 34 $cm^2$ in area and 7 cm high), filled with tap water 5 cm deep. The room in which they were housed was kept at 27-29 $^{o}$ C. with an automatic light schedule that was on for 14 h a day, to prevent estivation during the winter. Our standard feeding regimen in the colony is turtle pellets (Maduri) three times per week, supplemented by pieces of fish once per week. During the experiment, the turtles received half their daily ration in the experimental chamber (5 ml Beechnut baby food) and were fed an additional 5 mL of beef baby food each day 30 min after testing. They were not fed pellets or fish during the experiment. Cages and platforms were changed and autoclaved three times per week, after feeding.

**Figure 1**

*The Design of the Experiment is Displayed*



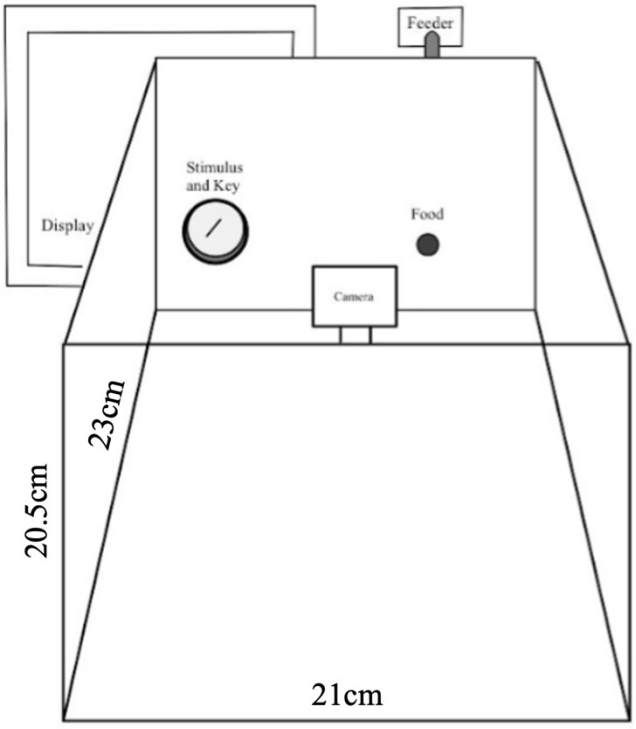

*Note.* The objective was to train turtles to discriminate between horizontal and vertical lines. Following achievement of criterion, they were tested for stimulus generalization.

**Apparatus**

The experimental chamber was made of watertight black Plexiglas and measured 21.0 × 23.0 cm in length and width, and 20.5 cm in height. On the front wall were a response key on the left and a food magazine on the right (Figure 2). The response key, 3.3 cm in diameter, was located 3.5 cm from the left wall and 2.0 cm from the floor. A computer screen mounted behind the panel presented the stimuli. The feeder opening was 0.9 cm in diameter, 1.0 cm from the bottom of the panel and 6.0 cm from the right-side wall. The same beef baby food (0.2 mL each time) was delivered through an aperture in the center of the disk, by a rubber tube attached to a 10-mL syringe mounted on a syringe pump. A feeder light was located 3.5 cm above the food opening. Water was added to the chamber to the depth of 4 cm. There was no house light, but the chamber had a translucent lid that allowed light in. A webcam was mounted on the back wall of the chamber, and each session was recorded. The stimuli were lines of different orientations, varying from vertical to horizontal in 15-degree steps (Figure 3).

**Figure 2**

*Experimental Chamber Used to Train Animals and Conduct Experiment*




*Note.* Figure is not drawn to scale.

**Procedure**

***Magazine Training***

The turtles were first pre-trained to eat beef baby food from the feeder for 20 reinforcements per day on 5 consecutive days. The food (0.2 ml per reinforcement) was delivered on a variable schedule that averaged once per minute. When the food was delivered, the feeder light was illuminated for 15 s. Once the animals were eating every reinforcement within the 15-s feeder light interval, they were trained to press a red key one time to receive baby food through the feeder. On the first day of training (and if necessary, on a few days following), a small amount of baby food was dabbed on the response key, to encourage contact. As soon as the turtles were hitting reliably, the key was no longer baited. Twenty reinforcements were available per day, with an intertrial interval of 15 s, and they were trained until they completed 20 reinforced trials in less than 25 min.

