Aquatic Mammals 2023, *49*(1), 73-86, DOI 10.1578/AM.49.1.2023.73

The Introduction of a Novel Computerized Apparatus to California Sea Lions (*Zalophus californianus*)

Kelley A. Winship,[1] Amber Ramos,[1] and Mark J. Xitco, Jr.[2]

[1]*National Marine Mammal Foundation, 2240 Shelter Island Drive #200, San Diego, CA 92106, USA*
E-mail: kelley.winship@nmmf.org
[2]*U.S. Navy Marine Mammal Program, Naval Information Warfare Center Pacific, Code 56700, 53560 Hull Street, San Diego, CA 92152, USA*

Abstract

The use of technology in laboratory and zoological settings has provided opportunities for advancement of cognition research as well as cognitive enrichment in a variety of species. Such systems have been successfully created for nonhuman primates and introduced to other anatomically and physiologically diverse species such as bears and tortoises. However, such systems have yet to be used with frequency in aquatic species given the challenge of incorporating accessible technology in such a setting. Herein, we report the successful creation and implementation of a novel manipulatable computerized system with California sea lions (*Zalophus californianus*) housed in outdoor sea pens. The Enclosure Video Enrichment (EVE) system was created and provided to three adult male sea lions living at the U.S. Navy's Marine Mammal Program. The interface was modified from those used with other species to accommodate the anatomical and physiological differences of the study subjects. Training procedures were adapted from those successfully used with nonhuman primates to emphasize successive learning approximations. Each of the sea lions introduced to EVE successfully learned to engage with the system at differing rates over the course of a year and a half. While each showed significant differences in interaction style (e.g., number of button presses), all were able to achieve the same criterion for acquisition. This system is the first recorded success in providing a technological means to test cognition in California sea lions through an animal-manipulated interface and has the potential to function as a form of cognitive enrichment in this species.

Key Words: computer task, cognition, marine mammal, cognitive enrichment, California sea lion, *Zalophus californianus*

Introduction

The use of technology in conducting cognitive studies in humans and animals has been prevalent for decades. Apparatuses have been created for primate species as a means to measure skills such as memory and planning using consistent testing methods, allowing for easier comparisons (see Perdue et al., 2018). First introduced to chimpanzees in the 1970s (Savage-Rumbaugh, 1977), the original presentation has been modified to test other primate species as well (e.g., Richardson et al., 1990; Washburn & Rumbaugh, 1992; Evans et al., 2008; Perdue et al., 2018). The Rumbaugh-X, used at Georgia State University's Language Research Center, has been incorporated in many different cognitive experiments and consists of a screen and a game controller for the animals to operate (Perdue et al., 2018). Utilizing a portable design, the apparatuses are brought to the animals and allow flexibility in presenting the system in different locations and contexts. The system facilitates comparative cognition research utilizing different species given the same type of task. For example, Beran & colleagues (2015) were able to comparatively test the planning ability of four species: rhesus monkeys (*Macaca mulatta*), capuchin monkeys (*Cebus apella*), chimpanzees (*Pan troglodytes*), and human children (*Homo sapiens*). By providing an identical task to all four primate species, direct comparisons in the evolutionary development of future-oriented processes, such as planning, could be evaluated (Beran et al., 2015).

In addition to scientific advancements, researchers in recent years have encouraged the introduction of cognitive enrichment into zoological settings in which animals are challenged to problem solve during the enrichment session (Clark, 2017; Makecha & Highfill, 2018). Such enrichment has included spatial challenges (e.g., Clark et al., 2013; Clark & Kuczaj, 2016), solving a puzzle (e.g., de Rosa et al., 2003; Kuczaj et al., 2009; Lauderdale & Miller, 2019), engaging in a cooperative task (e.g., Chalmeau, 1994; Péron et al., 2011; Plotnik et al., 2011; Kuczaj et al., 2015; Matrai et al., 2019), and interacting with computerized systems (Perdue et al., 2012; Kim-McCormack et al., 2016; Perdue, 2016; Egelkamp & Ross, 2018).

The diversity of games and stimuli that a computer system can present (Washburn et al., 1992) allows for various cognitive abilities to be tested and presents many opportunities to create variability with such a system in terms of type of gameplay as well as type of reinforcement administered (e.g., Washburn & Hopkins, 1994). Touchscreen interfaces have been used with success in zoological facilities (see Egelkamp & Ross, 2018, for review) but have been generally limited to terrestrial species, primarily primates. For species with anatomical differences that make using such a hand/finger driven controller challenging, researchers have been forced to construct large apparatuses to achieve similar findings (e.g., Schusterman & Kastak, 1993; Reichmuth Kastak & Schusterman, 2002b).

While researchers have been able to provide matching-to-sample tasks on computers for primates with relative ease (e.g., Washburn & Rumbaugh, 1992; Perdue et al., 2018), creating testing apparatuses for pinnipeds to evaluate the same concepts has required large contraptions and labor-intensive manipulation of physical stimuli (e.g., Schusterman & Kastak, 1993). Such apparatuses have resulted in the advancement of the understanding of sea lion cognition (Schusterman & Kastak, 1993; Reichmuth Kastak et al., 2001; Lindemann-Biolsi & Reichmuth, 2014), but a more portable and diverse testing system for marine mammals would provide benefits in both scientific and enrichment contexts. In the case of match-to-sample tasks, such a concept can be widely applied to various testing scenarios such as memory (e.g., Zentall & Smith, 2016), perception (e.g., Gierszewski et al., 2013), and facial recognition (e.g., Martin-Malivel & Okada, 2007). While video screens were used in Mauck & Dehnhardt's (1997) examination of mental rotation in sea lions, the animals only made contact with screens to denote a selection and were not responsible for driving a cursor in the same way that primates have been trained to interact with technology.

Cognitively challenging enrichment has not frequently been studied in California sea lions (*Zalophus californianus*), despite the pinniped's well-studied performance in cognitive experiments (e.g., Schusterman & Krieger, 1986; Schusterman & Kastak, 1993; Reichmuth Kastak & Schusterman, 2002a; Lindemann-Biolsi & Reichmuth, 2014). Evidence suggests that learning opportunities involving new behaviors and stimulus contingencies can serve as a form of enrichment while the animals are under stimulus control (Kastelein & Wiepkema, 1988; Laule & Desmond, 1998; Swaisgood & Shepherdson, 2005; Pomerantz & Terkel, 2009; Westlund, 2013) as the animals are provided the opportunity for cognitive challenge and social interactions. Thus, the creation of a testing system could provide additional enrichment to these animals.

The California sea lions in the care of the U.S. Navy's Marine Mammal Program (MMP) are housed in sea pens and provided with enrichment in the form of manipulatable objects and training sessions in their habitat as well as in open ocean, free release sessions. To provide additional enrichment within the home pen through the implementation of cognitive testing, a novel computerized system was introduced. The system needed to be animal-safe, easy to operate, cost-effective, operational using current session staffing (i.e., did not require additional personnel), and be portable to travel to and from animal habitats or other gameplay locations. The Enclosure Video Enrichment (EVE) system was designed to allow for cognitive gameplay video sessions as well as for use in conjunction with an automated feeder. We provide information on the successful deployment and training of this system with sea lions at the MMP, including training notes, data for performance trends observed in the subjects during later training phases, as well as lessons learned throughout the process.

Methods

Animals and Facility

The EVE system was created on-site at the MMP at the Naval Information Warfare Center (NIWC) Pacific in collaboration with the National Marine Mammal Foundation (NMMF). The sea lions were housed in 9 × 9 m^2 floating sea pens with attached haul-out areas in San Diego Bay, California. The MMP is accredited by the Association for Assessment and Accreditation of Laboratory Animal Care (AAALAC) and follows the standards of the U.S. Public Health Service Policy on the Humane Care and Use of Laboratory Animals and the Animal Welfare Act.

The subjects were three adult male California sea lions—"ANK," 12 y; "REX," 18 y; and "SLD," 19 y. They were selected based on their availability to regularly participate in these sessions. EVE sessions were run opportunistically with animals from July 2020 to October 2021. Participation in the sessions was voluntary, and duration of sessions depended on animal interest and success. Data presented herein was collected as the sea lions advanced through the initial Cursor Training Game (CTG), though the animals have since continued to interact with this and other games on EVE. Data collection with this system was approved under the MMP Institutional Animal Care & Use Committee (IACUC) Protocol #139-2020 and was reviewed by the Navy Bureau of Medicine and Surgery as Navy Research Database #1245.

