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Effects of Failure on California Sea Lion (*Zalophus californianus*) Gameplay Strategies and Interest in a Cognitive Task: Implications for Cognitive Enrichment in Pinnipeds

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Abstract: Cognitive enrichment for professionally managed species has become more prevalent in recent years in both zoological and research settings and has been encouraged as a means of welfare enhancement. However, the task's difficulty must be specifically tailored as it can impact the successful nature of the sessions, as tasks that are too simple or difficult may not be perceived as enriching by the animals. While pinnipeds are common in zoos, aquariums, and research facilities, few studies have explored the use of cognitively challenging enrichment in this species, and the level of difficulty and presence of failure on animal success and engagement in this type of session has not been assessed. In this study, gameplay strategies during computerized enrichment sessions were evaluated before and after a game that introduced failure, or the loss of opportunity to complete a level for a reward after an incorrect movement. Interest in participation during the session, measured as the latency without contact, was also tested as a proxy for this enrichment's effect on welfare. When incorrect movements resulted in a short pause and removed the opportunity to finish individual levels for a reward, all three sea lions tested significantly reduced the amount of time spent on each of several strategies they employed, but significantly increased the number of button presses per strategy, suggesting the animals focused on more precise movements as their proficiency improved. Two sea lions also showed a significant decline in latency without contact following the introduction of failure in the form of a single opportunity to complete a task for a reward after previously having unlimited opportunities, while one maintained a low latency without contact across both test conditions. The results suggest that more cognitively challenging tasks incorporating failure did not cause a reduction in gameplay performance and session interest in sea lions. Individual variation was also noted in strategy use, emphasizing the importance of evaluating the individual in terms of enrichment provision.

Keywords: California sea lion; animal cognition; marine mammal welfare; cognitive enrichment; technological enrichment

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1. Introduction

Implementing cognitive challenges for animals in professional care has recently become a focus of research and management efforts to improve welfare and enrichment programs [1–3]. Modern research on animal cognition has shifted focus to emotional welfare but investigation of cognitive needs is still lacking [4,5]. Animals are naturally highly motivated to explore and acquire resources in various conditions [6,7] (p. 264) as cited in [8].

Professionally managed habitats replace environmental challenges faced in the wild with structure, stability, and predictability, leaving animals minimal opportunities to exercise or further develop cognitive skills without management interventions [8–10]. Without proper cognitive challenges, animals may become "bored" (or in a state of "suboptimal arousal" as termed in [11]) or anxious and participate in aversive, self-directed behaviors such as feather plucking [12], over-grooming [13], or self-injurious behaviors [14,15], or may exhibit abnormal feeding behaviors, including regurgitation and reingestion of food [5,16,17]. Enrichment programs designed to reduce the expression of stereotypic behaviors are generally successful [18–20], and research has shown that the use of cognitively challenging enrichment impacts these behaviors [21–23] and can also positively affect social behaviors following sessions [24,25].

Appropriate levels of failure in interactive cognitive enrichment sessions can introduce challenges in an otherwise stable environment leading to increased engagement and learning [26–29]. Failure during cognitive challenges can be presented in many forms, such as perceptual error, failure to adapt, and failure to learn the most effective solution [29–31]. The defined forms of failure may be more or less perceptible to the animals. For instance, while failing to provide the correct answer due to lack of knowledge or recollection would be evident, failing to use the most efficient strategy to reach a target may not be. Patterns of behavior exhibited by individual animals may be characterized as failure to respond most effectively or efficiently, but the patterns may be adaptations developed through learning and experience [31]. As with all enrichment, the challenge and opportunity for failure must be appropriately tailored to the individual so as not to frustrate the animal [10].

The opportunity for failure has been discussed in previous sea lion cognition studies as a factor that can be beneficial or detrimental to individuals' success. For instance, Schusterman and Krieger [27] introduced two balls of differing sizes to a sea lion and taught her always to select the smaller ball. When the previously larger ball was presented with another even larger ball, the sea lion was able to transfer the concept after several failed attempts to select the correct response. Schusterman and Krieger [27] subsequently determined that sea lions use a specific image that can be modified to their present situation. Alternatively, Hille and colleagues [29] worked with a sea lion who exhibited a strong side preference and became discouraged by repetitive failure. Side preference, the favored selection of a stimulus to one side over the other, is one learning method observed in sea lions [29] and many other species (see first [32]). The identified preferential selection is similar to previously conditioned biases observed by Schusterman [33] and can be overcome through repetitive conditioning trials [29]. In their study, Hille and colleagues counteracted this bias by adjusting the level of difficulty and reducing the number of presented stimuli from three to two in an attempt to remotivate the sea lion [29].

When facing a new problem, sea lions have been observed utilizing various strategies that have yet to be thoroughly described. Identity matching-to-sample (MTS) tasks direct an animal to detect and report on the identity relationship and can be used for testing comparative cognition [34]. Pack et al. [34] proposed that, because sea lions have demonstrated the ability to apply the matching rule learned during MTS to new problems, they demonstrate the ability to learn additional concepts. Much like in Schusterman and Kastak's [30] study, the sea lion in Pack et al. [34] failed the strongest test of transfer of the matching rule. Such a test requires the animal to match new stimuli with few or no errors on the first presentation. However, in both cases, the animals were successful with the remaining tests, as they appeared to grasp the concept of the equivalence relations and matching rules, respectively [30,34]. Schusterman and Kastak [30] hypothesized that the sea lion in their study primarily relied on trial and error at the beginning of the study but transitioned to generalizing sample comparisons after symmetry training. The strategies utilized for the equivalence relations may be similar to discerning group members from territorial rivals, as California sea lions are gregarious [30]. Additionally, sea lions have the ability to acquire abstract concepts and integrate new information into previously established stimulus classes even if the information is in a different form (ex. auditory vs.

visual) [35]. Despite the extensive information regarding sea lion cognitive abilities, there have been few studies examining the use of cognitively challenging enrichment and its effect on pinniped welfare and session interest.