The turtles were then trained to press the red key twice on each trial (FR2) for 20 reinforcements per day. Again, they were trained until they completed 20 trials in 25 min or less. This key training stage lasted 15-17 days for each turtle.

***Discrimination Training***

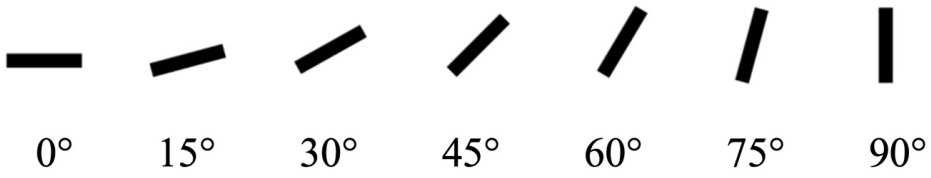
Discrimination training consisted of 10 trials with a vertical line and 10 trials with a horizontal line (0 and 90 degrees in Figure 3), presented in random (Gellermann, 1933) order, for a total of 20 trials per day. One of these was designated as the reinforced stimulus, the other the unreinforced. Two key presses to the reinforced stimulus were rewarded with baby food. Responses to the negative stimulus had no consequence. The reinforced stimulus remained illuminated until the turtle pressed the key twice and received the reinforcement. The unreinforced stimulus remained on for 60 s. Two turtles (#394 and #412) were trained with 90 degrees as the reinforced stimulus and one (#392) with 0 degrees reinforced.

Latencies to the first and second response on the key were recorded on each trial. The turtles were trained to a criterion of a difference of 40 s or more between the median latencies of the first response to the reinforced and unreinforced stimuli within the 20 trials on two consecutive days.

***Stimuli***

**Figure 3**

*The Seven Stimuli Used in Stimulus Generalization Testing*




*Note.* The stimuli consisted of black lines presented at different orientations ranging in 15-degree increments from 0° horizontal) to 90° (vertical). During the generalization phase, the five intermediate orientations (15°, 30°, 45°, 60°, and 75°) were used to evaluate the turtles' response compared to the original training stimuli.

***BrdU Injection Protocol***

Bromodeoxyuridine (BrdU, Sigma), a thymidine analog used to label proliferating cells, was administered to the turtles in this experiment, in the expectation that there would be differences in adult neurogenesis between turtles tested on stimulus generalization and home cage controls not given such testing. The small number of animals used, however, made it impossible to analyze the results of the BrdU experiment, and the results are not reported here. The injections began the day after the turtles reached criterion on the discrimination training. A total of nine injections were administered over 3 weeks, 3 injections per week. Each consisted of 50 mg/kg of BrdU in 1 mL/kg vehicle (80% dimethyl sulfoxide, DMSO, Sigma, and 20% saline). During the first week of injections, no testing was done. During the second and third week, the injections were done 30 min before the stimulus generalization testing. There were no injections during the last 2 weeks of stimulus generalization testing. Injections were given intracelomically (into the body cavity).

***Stimulus Generalization Testing***

One week after the start of the BrdU injections, a series of generalization tests was started, designed to evaluate the turtles' ability to transfer learned visual discriminations to novel but related stimuli. A total of 20 generalization trials were conducted each day during this phase, consisting of 6 trials of the original discrimination training (3 reinforced and 3 unreinforced), followed by 8 trials testing generalization (4 positive and 4 negative), and finishing with 6 more discrimination training trials. A sample sequence of trials is presented in Table 1.

For the purpose of clarity, the term *test stimuli* refers to the stimuli used in the generalization testing. These are designated *positive* if they were reinforced during the testing and *negative* if they were not. *Reinforced and unreinforced stimuli* will refer back to the turtles' previous discrimination training: which stimulus was reinforced varied between subjects in that stage.