EVE System

The EVE system was designed to be mobile as well as to be easy to operate and quick to set up and break down for sessions. A plastic utility cart was outfitted with a 27" Acer KB272 bix monitor and lockable wheels (Figure 1). The monitor was protected from water and animal contact using a plexiglass sheet attached to the front of the cart. A computer rested on the top of the cart inside of a protective case, with an external speaker and the game controller connected via Bluetooth and USB, respectively. The game controller for the sea lions consisted of a 6" × 6" electrical box with four 2.36" plastic arcade buttons placed in compass locations. The buttons were wired to a USB encoder which connected to the computer. An HDMI cable connected the computer to the monitor for sea lions to view and interact with the games. An automated feeder (described below) was designed to work in conjunction with the games and could be plugged in by a USB port. However, a trainer most often served as the "feeder" during the first year of EVE exposure and could reinforce the animals with fish, ice, and cheering.

The initial controller box was large (9" × 11"), with its purpose to prevent the sea lions from pressing multiple buttons at once, thus possibly inhibiting the understanding of each button's directionality. The animals did have several sessions in which pressing on the extra space of the box rather than the buttons was common. When a smaller controller was introduced a few sessions later, they quickly took to this design. While occasionally

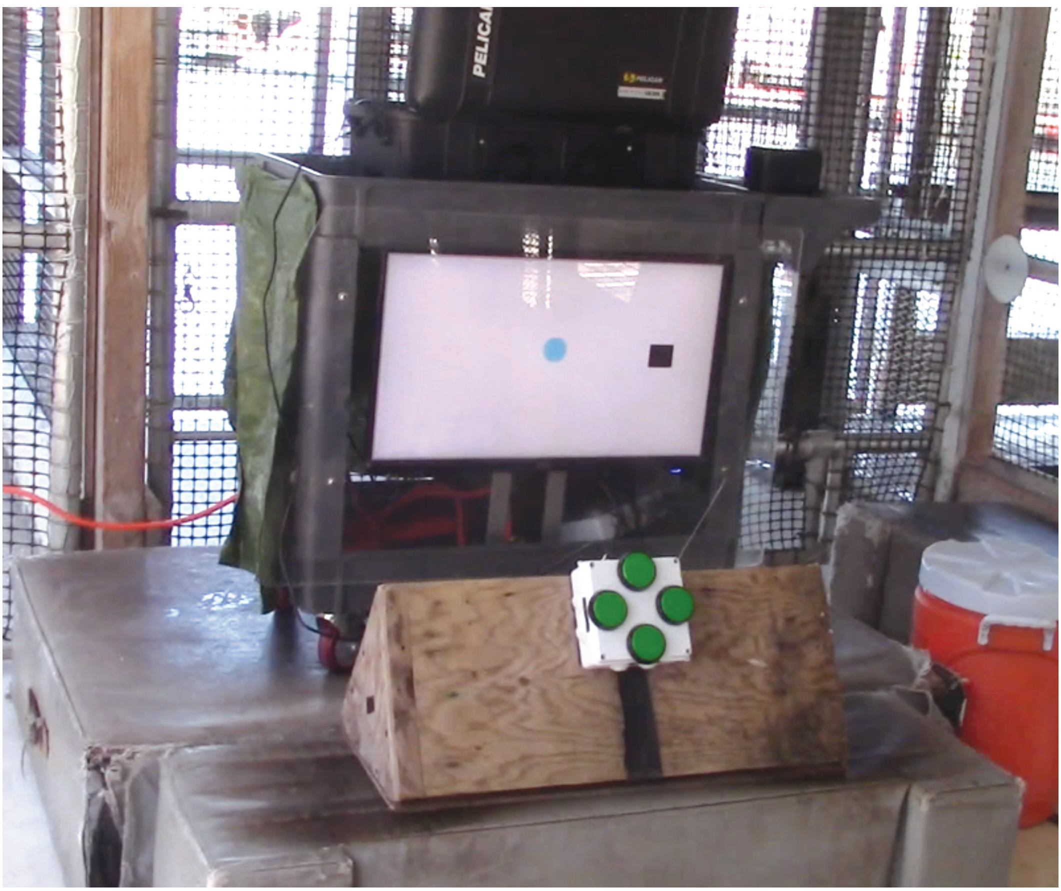

Figure 1. The Enclosure Video Enrichment (EVE) system. The controller was mounted on a wooden wedge and lifted by a pad for comfort.

multiple buttons were pressed (which resulted in diagonal movement), this did not seem to negatively impact the learning process for these three animals. Multiple button presses and diagonal movement did occur, but this primarily happened with ANK and was rare.

Sessions were completed when time and staffing allowed. Session length was determined by animal interest (e.g., level of focus and engagement), general performance, and portion of the daily food ration available for EVE sessions. If an animal was showing signs of disengagement or frustration, the session ended. Animals were reinforced with fish, ice, and cheering from the trainer; however, SLD had several lengthy (> 30 min) sessions in which ice and cheering were the only reinforcements available, and he continued to remain engaged.

To protect the buttons from environmental elements, as well as contact with the sea lions' muzzles, a plastic covering was initially used. The cover seemed to inhibit the animals' ability to find the buttons. When it was removed, they progressed rapidly. It is possible the cover made it more difficult for the animals to detect individual buttons using their vibrissae. Tension created by the cover also made depressing multiple buttons more likely, so the cover was removed after the first few sessions.

Automated Feeder

An automated feeder was constructed based on Goldblatt's (1992) design for a marine mammal feeder. The automated feeder used for this project consisted of an 8' × 3" clear PVC tube connected to a water tank. The operation of the feeder was controlled by an Arduino micro-controller, connected via USB to the computer and via a cable to a solenoid valve. Successful gameplay (i.e., moving the circle to contact the target) signaled the Arduino to operate the solenoid valve, which released air into the water tank. The change in pressure pushed water up to the tube, moving a plastic piston forward and pushing reinforcement (pieces of fish and ice) out of the tube. The feeder was introduced to the sea lions with EVE in July of 2021. It was used for ANK during ten of the sessions in this study, and for eight sessions with SLD. REX was not shown the feeder until after he had advanced from the CTG (see Table 1); it was not used in any of the sessions reported herein.

The Cursor Training Game (CTG)

EVE games were designed based on prior literature (Washburn et al., 1992) and programmed in C# using the *Unity Development* platform, Version 2019.2.15f1. The initial game for each sea lion was the CTG, which taught the cursor driving concept that is used in all other EVE games (see supplemental video footage). Data from game sessions (i.e., animal name, trial, response time, and directional button presses and durations) was exported to .csv files for use in records and analysis. All games were operated in the same manner: the cursor or "player" controllable by the animals was a bright blue circle (HEX: 00d8fb; RGB: rgba[0, 216, 251, 255]) that changed in size from large to small in later phases as the animals became more proficient at operating the controller. The cursor color was chosen based on behavioral color discrimination work that showed sea lions could discriminate blue from grey (Griebel & Schmid, 1992), but it also varied in brightness from both the target and background. The target on each trial was a black box on a white background, providing high contrast for visual detection by the animals. Once contact was made, a tone sounded, and the animal was reinforced with fish and encouragement from the trainer or the feeder as the next trial loaded. As in the case with the circle, the target object(s) became smaller and more challenging to contact as animals advanced through the training phases. In early phases, grey walls were used to restrict movement in directions away from the target. The walls were later used in other games, so their introduction early in the training process was seen as a benefit.

CTG Phases

Initially, the sea lions were presented with a relatively blank screen—just an open space in which the cursor could be moved across the screen with no target or clear goal. The trainer monitored sea lion eye movement and reinforced the animals for tracking the circular cursor or switching buttons. Once the sea lions were pressing buttons, looking at the screen, and occasionally tracking the circle's movement with their eyes, they began playing CTG trials with targets.