Anticipatory behavior before sessions is well documented with varying conclusions on animals' attitudes towards sessions [36–38]. However, the responses observed were the animal responding to the sessions indirectly and, therefore, could not define the animal's level of motivation towards or during a session [38,39]. Animal motivation to engage in an activity is influenced by the desire to increase biological fitness [39–41] and has been deemed an important component of animal welfare studies [42]. In professional care, animals are often asked to perform a task in exchange for portions of their daily diet. An animal's motivation to complete the requested task may be dependent on either the desire for the food or the desire to complete a task in exchange for a reward of some form such as food or a secondary reinforcer [9,10,12,39,43,44]. Contrafreeloading occurs when an animal chooses to work for food despite the availability of identical food [8,45]. Contrafreeloading contradicts optimal foraging theories and learning and motivation theories which predict that animals will maximize the reward ratio to the cost [8] and is well documented across taxa [8,46,47]. Furthermore, the Yerkes–Dodson law suggests that increased task difficulty decreases the optimum motivation for learning a task but individual differences in drive strength can influence individual performance [48]. Sea lions have demonstrated high degrees of complex associative learning and task focus [35], indicating they may be more motivated to complete difficult tasks. However, motivation to obtain rewards has been found to decrease in the presence of chronic stress and declining health status in various species [49–51]. Clegg and colleagues [39] weighed dolphins' willingness to participate in training sessions as a combination of presence in session, proximity to the trainer, desire for food, and the number of correct responses. Clegg et al. [39] also noted a decrease in the willingness to participate was significantly linked to decreased health status and appeared to be a more powerful indicator than individual measures such as the percentage of food consumed [39]. Although significant results were achieved, willingness to participate can be influenced by numerous variables (time of day, individual history, etc.) and would benefit from additional studies [38,51].

There is a lack of published information on pinniped welfare in managed populations, especially welfare influenced by cognitive enrichment or mental states. Currently, the main indicator of pinniped welfare in managed care described in the literature is the presence of stereotypic behaviors (e.g., [52,53]). Several studies have found that training sessions and novel enrichment devices have decreased the time spent on stereotypic behaviors in pinnipeds [53–57]. Kastelein and Wiepkema [57] noticed that Steller sea lions residing in a marine mammal park had a habit of routine-like swimming during the winter when there were no public encounters and limited training sessions. The sea lions displayed significantly less routine-like swimming during training sessions than during non-training weeks [57]. Smith and Litchfield [54] observed the influence of food-related and non-food-related enrichment devices on Australian sea lion activity budgets. The male sea lions spent nearly half their time pattern swimming prior to the introduction of enrichment. After enrichment was introduced, their pattern swimming decreased to a quarter of their time. In a similar study, Hocking and colleagues [56] specifically assessed the impacts of foraging-based enrichment on stereotypic behaviors. When presented with various foraging-based enrichment devices, Australian fur seals (*Arctocephalus pusillus doriferus*) in a professional care environment increased time dedicated to feeding and decreased pattern swimming. While pattern swimming and other repetitive stereotypic behaviors are not automatically a sign of poor welfare, increasing time spent on various natural behaviors may be beneficial in improving the animal's overall interest in their environment [56]. Overall, pinnipeds are easily trained and generally seen as cognitively advanced as they are relatively adaptive to their environments [55,58]. Even in the wild, pinnipeds have displayed advanced problem-solving abilities, such as their ability to raid fishermen's catches [55,58]. Specifically, sea lions have demonstrated high degrees of complex associative learning and task focus [35].

Allowing pinnipeds to exercise this cognitive ability in professional care environments is important for maintaining their overall welfare.

The cognitive abilities of sea lions have been tested, but their overall learning abilities are difficult to quantify, especially compared to more accessible terrestrial animals. Modern training methods minimize failure with successive approximations and positive reinforcement (e.g., [59]). Thus, learning in response to failure is not widely discussed for zoological species in professional care environments and may impact sea lion welfare during enrichment and cognitive training sessions. The following study assessed changes in technological gameplay performance after animals were presented with a game that implemented failure (i.e., no opportunity to receive a reward that trial) as a consequence of incorrect decisions, rather than allowing for continuing attempts at the same problem. Evaluations of the frequency of efficient and inefficient gameplay strategies, performance in the form of latency to success, and interest in the sessions measured in contact time versus latency to success were used to evaluate the effects of failure on individual learning and interest in the enrichment. The contact time includes the total time the animal was in contact with any buttons. Latency to success, hereby referred to as latency, includes the time from the first button push to the acquisition of the target.

2. Materials and Methods

2.1. Setting and Subjects

The National Marine Mammal Foundation (NMMF) and the Naval Information Warfare Center (NIWC) Pacific collaborated and developed an enclosure video enrichment system (EVE) at the U.S. Navy Marine Mammal Program (MMP). The three adult male sea lion subjects (ANK, REX, SLD) resided in 9×9 m^2 floating sea pens with adjacent haul-out spaces in San Diego Bay, California. Subjects were selected based on availability to consistently participate in training and subsequent experimental sessions [60].

2.2. EVE Apparatus

A 27″ Acer KB272 bix monitor, protected by a layer of plexiglass, was affixed to a plastic utility cart with lockable wheels for portability. An external speaker and game controller were connected through Bluetooth and USB to the computer and set atop the cart inside a protective container. Four 2.36″ plastic arcade circle-shaped buttons were positioned in compass positions on a 6 in by 6 in electrical box that served as the sea lions' game controller. A USB encoder attached to the computer was wired to the buttons. An HDMI connection linked the computer and monitor so the sea lions could watch and play the games simultaneously. The games can be used with an automated feeder device inserted into a USB port (see Figure 1), the design of which was based on Goldblatt's marine mammal feeder [61].