During the 8 trials of generalization testing, either the previously reinforced or non-reinforced stimulus was presented with a single novel line orientation. These novel stimuli varied in 15-degree increments between 15° (horizontal) and 75° (vertical), resulting in five different intermediate orientations (Figure 3). On a given day, the same pair of stimuli (4 positive, 4 negative) was used for all 8 trials (see Table 1), and on successive days, the order of the different pairs was randomized, but there were always 5 days with 90 degrees, followed by 5 days with 0 degrees.

**Table 1**

*Table showing order of how stimulus generalization trials were run for turtle trained on 90 degrees+, 0 degrees-*

| Day | Trials 1-6: (3 90 degrees reinforced, 3 0 degrees unreinforced) in random order) | Trials 7-14: Positive test stimuli, intermixed in random order with the negative test stimuli (4 trials each) | Trials 7-14: Negative test stimuli, intermixed in random order with the positive test stimuli (4 trials each) | Trials 15-20: (3 90 degrees reinforced, 3 0 degrees unreinforced) in random order) |
|---|---|---|---|---|
| Day 1 | 90+, 0- | 90 degrees | 75 degrees | 90+, 0- |
| Day 2 | 90+, 0- | 90 degrees | 15 degrees | 90+, 0- |
| Day 3 | 90+, 0- | 90 degrees | 45 degrees | 90+, 0- |
| Day 4 | 90+, 0- | 90 degrees | 60 degrees | 90+, 0- |
| Day 5 | 90+, 0- | 90 degrees | 30 degrees | 90+, 0- |
| Day 6 | 90+, 0- | 30 degrees | 0 degrees | 90+, 0- |
| Day 7 | 90+, 0- | 60 degrees | 0 degrees | 90+, 0- |
| Day 8 | 90+, 0- | 45 degrees | 0 degrees | 90+, 0- |
| Day 9 | 90+, 0- | 15 degrees | 0 degrees | 90+, 0- |
| Day 10 | 90+, 0- | 75 degrees | 0 degrees | 90+, 0- |
| Day 11 | 90+, 0- | 90 degrees | 30 degrees | 90+, 0- |
| Day 12 | 90+, 0- | 90 degrees | 45 degrees | 90+, 0- |
| Day 13 | 90+, 0- | 90 degrees | 15 degrees | 90+, 0- |
| Day 14 | 90+, 0- | 90 degrees | 75 degrees | 90+, 0- |
| Day 15 | 90+, 0- | 90 degrees | 60 degrees | 90+, 0- |
| Day 16 | 90+, 0- | 45 degrees | 0 degrees | 90+, 0- |
| Day 17 | 90+, 0- | 75 degrees | 0 degrees | 90+, 0- |
| Day 18 | 90+, 0- | 60 degrees | 0 degrees | 90+, 0- |
| Day 19 | 90+, 0- | 15 degrees | 0 degrees | 90+, 0- |
| Day 20 | 90+, 0- | 30 degrees | 0 degrees | 90+, 0- |

The test stimuli were presented in a randomized sequence (Gellermann, 1933). On days when the positive stimulus was presented with a test stimulus of a different orientation, the previously reinforced stimulus was positive. On days when a different orientation was presented with the negative stimulus, the different line orientation was positive. Thus, on half of the test trials, the previously reinforced stimulus was presented and reinforced and a novel stimulus was not reinforced; on the other half, a novel test stimulus was reinforced, and the previously unreinforced stimulus was presented and not reinforced. We did this because our apparatus could not be easily programmed to present trials in extinction. The procedure should not have biased the results, however, because the novel stimuli were reinforced and nonreinforced an equal number of times. This training was continued for 20 days. Latencies were recorded, and the latencies of the first response were used as the measure of generalization.

***Data Analysis***

The results from the discrimination training were analyzed using a repeated measures ANOVA with Day as one variable and Stimulus as the other. We also analyzed the last two days, when the animals' performance was at criterion, to demonstrate that they had learned the discrimination. The results from the stimulus generalization testing were analyzed using a repeated measures ANOVA with Stimulus as the variable. Median latencies to the first response were employed as the measure of response strength to minimize the influence of extreme outliers, which are common in turtle behavior.

The raw data are presented in Supplementary Material.