The CTG contained six phases, each comprised of trials with increasing difficulty (Figure 2) intended to shape the animals' understanding of directionality and precision of their control. The individual trials within each phase were designed to evenly distribute target directions across the game to counteract positional biases. Phase 1 levels reinforced brief contact with the buttons by providing multiple targets near the cursor. The sea lion was required to drive the cursor to touch all targets on each trial before moving on to the next trial, which resulted in equal reinforcement for each button direction over the course of the session. Some trials only required two or three directions (e.g., LEFT, RIGHT, DOWN); however, all directions were equally represented within the phase. The change in layout and number of targets

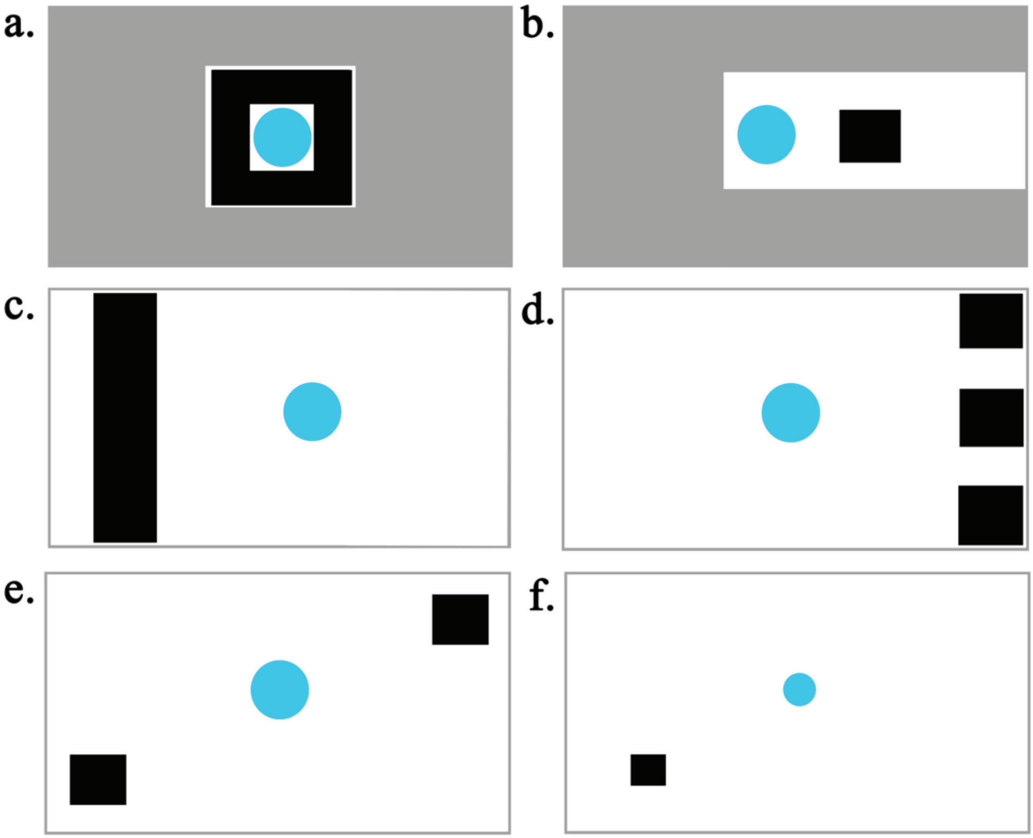

Figure 2. Example trials of Training Phases 1 (a), 2 (b), 3 (c), 4 (d), 5 (e), and 6 (f). The blue circle is the cursor controlled by the sea lion, the black rectangles are the target objects, and the grey walls restrict movement.

was implemented to vary the visual appearance on the screen and thus encourage attention toward the screen rather than toward the controller or trainer, as well to deter the learning of a sequence (e.g., UP, LEFT, DOWN, RIGHT). In Phase 2, one direction per trial was rewarded, with the ability to move in incorrect directions being limited by the grey walls. In Phase 3, the sea lion could move in all four directions; however, sustained movement in the correct direction resulted in a tone. For Phase 4, multiple targets (three to four) were located on one side of the screen. The sea lion was required to move in three of the four directions (e.g., RIGHT, UP, DOWN) within the same trial in order to move on; each contact resulted in a tone. The number of targets per trial was based on the amount of identical sized targets that could fit the entirety of that side of the screen. Phase 5 had fewer targets, and those targets were located on opposing sides of each other, requiring the sea lion to move in opposing directions within the same trial (e.g., UP and RIGHT and then DOWN and LEFT). Lastly, Phase 6 had one small target located at random positions on the screen.

Training to Interact with EVE

The desensitization process with EVE went rapidly. The Navy animals were not concerned with the cart or the screen when it was introduced and videos were played for them. Instead, they needed to be encouraged to look at the screen. Because the sea lions had a long training history of monitoring the attention and movement of the trainer and ignoring irrelevant external stimuli, the animals required training to understand that the screen was relevant. The sea lions were directed to sit in front of the cart while the researcher advanced trials manually rather than through gameplay (i.e., loading trials without moving the player). The trainer reinforced the animals for visually monitoring the changes on the screen based on sea lion eye movements. During sessions, the blue circle was never moved without the sea lion's own actions; rather, programming within the game allowed for manual trial progression through a key press on the computer. Thus, target and wall locations on the screen would change every 2 to 3 s as trials were manually advanced, providing visually distinct images to draw the animals' attention.

Programming within the game allowed for manual administration of the "success" tone without requiring contacting the target with the circle. Tone conditioning took a single session for each animal before they responded to the tone in a similar manner as they did to the verbal "Good" cue typically used by the trainers as a conditioned reinforcer to terminate a successful behavior.

The sea lions were next presented with a button that was not connected to the controller and encouraged to make contact with the button. This extra button was also used in instances where prompting the correct button on the controller was necessary in early phases (e.g., if the animal continually pressed on the controller box rather than a button). The button made a soft but audible "click" sound when depressed, which likely served as an additional reinforcer for the button pressing behavior. The trainer would also point to the correct button to prompt the sea lion to press it.

The sea lions moved through the six CTG phases at trainer discretion, with the ability to regress to earlier phases permitted. In the early phases (i.e., Phases 1 and 2), the amount of prompting and cueing was used as a measure to determine when the animal was improving and ready to move to the next phase. Criteria for advancement in subsequent phases included animals reliably tracking cursor movement visually, spontaneously switching buttons when the cursor stopped moving (i.e., made contact with a wall) or when going in an incorrect direction away or parallel to the target, as well as reduced time and number of button presses to contact the target. All three sea lions experienced different versions of CTG during its first introduction as modifications and improvements were made, making early comparisons between individuals difficult. Phases 1 and 2 initially did not have the grey walls to restrict movement and were subsequently modified based on animal performance. In the original Phase 1, in which targets were present on all four sides without grey walls to restrict movement, sea lions would hold a button and travel along the open space, making the return to the additional targets difficult. Thus, the grey walls prevented that movement and encouraged earlier success in that switching buttons, however briefly, would result in a tone. Biases toward certain buttons (in particular UP and LEFT) were noticed early on, and this was subsequently corrected through the requirement that the animals must press all buttons within one trial to move to the next phase. In early stages, the animals needed to only make contact with any button briefly to move on. When needed, the trainer would use the extra button as a prompt to press a button that had been neglected. Over time, these preferences disappeared.

During Phase 6, the performance of the sea lions was monitored to assess when the animal was considered to have acquired the concept of controlling the cursor and could move on to the next game. The criteria to advance from CTG for these three sea lions was to complete two consecutive sessions in which the average latency to success was less than 6 s from the first contact with a button (to travel from the starting point to one horizontal wall and then one vertical wall in two button presses was 3 s) and the average number of button presses per trial was less than seven presses (the minimum number of presses needed for most trials of Phase 6 was two). ANK and SLD were given additional sessions based on variability within earlier qualifying sessions to ensure concept acquisition before more challenging games were introduced (ANK: 4; SLD: 3).

Statistical Analyses

Nonparametric statistics (Kruskal Wallace and Mann-Whitney U) tests were performed given the uneven sample sizes of the data. Data regarding button presses, durations, and latency to contact were obtained from the data exported by the game. Analyses were conducted in *SPSS*, Version 21.

Results

All three California sea lions successfully graduated from the CTG and were considered proficient enough to operate additional games in the EVE system (Table 1). While the rates of acquisition varied, the sea lions were also exposed to differing training techniques, later-modified early EVE trials, and sessions of EVE with the automated feeder.

Each animal progressed from the CTG at different rates over the course of 16 mo (Table 2). REX's availability was such that his sessions were able to occur at a higher frequency, likely resulting in the faster acquisition of gameplay concepts. For ANK and SLD, the longest time period between sessions was 55 d, whereas for REX it was 21 d.