2.3. Procedures

The Cursor Training Game (CTG) was introduced during the summer of 2020 to the focal subjects. The six training phases (see [60]) were designed to systematically introduce the animals to the EVE system and functions to be successful at the task. The goal of the CTG was to move a blue circle cursor to touch a black square target(s) by pressing four directional buttons on a controller (Figure 2). Gameplay concepts, such as alternating buttons and pressing directions, were slowly introduced over the course of six different training phases modeled after those used by Washburn and Rumbaugh [22] through successive approximations. The sea lions were able to attempt to contact the box(es) an indefinite number of times. They would receive trainer prompts or assistance in early training phases when the animals required such intervention. By Phase 6, the final training phase in which one small box was located on the screen, the sea lions were no longer receiving prompts or cues. During Phase 6, ANK and SLD had fairly equal exposure to the automatic feeder and trainer-guided sessions as the methods were used interchangeably. After Phase 6, SLD was only exposed to the feeder for the first two sessions, and ANK was only exposed to trainer-guided sessions. However, REX was not exposed to the automatic feeder until the final three sessions of the data collection.

Figure 1. A sea lion playing CTG during a session in which reinforcement is provided by the automated feeder. When the sea lion is successful, the program communicates to an Arduino that is connected to a pressurized air tank, which pushes water into the cylinder and moves a piston forward, releasing pieces of fish and ice.

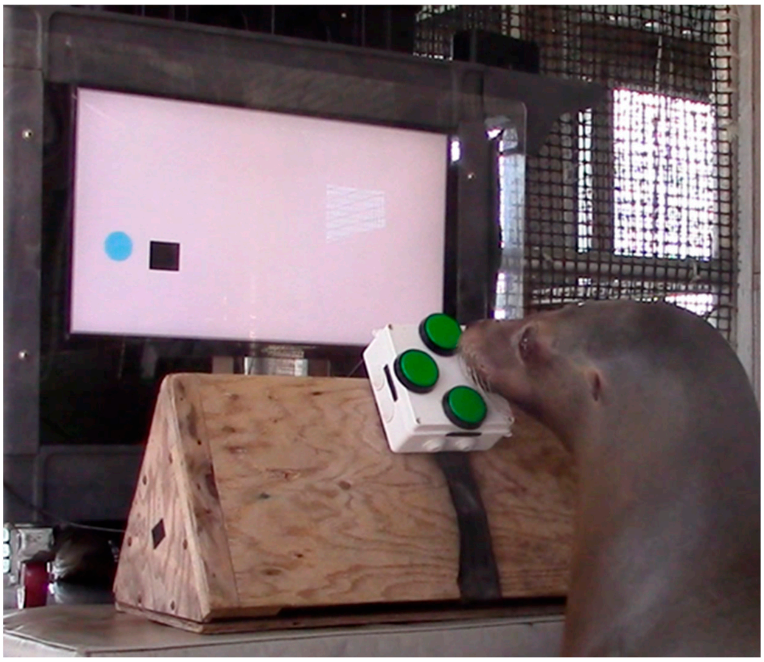


Figure 2. Example of a CTG Phase 6 Trial.

Following the acquisition of the cursor driving concept taught in the CTG (see [60]), the subjects were introduced to a different gameplay concept (i.e., MAZE or match to sample, MTS; see Figure 3) that introduced the opportunity to fail when incorrect decisions were made. For this study, failure was a consequence in the trials in which incorrect button presses resulted in the trial ending with no opportunity to receive reinforcement or continue that trial. Failed trials resulted in a frozen screen for three seconds before the next trial loaded. In MAZE, REX could only move the cursor to the left or right; thus, to succeed at the task, choices of strategically falling from platforms to drop onto the target box at the bottom of the screen needed to be made. If he went in an incorrect direction and fell off the platform away from the target, the cursor would "fall" off of the screen. This game was based on Beran and colleagues' [62] work to test planning behavior in primates. REX was given modified introductory trials to understand this concept in which the cursor only dropped off a single, lower platform to contact a target.