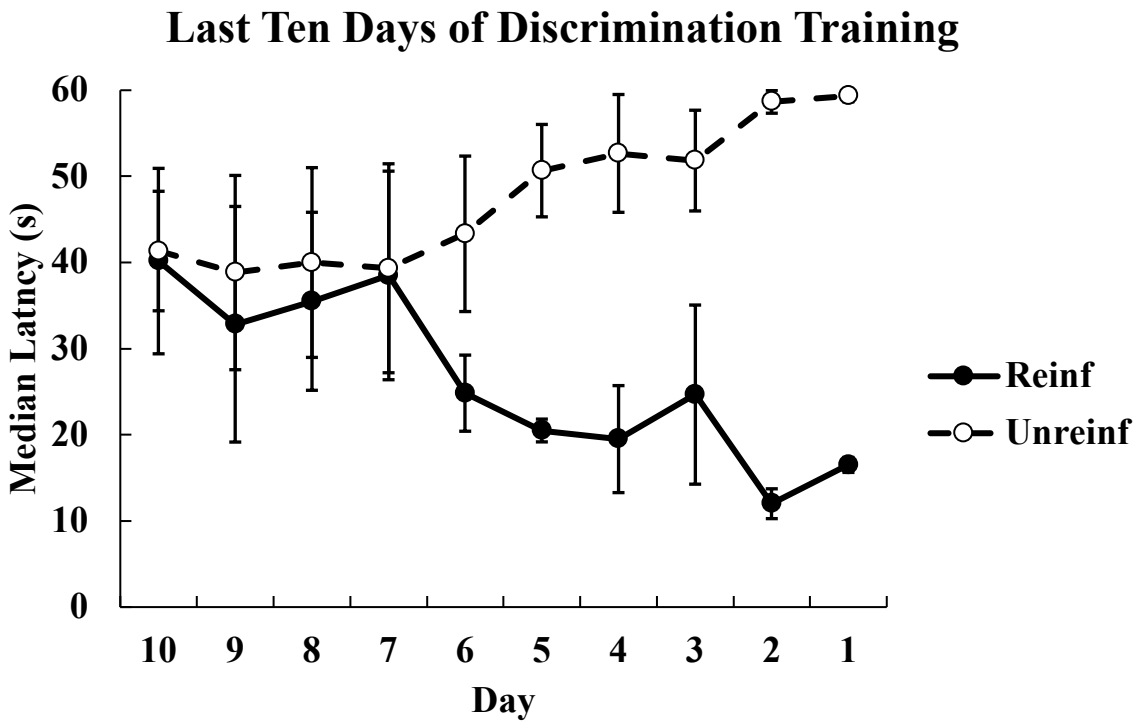
## Results

### Discrimination Training

All three turtles learned the discrimination, although they varied markedly in number of days of training. Turtle #392 took 15 days to reach criterion, turtle #412 reached it in 28 days, and turtles #394 needed 32 days. For this reason, the group learning curve shown in Figure 4 is for the last 10 days of training, when the animals were learning the discrimination.

**Figure 4**

*Median Latencies During the Final Ten Days of Discrimination Training*




*Note.* All three turtles reached the learning criterion, defined as a minimum 40-s difference between the median latencies for reinforced and unreinforced stimuli over two consecutive days. Reinf: reinforced stimulus; Unreinf: unreinforced stimulus.