There was a significant difference in the number of trials per session ($H[2] = 9.431$; $p < 0.01$) and session duration in minutes ($H[2] = 18.461$; $p < 0.001$) between the three animals over the course of their training (Figure 3). ANK (Mean Rank = 58.39) had significantly shorter sessions ($U = 1{,}614.00$, $z = -2.02$, $p < 0.05$) than REX (Mean Rank = 71.64). SLD's (Mean Rank = 73.33)

Table 1. Information about individual animal acquisition of the button pressing concept

Animal	Start date (d/mo/y)	End date (d/mo/y)	Total session days	Avg. days between sessions	Total trials	Total time (min)	Avg. session length (min)	Median trials per session
ANK	23/7/20	14/10/21	64	6.62	2,050	817	11.84	26
REX	9/9/20	6/5/21	59	4.12	1,626	819	13.88	23
SLD	3/8/20	20/9/21	63	7.00	2,436	1,367	22.78	34

Table 2. The number of sessions completed for each animal by month and year. While REX was the last animal to be exposed to EVE, he was the first to complete training.

	2020						2021										
Animal	July	Aug	Sept	Oct	Nov	Dec	Jan	Feb	March	April	May	June	July	Aug	Sept	Oct	Total
ANK	2	6	4	8	3	1	1	1	3	1	1	5	7	10	8	3	64
REX			3	1	11	18	5	5	11	4	1						59
SLD		6	2	11	7	4	1	1	2	1	1	5	7	10	5		63

sessions were significantly longer than ANK's (Mean Rank = 52.12; U = 1,181.50, z = -4.204, $p < 0.001$). SLD (Mean Rank = 67.39) also had significantly longer sessions than REX (Mean Rank = 52.48; U = 1,326.50, z = -2.361, $p < 0.05$).

SLD (Mean Rank = 73.33) completed significantly more trials than ANK (Mean Rank = 57.76; U = 1,570.50, z = -2.36, $p < 0.05$). This trend was also seen when comparing SLD's (Mean Rank = 69.21) trial count per session with REX's (Mean Rank = 50.64; U = 1,217.50, z = -2.939, $p < 0.01$).

Phase 6 Comparisons

Each sea lion achieved acquisition criteria within 13 Phase 6 sessions. ANK completed 13 sessions (584 trials), REX completed 13 sessions (479 trials), and SLD completed 12 sessions (576 trials) before graduating from the CTG. The latency to success (Figure 4) declined over the Phase 6 sessions for each animal. Pearson correlations between the Phase 6 session number and the latency to contact established significant negative correlations for ANK (r[582] = -0.330; $p < 0.001$), REX (r[477] = -0.218; $p < 0.001$), and SLD (r[574] = -0.155; $p < 0.001$).

The number of button presses per trial declined for ANK and SLD but remained relatively stable for REX from the first session to the last session of Phase 6 (Figure 5). Pearson's correlations showed significant negative correlations between Phase 6 sessions and number of button presses for ANK (r[582] = -0.213; $p < 0.001$) and SLD (r[574] = -0.201; $p < 0.001$), while the correlation for REX (r[477] = 0.088; $p = 0.054$) was not significant.

During Phase 6 of CTG, there was significant difference across all animals in the latency to contact the target (H[2] = 14.887; $p = 0.001$) and the number of button presses (H[2] = 39.034; $p < 0.001$) per trial (Figure 6). ANK (Mean Rank = 578.80) pressed the buttons significantly more than REX (Mean Rank = 473.93; U = 112,053.00, z = -5.60, $p < 0.001$). ANK (Mean Rank = 628.77) also had significantly more button presses per session than SLD (Mean Rank = 530.64; U = 139,470.50, z = -5.043, $p < 0.001$). SLD's (Mean Rank = 545.32) latency to contact the target was significantly shorter than ANK (U = 147,931.00, z = -3.553, $p < 0.001$). SLD (Mean Rank = 502.03) was also significantly faster to success than REX (Mean Rank = 559.22; U = 122,966.00, z = -3.035, $p < 0.01$).

Lessons Learned

When first exposed to EVE, the sea lions did not attend to the screen but would react at the sound of the conditioned tone. To encourage focus on the screen, sessions were conducted in which the researcher rapidly progressed through the trials manually. Trainers then reinforced animals for taking notice of the change. The Blank Screen trial was also used in such a way that the sea lions were encouraged to press a button, with the trainer reinforcing the sea lion for visually tracking the blue circle moving across the screen.

Over time, the sea lions began to focus more intensely on the screen and would visually monitor the movement of the blue circle. Eventually, when the circle would stop moving at the edge of the screen as it came in contact with the thin grey walls framing the space, the sea lions began switching to a different button. As the sea lions learned the goal (i.e., come into contact with the square), they began switching buttons more

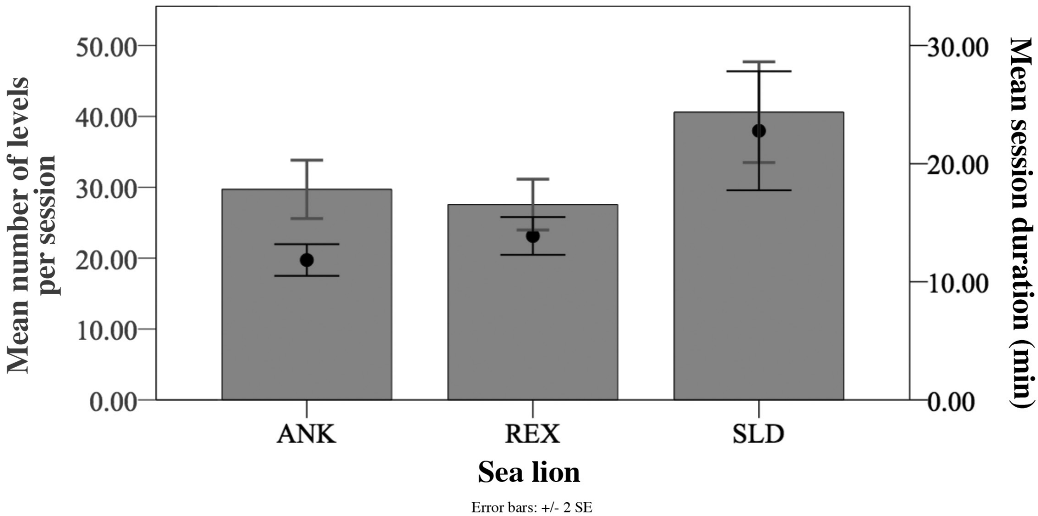

Figure 3. Outcomes of the mean number of trials per session (grey bars) and mean session duration in minutes (black circles) for each of the animals prior to obtaining proficiency moving the cursor

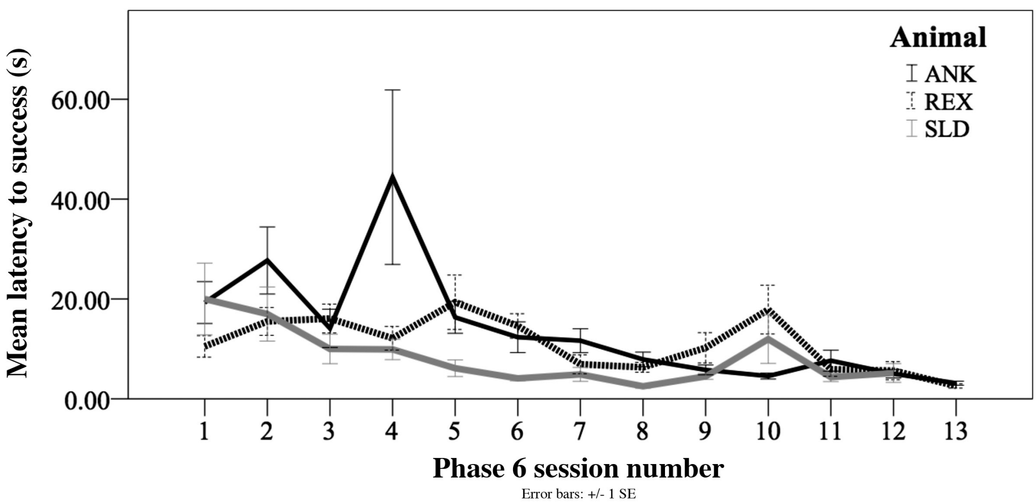

Figure 4. Observations of the mean latency to success in seconds for each sea lion during Phase 6 sessions

rapidly when the cursor went in the incorrect direction. During this time, they heavily relied on the edges of the screen and held buttons down until movement ceased (i.e., the cursor contacted the edge of the screen) before switching buttons.