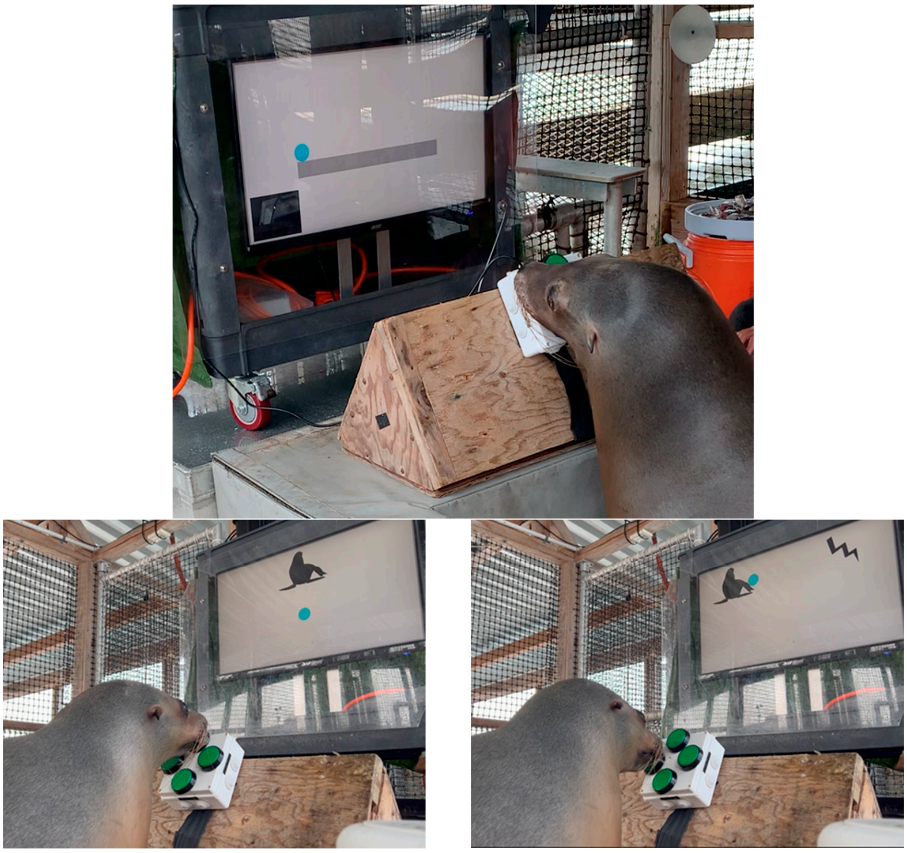


Figure 3. Example of a MAZE introductory training trial (**top**), a MTS S+ presentation screen (**bottom left**), and a MTS choice screen with the S+ and S- (**bottom right**).

During MTS, ANK and SLD were shown an arbitrary, 2D black shape or symbol above the cursor. Once they contacted this sample shape with the cursor, two options appeared, one on either side of the cursor: the same shape again, and a different, alternative shape. To be successful at the task, the subject had to move the cursor to contact the shape that matched the sample. In the MTS trials, movements were not restricted in any direction, as in MAZE. If the subject did not make contact with the correct shape in MTS, the screen froze for three seconds and was unresponsive to button presses, then a subsequent trial loaded without the opportunity to try the same trial again.

During the CTG, incorrect button presses (i.e., moving away from the target or narrowly missing the target) never resulted in such a failure, as player movement was never frozen, and the animal could continue the same trial until contact was made.

Following the MAZE and MTS sessions, the sea lions were given the opportunity to play the CTG Phase 6 trial (termed "Post-Advancement" hereafter) to maintain the button-pressing behaviors and the reinforcement value of the EVE system. To determine whether these more challenging games impacted performance and interest in a previously mastered task, the sea lions' button-pressing strategies and interest levels during the CTG Phase 6 trials Pre- and Post-Advancement were tested.

2.4. Data Analysis

The tasks were written in C# using version 2019.2.15f1 of the Unity Development platform [63]. The games collected pertinent information during gameplay, such as button presses, latency to contact the target, total contact time with the buttons, and session duration. Gameplay videos were viewed to identify and operationally define strategies utilized by each subject. Videos were also annotated with a coding sheet developed in Solomon Coder 19.08.02 [64]. Two raters calculated inter-observer reliability for 20% of trials (IRR $\geq$ 80%). Strategies were operationally defined by gameplay strategies and included circling, staircasing, wall surfing, targeting, superstitious, or diagonal movements (see Table 1 and Video S1: Examples of Defined Strategies for operational definitions). Latency to contact the target was defined as the time from the first push until the player reached the target. Total contact time was the sum of the button push durations for each trial. Button push durations were recorded by the game and exported to .csv files. Latency to contact the target, and total contact time and session duration were all measured in seconds, while button presses were classified by direction and frequency. Strategies, button presses, latency to contact the target, total contact time, and session duration were compared across the testing conditions within the CTG (Phase 6) before and after exposure to failure presented in advancement trials (Post-Advancement following MAZE and MTS) with non-parametric repeated measures and comparative statistics were used due to test assumptions being violated (e.g., Levene's test).

Table 1. Focal strategies, operational definitions, and visual examples.