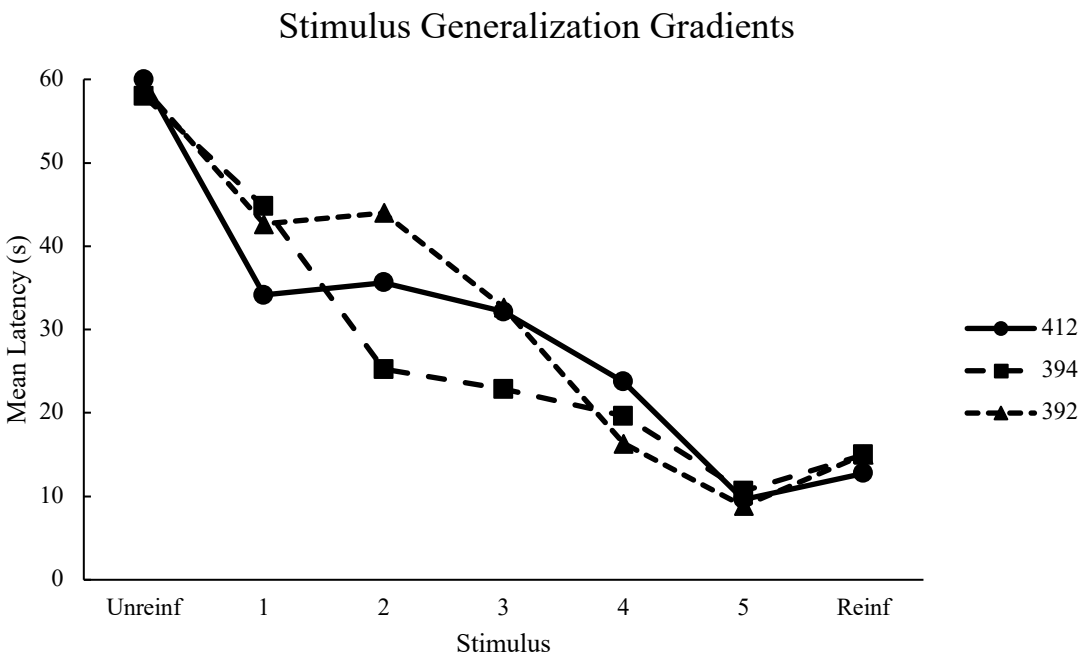
Analysis of the criterion days for all three animals showed a significant difference between the latency to the reinforced and unreinforced stimuli, $F(1, 2) = 1216.70$, $p < .001$, and no Days effect or interaction between Stimulus and Days, $p < .05$ for both. Analysis of the first 15 days of training showed no effect of Stimulus, $F(1,2) = 0.55$ $p = .54$, or Days, $F(14, 28) = 1.06$, $p = .43$, and no interaction between them, $F(14,28) = 0.98$, $p = .49$.

**Stimulus Generalization Testing**

The results from the generalization tests are shown in Figure 5, shown as the mean of each animal's median latencies to the first response for each stimulus. The turtles showed the fastest latencies to the previously reinforced stimulus and the slowest to the previously unreinforced one. Latency to the intermediate stimuli varied systematically with similarity to the reinforced and unreinforced stimuli, as seen in the figure. For statistical analysis, the data were analyzed with the latency to the reinforced stimulus, regardless of whether it was 90 degrees or 0 degrees, being analyzed together, and the intermediate stimuli and unreinforced stimuli grouped similarly. The results showed a significant overall ANOVA, $F(4,8) = 12.70$, $p = .002$. Excel was used to determine the best-fit function for the average of the three curves. The curve was fit by an exponential function with an $R^2$ of .96.

**Figure 5**

*Stimulus Generalization Gradients for Each Animal Based on Response Latency*




*Note.* These are the means for each animal of the median latencies to the first response. Response latency varied as a function of stimulus orientation, forming a generalization gradient. 1-5 on the x-axis represents the 15-degree increments between 15° and 75°. Unreinf: unreinforced stimulus; Reinf: reinforced stimulus.

## Discussion

The purpose of this study was to examine whether painted turtles are capable of stimulus generalization when trained to discriminate between visual stimuli. After learning to distinguish between a vertical and a horizontal line, the turtles were tested with intermediate line orientations to see how their response times changed with similarity to the training stimuli. The findings showed that the turtles responded fastest to the orientation they had been trained to recognize as reinforced, slowest to the opposite (unreinforced) orientation, and with intermediate speeds to the new stimuli that were visually between the two. This systematic, graded pattern of response latencies indicates that the turtles generalized their learned behavior based on similarity. This is the first formal demonstration of a generalization gradient in non-avian reptiles.

This behavioral outcome is consistent with the fundamental principles of classical and operant conditioning, demonstrating that the inhibitory and excitatory associations formed during training possess the capacity to transfer to novel stimuli. Although our methodology was somewhat unorthodox, in that the test stimuli were reinforced and unreinforced on different test days, the result was nondifferential reinforcement of the test stimuli. This nondifferential reinforcement should not have produced any bias in the results. The findings extend the established phenomenon of stimulus generalization across the vertebrate lineage, providing a key data point for the reptilian class and underscoring the evolutionary conservation of this cognitive mechanism.