When the targets were first presented as "floating" in Phase 4, the sea lion needed to stop pressing the button mid-screen without relying on the walls; this became an additional challenge (Figure 7). Because of the predisposition of some animals to continue to press until the cursor collided with a wall, trainer intervention was applied in some instances. Trainers would ask the animal to "wait" mid-press, stopping the cursor at the correct time and giving the animal the opportunity to make a button change in a different direction. After Phase 2, the trainers generally did not cue particular buttons as the sea lions were regularly switching buttons when movement on the screen would cease. Rather, the trainers tried to set the animals up to select the correct button by asking them to "wait," backing the animal up from the screen, or by changing the animal's body position such as walking

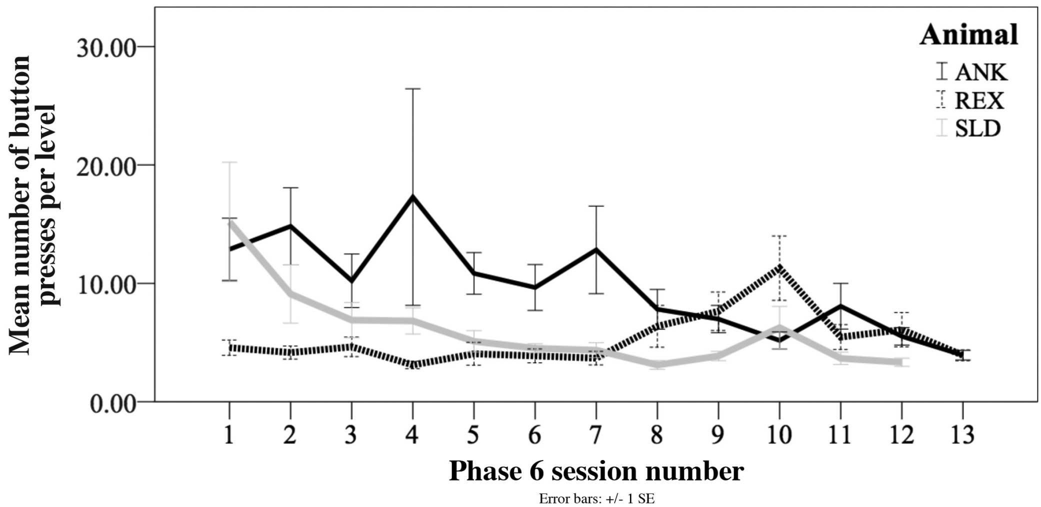

Figure 5. Observations for the average number of button presses per trial by each sea lion during Phase 6 sessions

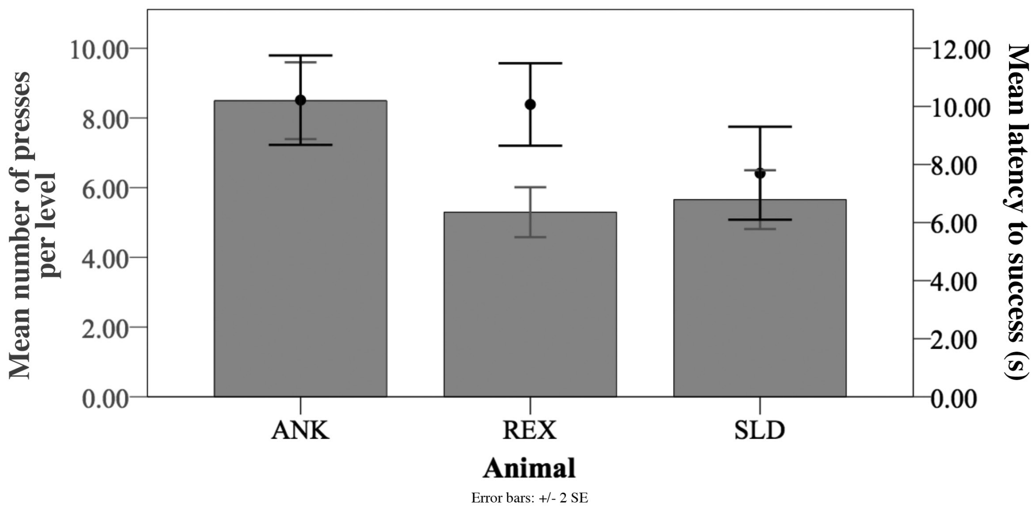

Figure 6. Outcomes of the number of presses (grey bars) and latency to contact the target (black circles) for each individual during Phase 6

them away and returning. This "reset" aided the animals in pressing different buttons and in learning to come off one button prior to hitting a wall.

While learning this button-pressing skill, sea lions were also noted to approach the targets with the cursor in a clockwise direction, lining up with the target from a distance before closing the distance to contact the target. The possibility of this strategy, as well as other patterns (e.g., moving as if on a staircase), warrants further investigation.

Discussion

We present the first successful use of a cursor-driven computerized testing system by California sea lions living in professional care. While such research paradigms have been used for decades in species such as chimpanzees (Savage-Rumbaugh, 1986) and pigeons (*Columba livia domestica*; Blough, 1977), and have recently been implemented in other zoological species such as red-footed tortoises (*Chelonoidis carbonaria*; Mueller-Paul et al., 2014),

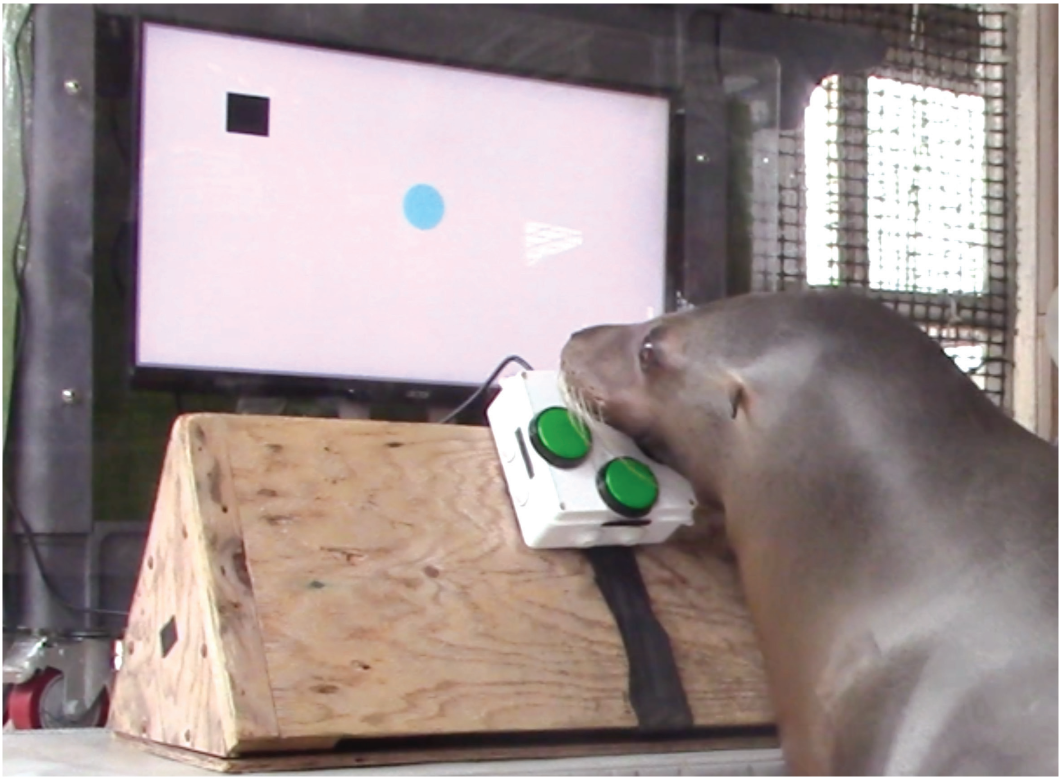

Figure 7. Screen shot showing the behavior of a California sea lion in Phase 6 with a "floating" target

mandrill monkeys (*Mandrillus sphinx*; Leighty et al., 2011), and sun bears (*Helarctos malayanus*; Perdue, 2016), the ecological and biological constraints of marine mammals have prevented an easy adaptation of this design. Comparisons between sea lion cognition and other species tested in similar ways are now possible using the EVE system. EVE is easy to set up and operate, relatively inexpensive, and can be used in conjunction with an automated feeder. We are aware of no other published examples of a video game system operated by sea lions.