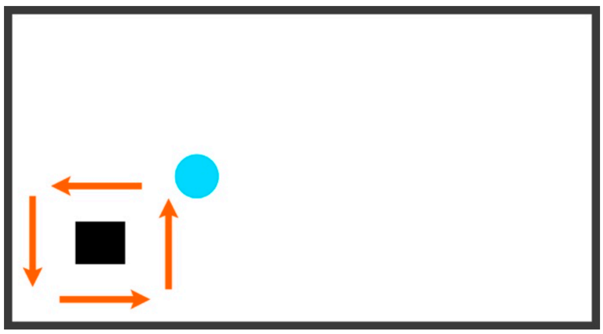
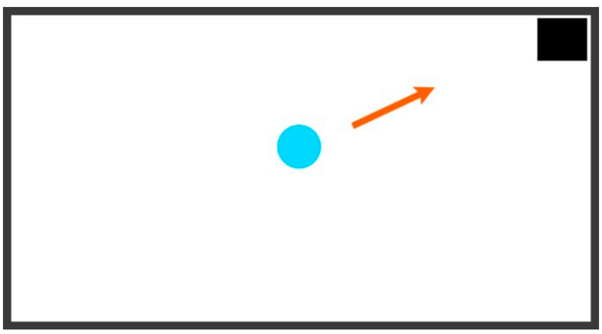
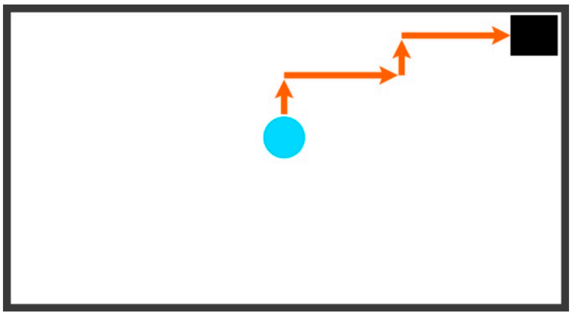
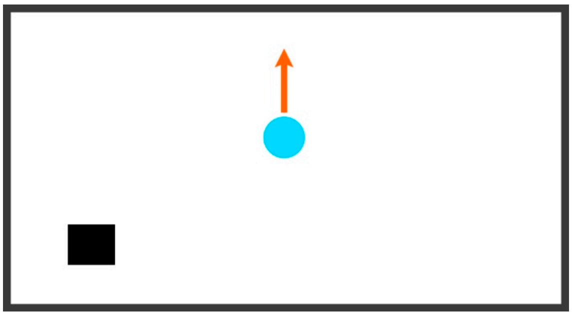
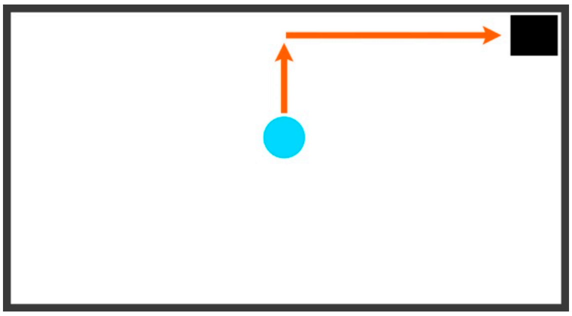
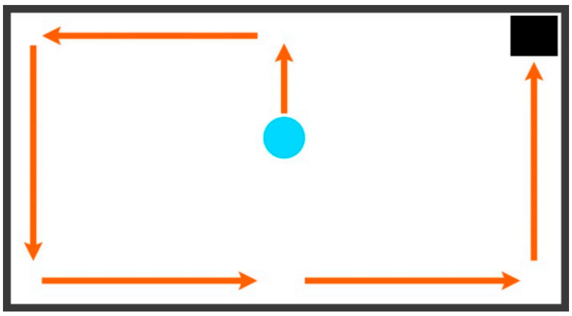
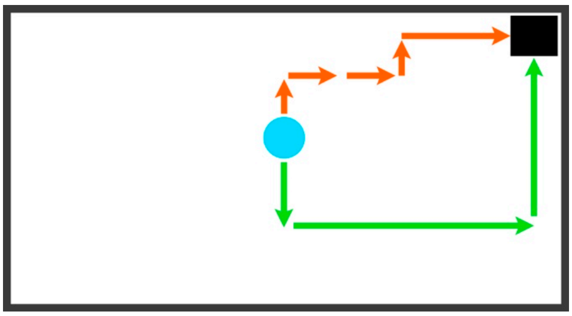
Strategy	Operational Definition	Button-Pushing Example	Visual Representation of Cursor Moves
Circling	Any set of five button presses where buttons are pressed in order either clockwise or counterclockwise in the same direction. Restrictions: limited to less than half of the screen (x < 0.8 s)	UP, RIGHT, DOWN, LEFT, UP	
Diagonal	Any movement that utilizes two buttons simultaneously	UP and RIGHT	

Table 1. *Cont.*

Strategy	Operational Definition	Button-Pushing Example	Visual Representation of Cursor Moves
Staircasing	An alternating series of at least three alternating vertical and horizontal movements	UP, RIGHT, UP, RIGHT	
Superstitious	A superstitious initial movement (e.g., UP), followed by a pause. Restrictions: Can only be considered for the first movement of the trial.	UP	
Targeting	One or two direct movements to the target that result in acquiring the target. Restrictions: Can only be considered for the first two moves of the trial	UP, RIGHT	
Wall Surfing	Continuous movements in the same direction along the wall. Considerations: the cursor starts in the center for all Phase 6 and Post-Advancement (time taken to move to wall is not considered in wall-surfing duration)	(UP), LEFT, DOWN, RIGHT, RIGHT, UP	
No Explicit Strategy (NES)	Any movements that cannot be considered as any defined strategy. Considerations: may include unsuccessful presses of defined strategy criteria (ex. A: unsuccessful staircase)	Ex. A: UP, RIGHT, RIGHT, UP, RIGHT Ex. B: DOWN, RIGHT, UP	

2.5. Ethics Statement

The MMP adheres to the standards of the Animal Welfare Act and the United States Public Health Service Policy on the Humane Care and Use of Laboratory Animals and is accredited by the Association for Assessment and Accreditation of Laboratory Animal Care (AAALAC). Any trials where the button-pushing data obtained from the videos did not align with the game output were discarded, and flagged as issues with the apparatus, as the controller could become stuck or unresponsive due to sea lion interaction, such as moisture, saliva, or fish remnants.

3. Results

3.1. Frequency of Strategies by Testing Condition and Individual

In Phase 6, the frequency of strategies used did not differ significantly for all sea lions combined (Brown–Forsythe: $F(5, 2.72) = 5.82$, $p = 0.102$). However, post hoc analysis revealed no significant differences among pairings. Similarly, in Post-Advancement the frequency of strategies used by all subjects combined also differed significantly (Brown–Forsythe: $F(5, 4.99) = 11.15$, $p < 0.010$). Post hoc analysis revealed staircase was used significantly more than circling (M = 2.67, SD = 3.05) and superstitious (M = 28.66, SD = 11.72). The frequency of each strategy used differed significantly with both conditions and subjects combined (Brown–Forsythe: $F(5, 6.68) = 5.28$, $p < 0.05$). Post hoc analysis revealed targeting (M = 158.17, SD = 48.22) was used significantly more than circling (M = 6.50, SD = 7.89), diagonal (M = 23.20, SD = 24.85), superstitious (M = 28.00, SD = 2.08), and staircasing (M = 84.57, SD = 43.74) was used significantly more than circling (Games Howell, $p < 0.05$) (Figure 4). No significant differences were observed in the frequency of strategies used among sea lions in Phase 6 (Brown–Forsythe: $F(2, 8.67) = 0.44$, $p = 0.66$), Post-Advancement (Brown–Forsythe: $F(2, 9.37) = 0.49$, $p = 0.63$), and both testing conditions combined (Brown–Forsythe: $F(2, 22.93) = 0.88$, $p = 0.43$).