All three turtles successfully reached the discrimination criterion, showing a significant difference in latency between the reinforced and unreinforced stimuli on the criterion days. The lack of a significant effect of Day or Day × Stimulus interaction ($p > .05$) in the first 15 days is disappointing but reflects the fact that one turtle (#392) had learned the discrimination, but the other two were still responding similarly to the two stimuli—they required 28 and 32 days to reach criterion. For this reason, the last 10 days are presented (Figure 5), and it is clear that all three animals had differentiated between the two stimuli. During the generalization phase, latency varied systematically across the different line orientations. The clear progression from shorter to longer latencies as stimuli became less like the reinforced orientation demonstrates that the turtles formed a meaningful association between the stimulus and the reward and could extend that learning to similar but not identical cues.

As described in the Introduction, the issue of generalization gradient shapes arises when theorists postulate a particular shape to make predictions about generalization behavior (e.g., Hull, 1943; Spence, 1937). Gradients are generally fit to either exponential or Gaussian curves (Ghirlanda & Enquist, 2003). Our data fit an exponential function well.

Using latency as the main measure in this experiment was valuable because it captured subtle differences in response strength that may not be visible when using only amplitude measures like number of responses or accuracy. The consistent direction of the latency gradients across all three turtles supports the idea that stimulus similarity directly influenced the decision-making process, even though the test stimuli had not been reinforced differentially. Latency is rarely used to measure generalization gradients, but it is used in response bias tests (e.g., Hoehfurtner et al., 2025). In these tests, too, subtle differences in approach latencies can be detected. Red-footed tortoises show differential responses to different spatial locations located nearer or farther away from the location originally reinforced. It should be noted that Yarczower and Bitterman (1965), studying stimulus generalization of wavelength in goldfish (*Carassius auratus)*, demonstrated that similar results were obtained with either amplitude (number of responses) or latency as a measure (but see Castro & Wasserman, 2010, for a contrasting example).

In the context of comparative literature, this study is a critical step. While previous work by Leighty et al. (2013) examined discrimination in turtles using brightness, they utilized a choice measure and did not report a quantitative generalization gradient. Our finding, utilizing line orientation and a continuous latency measure, provides the first direct evidence of a classic generalization gradient in the order Testudines. Although the sample size was small, the patterns were strong and highly consistent across individuals. Many other vertebrate groups, in addition to mammals, have been shown to demonstrate stimulus generalization (fishes: Dailey & Braun, 2011; Fay, 1970; Watanabe, 2024; Yarczower & Bitterman, 1965; birds: Hearst, Koresko, & Poppen, 1964; O'Donoghue et al., 2020; Powers, Caine, & Kaplan, 1983; Schneider & Kicliter, 2009; Soto & Wasserman, 2010), and the behavior is no doubt selected for, as it is adaptive. Being able to respond to stimuli similar to familiar stimuli in a similar way allows organisms to take advantage of changes in the environment. It may convey an advantage in cognitive tasks.

Future research should examine other species of non-avian reptiles, to examine whether stimulus generalization is generally present in these groups. It would also be useful to explore whether different kinds of stimuli—such as color, brightness, movement, or spatial location in response bias tests—produce similar generalization patterns, or whether turtles generalize differently depending on the stimuli involved. Examining both male and female turtles or individuals of different ages could also help identify whether these learning abilities are affected by biological or developmental factors.

In summary, this study provides clear behavioral evidence that painted turtles can form and generalize visual discriminations. Their systematic response patterns across stimulus orientations indicate that they recognize degrees of similarity rather than treating each stimulus as entirely separate. The significant statistical results confirm that the variation in latency was not random but meaningfully tied to the learned association. Overall, these findings suggest that turtles, like many other vertebrates, use general learning processes to interpret and respond to patterns in their environment. Latency proved to be a sensitive and reliable way to measure this behavior, and it may be a valuable tool for future research on learning and perception in reptiles.


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