Designing a controller for the sea lions to operate was the main challenge faced when constructing EVE. Because of the slimy nature of their fish reinforcement and the tendency of fish remnants to cling to whiskers, touch screens were not pursued. Instead, the decision was made to use a four-button controller, which would allow their eyes to still easily see the screen while they operated the buttons. A joystick was considered; however, the concern that the sea lions would engage by biting it, breaking it, or potentially injuring themselves when interacting with it using their face (e.g., poking the eyes) discouraged its implementation.

It is important to note that while the sea lions did appear to learn the directionality of the buttons, they were observed leaning in the target's direction while pressing a button. For example, if the target was UP and RIGHT from the cursor, the sea lion would press UP but lean its head toward the RIGHT. Thus, a joystick-like controller might be very intuitive for these animals if one was fabricated to be large, strong, and safe enough for them to operate.

Individual differences in all areas of acquisition and participation were seen between these three animals. SLD had longer sessions and went through more trials per session on average than ANK and REX. SLD also had sessions in which only ice was available as reinforcement, yet he continued to stay engaged with the system. During these ice-only sessions, progression to the next CTG phase was not undertaken. Rather, SLD continued on a lower CTG phase with which he had a reinforcement history and was considered to be somewhat proficient at playing. Advancement was only undertaken when fish could be used to reinforce the more challenging trials and maintain the reinforcement value of EVE.

ANK pressed the buttons significantly more often than the other two sea lions, though his latency to contact was very similar to REX's. REX and SLD pressed the buttons a similar number of times;

however, SLD's latency to contact the target was significantly shorter than REX's. Thus, it appears that SLD's movements toward the target were more efficient, whereas REX might have taken "longer" ways with a similar number of presses. It is important to note that efficiency was not a criterion of this game (i.e., there was no time limit placed on contacting the target), but it did result through the natural gameplay progression. Regardless of the number of presses or the duration of the latency to success, the sea lion was reinforced for contacting the target. Thus, reductions in button presses and latency were a natural occurrence for the animals as they progressed through CTG phases, likely to more rapidly receive reinforcement with less effort. However, further research is needed into the strategies that these animals used as they acquired the cursor driving skill.

Over the course of Phase 6, ANK and SLD generally had a steady decline in the number of presses per trial, as well as the amount of time to contact the target. REX's latency shortened, but the number of presses he used per trial remained stable from the first to the last session. Thus, while both criteria were used as a measure to determine the acquisition of the directionality and cursor movement concept, the reduction in latency might be the most telling standard in proficiency assessment. REX was also the last animal to begin interacting with EVE, thus the training procedure and trials had been tested and modified from SLD's and ANK's early sessions.

It is perhaps noteworthy that animals in later stages of learning acquisition were observed to occasionally take the "long" way to contact a target, potentially finding the action of controlling the cursor inherently reinforcing as they watched it move. Previous studies suggest that being able to control a stimulus is reinforcing as macaques (*Macaca nemestrina*; Paukner et al., 2005) and capuchins (Paukner et al., 2009) prefer to observe a human imitating their own actions as they manipulated a cube compared to watching a human doing different actions than the monkeys as they manipulated their cubes. Similarly, human infants seem to enjoy observing their own reflections prior to understanding that they are the human in the reflection (see Rochat, 2001). Observations of the reinforcing nature of choice have been reported elsewhere in animals (Tarou et al., 2004; Egelkamp & Ross, 2018), and control has been noted as one of the Four Cs of psychological well-being in primates and is an important facet of enrichment (Washburn, 2015). Such results warrant further investigation in sea lions.

The success of this system provides research opportunities for scientists and animal care staff at facilities housing pinnipeds, as well as the potential for improved enrichment and welfare for sea lions (Egelkamp & Ross, 2018). Pinniped enrichment programs have included objects (Kuczaj et al., 2002; Smith & Litchfield, 2010) and feeding manipulations (Hocking et al., 2015), as well as the addition of novel scents (Samuelson et al., 2016). The diversity within the type of games provided, as well as EVE's capability to show videos or play audio, provides ample variability for an enrichment program (Kuczaj et al., 2002) as well as a research paradigm (Perdue et al., 2018). While fully aquatic species such as bottlenose dolphins (*Tursiops truncatus*), rough toothed dolphins (*Steno bredanensis*; Winship & Eskelinen, 2018), and killer whales (*Orcinus orca*; Hanna et al., 2017) have been shown video as enrichment, there is no published data regarding pinniped exposure to this type of media. With the ability to drive a cursor, the sea lions could choose from several types of media. The ease of variability of EVE may mitigate issues that have limited the frequency of enrichment deployment in zoological facilities: staff time and required effort (Hoy et al., 2010).

Providing animals in professional care with a stimulating and challenging environment is a key component in achieving animal welfare goals (Clegg et al., 2015; Washburn, 2015; Makecha & Highfill, 2018). The implementation of enrichment is commonly used to target stereotypic behaviors, and such programs are generally successful in achieving this goal (e.g., Swaisgood & Shepherdson, 2005; Shyne, 2006). Diversity in enrichment type (e.g., objects, scents, sounds, visual changes) allows for combinations that can be catered to particular species or an individual's interests (e.g., Eskelinen et al., 2015). Such variability is an important component of enrichment programs as it reduces opportunities for habituation (Kuczaj et al., 2002), thus extending the effectiveness of particular enrichment devices.

EVE has the potential to improve sea lion welfare by providing cognitive enrichment (Perdue et al., 2018), variability (Kuczaj et al., 2002), choice (Perdue et al., 2014), and control (Buchanan-Smith & Badihi, 2012). REX was observed to have improved weight maintenance and performance in voluntary husbandry behaviors (e.g., blood draw) following his exposure to EVE, and the system has been used as a secondary reinforcer following successful husbandry behaviors. However, linking these welfare benefits to EVE access requires additional testing.

Better understanding of sea lion cognitive abilities can provide researchers with information regarding species resiliency to rapidly changing environments as a result of anthropogenic behavior (Greggor et al., 2014, 2020; Mumby & Plotnik, 2018). Additionally, as documentation of domoic acid toxicity increases in marine mammals (Simeone et al., 2015), monitoring changes in cognitive function of rescued and non-releasable pinnipeds using this system may help veterinarians monitor cognitive changes associated with neurological disease as these animals age (Hoard & Janech, 2019; Simeone et al., 2019). Also, testing potential avenues for treatment using non-releasable animal performance at various tasks following exposure to medical interventions may provide insight into the development of additional treatments to be used in instances of future stranded animals to increase successful release outcomes.

Future studies incorporating EVE should investigate its use as enrichment outside of training sessions, as well as modifying the type of reinforcement (e.g., videos, the automated feeder) and the reinforcement schedule. Other interests include the learning processes, individual preferences in games, and how individual characteristics could influence the patterns and strategies observed between animals.

Note: A supplemental video for this article is available in the "Supplemental Material" section of the *Aquatic Mammal*s website: https://www.aquaticmammalsjournal.org/index.php?option=com_content&view=article&id=10&Itemid=147.

Acknowledgments

We would like to express gratitude to the Navy employees, contractors and students who aided in the construction, training, and deployment of EVE and their continued support of this system, especially Christian Harris, Jennifer Dunham, Mike Burton, Anson Brune, David Fitzgerald, Alycia Coulombe, Taylor Megginson, Chrissy Lamendola, and Grace Frame.