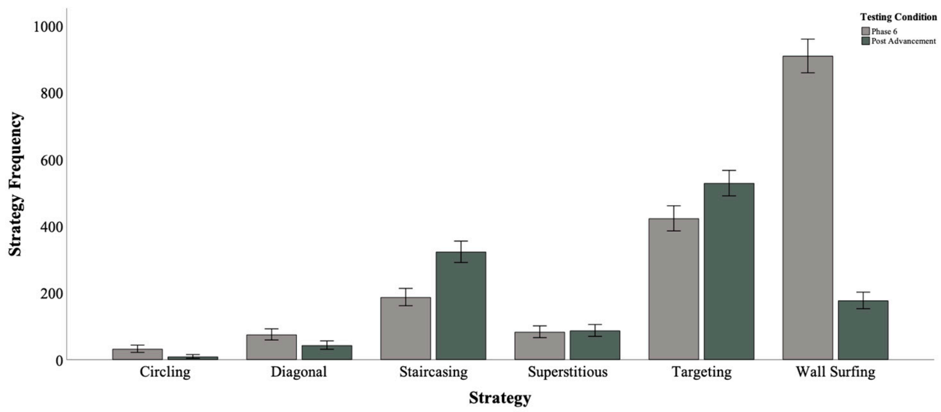


Figure 4. Frequency of strategies used by all sea lions in Phase 6 and Post-Advancement.

3.2. Strategy Duration and Button Pushes Compared between Conditions-Paired t-Test

Mean strategy duration was significantly higher during Phase 6 (M = 2.10, SD = 2.08) than Post-Advancement (M = 1.24, SD = 1.97), a significant mean decrease of 0.97 s (Wilcoxon signed rank test: $Z = -5.02$, $p < 0.001$) (Table 2).

However, the mean number of button pushes per strategy was significantly lower in Phase 6 (M = 2.12, SD = 1.45) than Post-Advancement (M = 2.67, SD = 1.35), a significant mean increase of 0.55 pushes per strategy (Wilcoxon signed rank test: $Z = -10.96$, $p < 0.001$).

The mean duration of individual strategies differed significantly in Phase 6 (Brown–Forsythe: $F(5, 91.77) = 110.42$, $p < 0.001$). Post hoc analysis revealed the strategy duration of circling was significantly greater than all strategies, the diagonal strategy was used significantly less than all other strategies except targeting, and the targeting strategy had a significantly lower duration of use than all strategies except diagonal (Games Howell: $p < 0.05$). Strategy duration also differed significantly in Post-Advancement (Brown–

Forsythe: F(5, 42.57) = 55.72, $p < 0.001$). Post hoc analysis revealed that the duration of circling was greater than all other strategies, whereas the duration using strategies of diagonal and targeting was significantly lower than all other strategies (Figure 5).

Table 2. Combined mean strategy duration of all sea lions by strategy in Phase 6 and Post-Advancement.

Mean Strategy Duration (Seconds) by Testing Condition and Strategy—All Sea Lions Combined				
Strategy	**Testing Condition**	**N**	**Mean**	**D**
Circling	Phase 6	31	5.52	2.49
	Post-Advancement	8	4.49	1.31
Diagonal	Phase 6	74	0.79	0.60
	Post-Advancement	42	0.54	0.43
Staircasing	Phase 6	186	1.70	1.00
	Post-Advancement	322	1.55	0.59
Superstitious	Phase 6	82	1.57	0.88
	Post-Advancement	86	1.31	0.56
Targeting	Phase 6	422	0.94	0.56
	Post-Advancement	527	0.81	0.47
Wall Surfing	Phase 6	422	2.46	2.29
	Post-Advancement	527	1.47	1.43

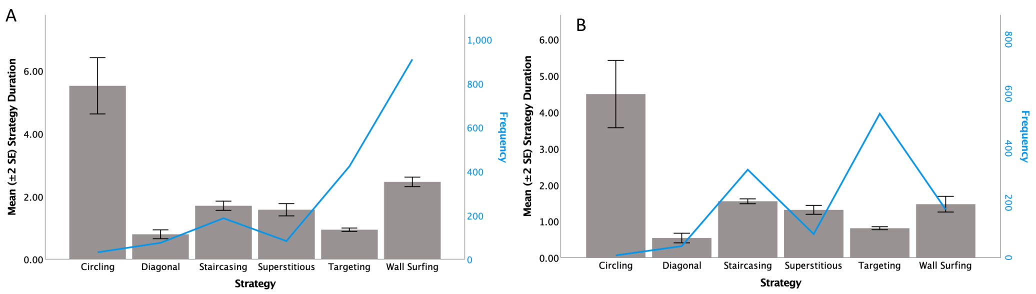


Figure 5. Mean (±2 SE) strategy duration and frequency of use of strategies for testing conditions: (**A**) Phase 6 and (**B**) Post-Advancement. (±2 SE).

An ANCOVA was conducted to test for interactions among multiple independent variables and account for paired data of testing conditions and sea lions. Within the model, strategy duration differed significantly among sea lions (F(2, 3.44) = 4.37, $p < 0.013$), total button pushes (F(1, 3457.90) = 4.37, $p < 0.000$) in the strategy testing condition were significant (F(5, 26.21) = 33.34, $p < 0.001$). Strategy duration had a significant interaction when compared to testing condition and strategy (F(5, 32.78) = 41.70, $p < 0.001$), strategy and sea lion (F(10, 40.12) = 51.04, $p < 0.001$), and testing condition, sea lion, and strategy (F(7, 40.50) = 51.52, $p < 0.001$).