Literature Cited

Beran, M. J., Parrish, A. E., Futch, S. E., Evans, T. A., & Perdue, B. M. (2015). Looking ahead? Computerized maze task performance by chimpanzees (*Pan troglodytes*), rhesus monkeys (*Macaca mulatta*), capuchin monkeys (*Cebus apella*) and human children (*Homo sapiens*). *Journal of Comparative Psychology*, *129*(2), 160-173. https://doi.org/10.1037/a0038936

Blough, D. S. (1977). Visual search in the pigeon: Hunt and peck method. *Science*, *196*, 1013-1014. https://doi.org/10.1126/science.860129

Buchanan-Smith, H. M., & Badihi, I. (2012). The psychology of control: Effects of control over supplementary light on welfare of marmosets. *Applied Animal Behaviour Science*, *137*(3-4), 166-174. https://doi.org/10.1016/j.applanim.2011.07.002

Chalmeau, E. (1994). Do chimpanzees cooperate in a learning task? *Primates*, *35*(3), 385-392. https://doi.org/10.1007/BF02382735

Clark, F. E. (2017). Cognitive enrichment and welfare: Current approaches and future directions. *Animal Behavior and Cognition*, *4*(1), 52-71. https://doi.org/10.12966/abc.05.02.2017

Clark, F. E., & Kuczaj II, S. A. (2016). Lateralized behavior of bottlenose dolphins using an underwater maze. *International Journal of Comparative Psychology*, *29*(1), 1-16. https://doi.org/10.46867/ijcp.2016.29.00.19

Clark, F. E., Davies, D. L., Madigan, A. W., Warner, A. J., & Kuczaj II, S. A. (2013). Cognitive enrichment for bottlenose dolphins (*Tursiops truncatus*): Evaluation of a novel underwater maze device. *Zoo Biology*, *32*(6), 608-619. https://doi.org/10.1002/zoo.21096

Clegg, I. L. K., Borger-Turner, J. L., & Eskelinen, H. C. (2015). C-Well: The development of a welfare assessment index for bottlenose dolphins (*Tursiops truncatus*). *Animal Welfare*, *24*, 267-282. https://doi.org/10.7120/09627286.24.3.267

de Rosa, C., Vitale, A., & Puopolo, M. (2003). The puzzle-feeder as feeding enrichment for common marmosets (*Callithrix jacchus*): A pilot study. *Laboratory Animals*, *37*, 100-107. https://doi.org/10.1258/00236770360563732

Egelkamp, C. L., & Ross, S. R. (2018). A review of zoo-based cognitive research using touchscreen interfaces. *Zoo Biology*, *38*(2), 220-235. https://doi.org/10.1002/zoo.21458

Eskelinen, H. C., Winship, K. A., & Borger-Turner, J. L. (2015). Sex, age, and individual differences in bottlenose dolphins (*Tursiops truncatus*) in response to environmental enrichment. *Animal Behavior and Cognition*, *2*(3), 241-253. https://doi.org/10.12966/abc.08.04.2015

Evans, T. A., Beran, M. J., Chan, B., Klein, E. D., & Menzel, C. R. (2008). An efficient computerized testing method for the capuchin monkey (*Cebus apella*): Adaptation of the LRC-CTS to a socially housed nonhuman primate species. *Behavior Research Methods*, *40*(2), 590-596. https://doi.org/10.3758/BRM.40.2.590

Gierszewski, S., Bleckmann, H., & Schluessel, V. (2013). Cognitive abilities in Malawi cichlids (*Pseudotropheus* sp.): Matching-to-sample and image/mirror-image discriminations. *PLOS ONE*, *8*(2), e57363. https://doi.org/10.1371/journal.pone.0057363

Goldblatt, A. (1992). Automatic feeder for marine mammals. *Aquatic Mammals*, *18*(3), 82-84.

Greggor, A. L., Berger-Tal, O., & Blumstein, D. T. (2020). The rules of attraction: The necessary role of animal cognition in explaining conservation failures and successes. *Annual Review of Ecology, Evolution, and Systematics*, *51*, 483-503. https://doi.org/10.1146/annurev-ecolsys-011720-103212

Greggor, A. L., Clayton, N. S., Phalan, D., & Thornton, A. (2014). Comparative cognition for conservationists. *Trends in Ecology and Evolution*, *29*(9), 489-495. https://doi.org/10.1016/j.tree.2014.06.004

Griebel, U., & Schmid, A. (1992). Color vision in the California sea lion (*Zalophus californianus*). *Vision Research*, *32*(3), 477-482. https://doi.org/10.1016/0042-6989(92)90239-F

Hanna, P., Brown, B., Winship, K., Cameron, D., Hill, H., & Kuczaj, S. (2017). A killer whale's (*Orcinus* *orca*) response to visual media. *International Journal of Comparative Psychology*, *30*, 1-14. https://doi.org/10.46867/ijcp.2017.30.00.11

Hoard, V. F., & Janech, M. G. (2019). Neurological deficits in stranded California sea lions. *Veterinary Record*, *185*(10), 301-303. https://doi.org/10.1136/vr.l5400

Hocking, D. P., Salverson, M., & Evans, A. R. (2015). Foraging-based enrichment promotes more varied behaviour in captive Australian fur seals (*Arctocephalus pusillus doriferus*). *PLOS ONE*, *10*(5), e0124615. https://doi.org/10.1371/journal.pone.0124615

Hoy, J. M., Murray, P. J., & Tribe, A. (2010). Thirty years later: Enrichment practices for captive mammals. *Zoo Biology*, *29*(3), 303-316. https://doi.org/10.1002/zoo.20254

Kastelein, R. A., & Wiepkema, P. R. (1988). The significance of training for the behaviour of Steller sea lions (*Eumetopias jubata*) in human care. *Aquatic Mammals*, *14*(1), 39-41.

Kim-McCormack, N. N. E., Smith, C. L., & Behie, A. M. (2016). Is interactive technology a relevant and effective enrichment for captive great apes? *Applied Animal Behaviour Science*, *185*, 1-8. https://doi.org/10.1016/j.applanim.2016.09.012

Kuczaj II, S. A., Gory, J. D., & Xitco, M. J., Jr. (2009). How intelligent are dolphins? A partial answer based on their ability to plan their behavior when confronted with novel problems. *The Japanese Journal of Animal Psychology*, *59*(1), 99-115. https://doi.org/10.2502/janip.59.1.9

Kuczaj II, S. A., Winship, K. A., & Eskelinen, H. C. (2015). Can bottlenose dolphins (*Tursiops truncatus*) cooperate when solving a novel task? *Animal Cognition*, *18*, 543-550. https://doi.org/10.1007/s10071-014-0822-4

Kuczaj II, S. A., Lacinak, T., Otto, F., Trone, M., Solangi, M., & Ramos, J. (2002). Keeping environmental enrichment enriching. *International Journal of Comparative Psychology*, *15*(2), 127-137. https://doi.org/10.46867/C4XK5N

Lauderdale, L. K., & Miller, L. J. (2019). Common bottlenose dolphin (*Tursiops truncatus*) problem solving strategies in response to a novel interactive apparatus. *Behavioural Processes*, *169*, 103990. https://doi.org/10.1016/j.beproc.2019.103990

Laule, G., & Desmond, T. (1998). Positive reinforcement training as an enrichment strategy. In D. H. Shepherdson, J. D. Mellen, & M. Hutchins (Eds.), *Second nature – Environmental enrichment for captive animals* (pp. 302-313). Smithsonian Institution Press.

Leighty, K. A., Maloney, M. A., Kuhar, C. W., Phillips, R. S., Wild, J. M., Chaplin, M. S., & Bettinger, T. L. (2011). Use of a touchscreen-mediated testing system with mandrill monkeys. *International Journal of Comparative Psychology*, *24*(1), 60-75. https://doi.org/10.46867/IJCP.2011.24.01.05

Lindemann-Biolsi, K. L., & Reichmuth, C. (2014). Cross-modal transitivity in a California sea lion (*Zalophus californianus*). *Animal Cognition*, *17*, 879-890. https://doi.org/10.1007/s10071-013-0721-0

Makecha, R. N., & Highfill, L. E. (2018). Environmental enrichment, marine mammals, and animal welfare: A brief review. *Aquatic Mammals*, *44*(2), 221-230. https://doi.org/10.1578/AM.44.2.2018.221

Martin-Malivel, J., & Okada, K. (2007). Human and chimpanzee face recognition in chimpanzees (*Pan troglodytes*): Role of exposure and impact on categorical perception. *Behavioral Neuroscience*, *121*(6), 1145-1155. https://doi.org/10.1037/0735-7044.121.6.1145

Matrai, E., Ng, A. K. W., Chan, M. M. H., Gendron, S. M., & Dudzinski, K. M. (2019). Testing use of a potential cognitive enrichment device by an Indo-Pacific bottlenose dolphin (*Tursiops aduncus*). *Zoo Biology*, *39*(3), 156-167. https://doi.org/10.1002/zoo.21536

Mauck, D., & Dehnhardt, G. (1997). Mental rotation in a California sea lion (*Zalophus californianus*). *Journal of Experimental Biology*, *200*, 1309-1316. https://doi.org/10.1242/jeb.200.9.1309