3.3. Latency to Target Contact

Mean latency to contact the target in Phase 6 was significantly longer for ANK M = 11.64, SD = 24.57) compared to REX (M = 6.59, SD = 9.39) and SLD (M = 2.59, SD = 5.60) (Brown–Forsythe: F(2, 605.62) = 33.74, $p < 0.001$); mean latency was also longer for REX compared to SLD (Games Howell, $p < 0.05$). Mean latency in Post-Advancement did not differ significantly among or between ANK (M = 3.83, SD = 7.99) compared to REX (M = 3.85, SD = 4.96) and SLD (M = 3.16, SD = 5.50) (Brown–Forsythe: F(2, 1028.10) = 1.82, $p = 0.163$). Mean latency among ANK (M = 3.84, SD = 7.99), REX (M = 3.85, SD = 4.96), and SLD (M = 3.16, SD = 5.50) revealed no significant differences between sea lions (Brown–Forsythe: F(2, 1028.10) = 1.82, $p = 0.166$) (Figure 6).

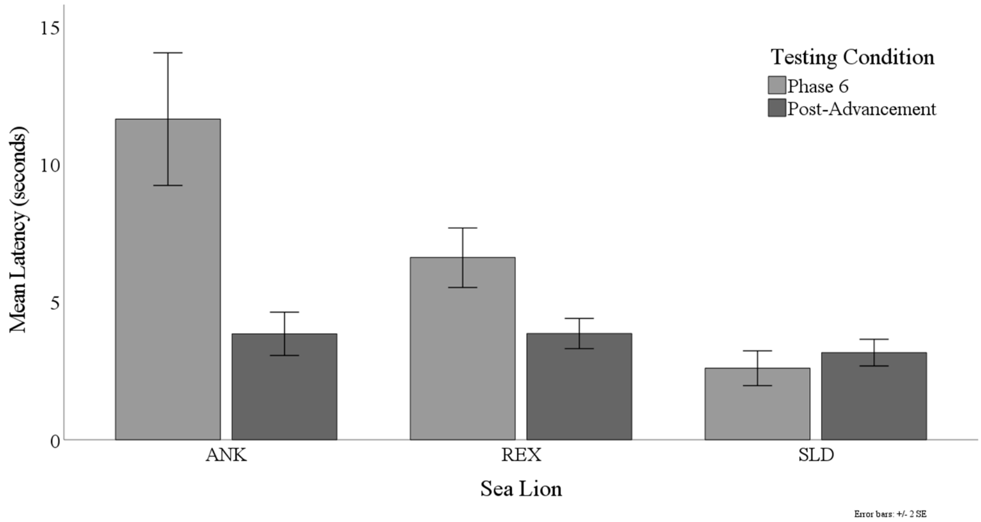


Figure 6. Mean (±2 SE) trial latency among sea lions and across testing conditions.

Mean trial latency was significantly higher in Phase 6 (M = 9.80, SD = 21.04) than Post-Advancement (M = 3.42, SD = 6.10), a mean decrease of 6.38 s, (Wilcoxon signed rank test: Z = −8.64, $p < 0.001$). Additionally, the total contact time of the sea lions pushing the buttons in Phase 6 (M = 6.87, SD = 10.30) was significantly higher than Post-Advancement (M = 1.80, SD = 2.65), a mean decrease of 5.07 s (Wilcoxon signed rank test: Z = −10.48, $p < 0.001$).

Latency without contacting the buttons was also significantly higher in Phase 6 (M = 2.92, SD = 14.22) than Post-Advancement (M = 1.26, SD = 4.16), a mean decrease of 1.66 s (Wilcoxon signed rank test: Z = −6.31, $p < 0.001$) (Figure 7).

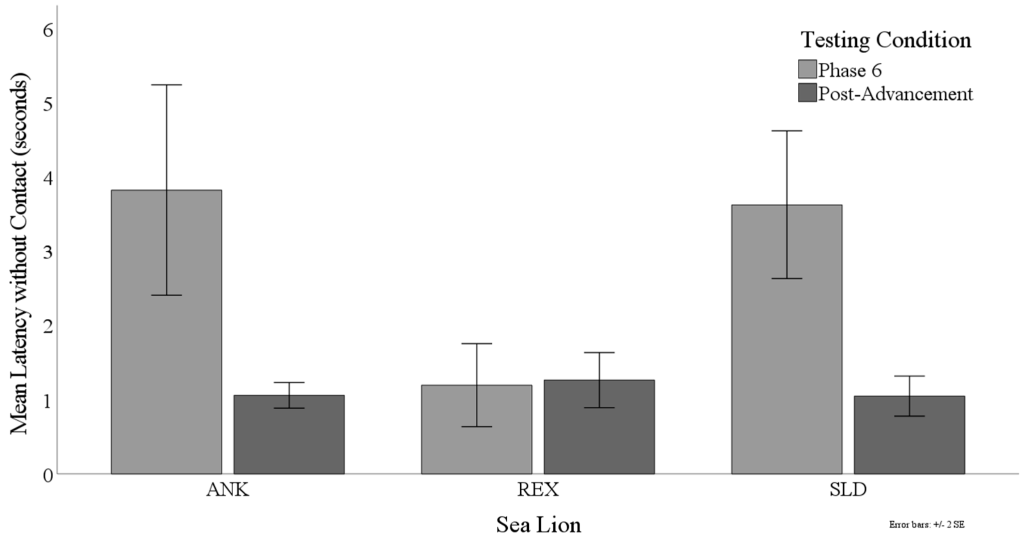


Figure 7. Mean (±2 SE) latency without contact among sea lions and between testing conditions.

4. Discussion

Evaluation of strategy use of sea lions during a computerized task before and after the introduction of failure showed continued learning and advancement of concepts without the loss of interest in the testing device. Two sea lions, ANK and SLD, showed a significant increase in interest and engagement with the CTG in the expression of reduced latency without contact. Although trainer presence could influence animal engagement or performance, there were no significant differences for the variables of interest (Strategy Frequency, Strategy Duration, Level Latency, Total Contact Time, Latency without Contact, and the

Total number of Button pushes) for Phase 6, and Phase 6 and Post-Advancement combined. REX maintained a low latency without contact in both the Phase 6 and Post-Advancement phases, presenting just a slight and insignificant increase in latency.

Wall surfing, targeting, and staircasing were the most frequent strategies observed overall. The use of the strategy of wall surfing significantly decreased from Phase 6 to Post-Advancement, while more efficient strategies, such as staircasing and targeting, increased in Post-Advancement. Both MTS and MAZE did not require the animals to wall surf, and thus may have allowed practice in precision movements. For MTS, ANK, and SLD were essentially practicing the targeting strategy, as the target and the match appeared UP and either to the LEFT or the RIGHT, respectively. The format of MTS should have also encouraged the increase of the existing superstitious behavior, as ANK and SLD were encouraged to push UP, pause to look at the screen, and then continue to the correct stimulus on either side of their cursor.

In MAZE, REX was only able to utilize the LEFT and RIGHT buttons, and the placement of walls and platforms prevented REX from wall surfing. The game required staircase-like movements, in which the sea lion would move to the left or right, and then "gravity" would drop the cursor to the target. The application of strategies used in one game to another follows the description of sea lions' ability to learn how to learn by Harlow [32], which is the ability to learn how to respond to individual problems and learn the general nature of problems. Both of REX's games involved moving a cursor to a black box (the target).

The number of button pushes increased while the duration of the strategy went down, suggesting that while the animals became quicker at each strategy, they may have used the increased number of button presses to increase precision. Additionally, the number of button presses differed across strategies within and between conditions. The increase in pressing may also be attributed to heightened levels of engagement or anticipation, or even impatience with the cursor movement speed. In a test of patience in humans using a computer game, women participants were noted to impulsively press a non-functioning button while waiting [65]. When testing the system response time of humans playing computer games, button presses of certain individuals were more frequent during longer delays [66], and multiple presses have been considered to reflect the intention to complete a task [67].

Overall, the duration of all strategies decreased from Phase 6 to Post-Advancement, suggesting the animals became more efficient at each strategy and at reaching the target as a whole. The most efficient strategies observed were targeting and diagonals as they required the fewest button pushes and resulted in the shortest latency to contact times. When the target was in a corner (ex. top corner of the screen), diagonals were the most efficient strategy but if the target was in any other position (ex. directly above the player) targeting was most efficient. It is possible that the equal distribution of pressure on both buttons to produce a diagonal motion was too difficult for the animals to master or that the animals preferred more precise movements in the form of the less efficient circling or the more efficient staircasing. Wall surfing, while more time-consuming, allowed the animals to line up to the target from a farther distance before moving directly to it. As the animals continued to master the ability to stop and switch button presses, this strategy may have provided additional time for the animals to make adjustments from a distance. The frequency of the use of a less efficient and more time-consuming strategy of wall surfing may also be impacted by the inherent reinforcement value of controlling stimuli [68–70]. Preference for choice has been noted with primates when playing computerized tasks [22,71]. While the sea lion player has the choice to select any buttons in any pattern, utilizing wall surfing allows the player to move along the border of the screen and select a longer but more linear path to the target. Thus, wall surfing may have continued due to the reinforcing nature of driving the cursor through controlling the stimuli and choosing its direction, as the reinforcement received at the end of the trial was not dependent on the speed of target acquisition.

Improved proficiency was noted, as latency to contact the target was greater in Phase 6 than in Post-Advancement for all animals combined. SLD increased in latency slightly, but this change was not significant. However, this individual had the lowest latency to contact the target than any other sea lion, regardless of testing condition. The total contact time also decreased between the two conditions, as well as the latency without contact. These results suggest that the animals were more engaged during Post-Advancement than Phase 6. REX's latency without contact was only slightly higher but was the lowest of all three sea lions regardless of condition. Thus, REX may have found the task consistently engaging, compared to ANK and SLD, whose interest in contact latency increased after the games that introduced failure. Individual variation in enrichment preferences have been reported in marine mammals [72–74], as well as sea lion expression of behavioral traits [75,76]. Further investigation in the interest of individual sea lions in cognitive enrichment is warranted.

It is possible that the animals' increased interest and proficiency with the CTG was not directly positively impacted by the introduction of the games with failure; however, these games did not negatively impact the gameplay or levels of interest of the animals. Future research could examine how gameplay in additional CTG sessions, following the acquisition of the concept [60], differs from sessions that happen following the impact of failure to ascertain whether such failure could have inhibited even further interest in the apparatus, or if it only maintains the same level. Ultimately, this study was limited by a small sample size and lack of a control group; however, these data support the introduction of more challenging computerized tasks to California sea lions, in terms of providing opportunities where learning can be encouraged by exposure to failure.

Studies on human response to failure while playing video games suggest that some individuals react very differently when confronted with failure [77]. Diener and Dweck [78] suggest a "mastery orientation" mindset among individuals who respond positively to failure. In response to failing a difficult problem, these individuals show a heightened effect and increased effort [79]. Alternatively, some individuals may exhibit learned helplessness post-failure, characterized by boredom, anxiety, absence of progress, and use of ineffective or impossible strategies [78]. It is likely that the aforementioned pinniped players in this study have been previously conditioned towards a mastery orientation mindset with a built-in positive response to failure, consistent with their training history which applies the psychological principals of operant conditioning, reinforcement, and successive approximations to optimize success [59]. While individual variation in performance was observed here and in prior work with EVE [60], assessing individual characteristics that may have impacted strategies and responses could be beneficial [75,76].

As the system continues to expand to include additional games, continuing to provide previous tasks as added enrichment variability should maintain the enriching nature of EVE [59,80]. Future research could explore how the performance during the challenging session may have predicted the strategies and efficiency of animals in easier games they are subsequently provided.

Supplementary Materials: The following supporting information can be downloaded at: https://www.mdpi.com/article/10.3390/jzbg4010021/s1, Video S1: Examples of Defined Strategies.

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