Mueller-Paul, J., Wilkinson, A., Aust, U., Sterurer, M., Hall, G., & Huber, L. (2014). Touchscreen performance and knowledge transfer in the red-footed tortoise (*Chelonoidis carbonaria*). *Behavioural Processes*, *106*, 187-192. https://doi.org/10.1016/j.beproc.2014.06.003

Mumby, H. S., & Plotnik, J. M. (2018). Taking the elephants' perspective: Remembering elephant behavior, cognition and ecology in human-elephant conflict mitigation. *Frontiers in Ecology and Evolution*, *6*. https://doi.org/10.3389/fevo.2018.00122

Paukner, A., Suomi, S. J., Visalberghi, E., & Ferrari, P. F. (2009). Capuchin monkeys display affiliation toward humans who imitate them. *Science*, 325(5942), 880-883. https://doi.org/10.1126/science.1176269

Paukner, A., Anderson, J. R., Borelli, E., Visalberghi, E., & Ferrari, P. F. (2005). Macaques (*Macaca nemestrina*) recognize when they are being imitated. *Biology Letters*, *1*, 219-222. https://doi.org/10.1098/rsbl.2004.0291

Perdue, B. M. (2016). The effect of computerized testing on sun bear behavior and enrichment preferences. *Behavioral Sciences*, *6*(4), 19. https://doi.org/10.3390/bs6040019

Perdue, B. M., Beran, M. J., & Washburn, D. A. (2018). A computerized testing system for primates: Cognition, welfare, and the Rumbaughx. *Behavioural Processes*, *156*, 37-50. https://doi.org/10.1016/j.beproc.2017.12.019

Perdue, B. M., Clay, A. W., Gaalema, D. E., Maple, T. L., & Stoinski, T. S. (2012). Technology at the zoo: The influence of a touchscreen computer on orangutans and zoo visitors. *Zoo Biology*, *31*(1), 27-39. https://doi.org/10.1002/zoo.20378

Perdue, B. M., Evans, T. A., Washburn, D. A., Rumbaugh, D. M., & Beran, M. J. (2014). Do monkeys choose to choose? *Learning & Behavior*, *42*, 164-175. https://doi.org/10.3758/s13420-014-0135-0

Péron, F., Rat-Fischer, L., Lalot, M., Nagle, L., & Bovet, D. (2011). Cooperative problem solving in African grey parrots (*Psittacus erithacus*). *Animal Cognition*, *14*, 545-553. https://doi.org/10.1007/s10071-011-0389-2

Plotnik, J. M., Lair, R., Suphachoksahakun, W., & de Waal, F. B. M. (2011). Elephants know when they need a helping trunk in a cooperative task. *Proceedings of the*

National Academy of Sciences, *108*(12), 5116-5121. https://doi.org/10.1073/pnas.1101765108

Pomerantz, P., & Terkel, J. (2009). Effects of positive reinforcement training techniques on the psychological welfare of zoo-housed chimpanzees (*Pan troglodytes*). *American Journal of Primatology*, *71*, 687-695. https://doi.org/10.1002/ajp.20703

Reichmuth Kastak, C., & Schusterman, R. J. (2002a). Long-term memory for concepts in a California sea lion (*Zalophus californianus*). *Animal Cognition*, *5*(4), 225-232. https://doi.org/10.1007/s10071-002-0153-8

Reichmuth Kastak, C., & Schusterman, R. J. (2002b). Sea lions and equivalence: Expanding classes by exclusion. *Journal of the Experimental Analysis of Behavior*, *78*, 449-465. https://doi.org/10.1901/jeab.2002.78-449

Reichmuth Kastak, C., Schusterman, R. J., & Kastak, D. (2001). Equivalence classification by California sea lions using class-specific reinforcers. *Journal of the Experimental Analysis of Behavior*, *76*, 131-158. https://doi.org/10.1901/jeab.2001.76-131

Richardson, W. K., Washburn, D. A., Hopkins, W. D., Savage-Rumbaugh, E. S., & Rumbaugh, D. M. (1990). The NASA/LRC Computerized Test System. *Behavior Research Methods, Instruments, & Computers*, *22*(2), 127-131. https://doi.org/10.3758/BF03203132

Rochat, P. (2001). *The infant's world*. Harvard University Press.

Samuelson, M. M., Lauderdale, L. K., Pulis, K., Solangi, M., Hoffland, T., & Lyn, H. (2016). Olfactory enrichment in California sea lions (*Zalophus californianus*): An effective tool for captive welfare? *Journal of Applied Animal Welfare Science*, *20*(1), 75-85. https://doi.org/10.1080/10888705.2016.1246362

Savage-Rumbaugh, E. S. (1986). *Ape language: From conditioned response to symbol*. Columbia University Press. https://doi.org/10.7312/sava90374

Schusterman, R. J., & Kastak, D. (1993). A California sea lion (*Zalophus californianus*) is capable of forming equivalence relations. *The Psychological Record*, *43*(4), 823-839. https://doi.org/10.1007/BF03395915

Schusterman, R. J., & Krieger, K. (1986). Artificial language comprehension and size transposition by a California sea lion (*Zalophus californianus*). *Journal of Comparative Psychology*, *100*(4), 348-355. https://doi.org/10.1037/0735-7036.100.4.348

Shyne, A. (2006). Meta-analytic review of the effects of enrichment on stereotypic behavior in zoo mammals. *Zoo Biology*, *25*, 317-337. https://doi.org/10.1002/zoo.20091

Simeone, C. A., Gulland, F. M. D., Norris, T., & Rowles, T. K. (2015). A systematic review of changes in marine mammal health in North America, 1972-2012: The need for a novel integrated approach. *PLOS ONE*, *10*(11), e0142105. https://doi.org/10.1371/journal.pone.0142105

Simeone, C., Fauquier, D., Skidmore, J., Cook, P., Colegrove, K., Gulland, F., Dennison, S., & Rowles, T. K. (2019). Clinical signs and mortality of non-released stranded California sea lions housed in display facilities: The suspected role of prior exposure to algal toxins. *Veterinary Record*, *185*(10), 304. https://doi.org/10.1136/vr.105371

Smith, B. P., & Litchfield, C. A. (2010). An empirical case study examining effectiveness of environmental enrichment in two captive Australian sea lions (*Neophoca cinerea*). *Journal of Applied Animal Welfare Science*, *13*(2), 103-122. https://doi.org/10.1080/10888700903371863

Swaisgood, R. R., & Shepherdson, D. J. (2005). Scientific approaches to enrichment and stereotypies in zoo animals: What's been done and where do we go next? *Zoo Biology*, *24*(6), 499-518. https://doi.org/10.1002/zoo.20066

Tarou, L. R., Kuhar, C. W., Adcock, D., Bloomsmith, M. A., & Maple, T. L. (2004). Computer-assisted enrichment for zoo-housed orangutans (*Pongo pygmaeus*). *Animal Welfare*, *13*, 445-453.

Washburn, D. A. (2015). The four Cs of psychological wellbeing: Lessons from three decades of computer-based environmental enrichment. *Animal Behavior and Cognition*, *2*(3), 218-232. https://doi.org/10.12966/abc.08.02.2015

Washburn, D. A., & Hopkins, W. D. (1994). Video-tape versus pellet-reward preferences in joystick tasks by macaques. *Perception and Motor Skills*, *78*, 48-50. https://doi.org/10.2466/pms.1994.78.1.48

Washburn, D. A., & Rumbaugh, D. M. (1992). Testing primates with joystick-based automated apparatus: Lessons from the Language Research Center's Computerized Test System. *Behavior Research Methods, Instruments, & Computers*, *24*(2), 157-164. https://doi.org/10.3758/BF03203490

Washburn, D. A., Rumbaugh, D. M., & Richardson, W. K. (1992). The Language Research Center's Computerized Test System for environmental enrichment and psychological assessment. *Contemporary Topics in Laboratory Animal Science*, *31*(6), 11-15.

Westlund, K. (2013). Training is enrichment—and beyond. *Applied Animal Behaviour Science*, *152*, 1-6. https://doi.org/10.1016/j.applanim.2013.12.009

Winship, K. A., & Eskelinen, H. C. (2018). Behavioral responses of two species of dolphins to novel video footage: An exploration of sex differences. *Zoo Biology*, *37*(6), 399-407. https://doi.org/10.1002/zoo.21444

Zentall, T. R., & Smith, A. P. (2016). Delayed matching-to-sample: A tool to assess memory and other cognitive processes in pigeons. *Behavioural Processes*, *123*, 26-42. https://doi.org/10.1016/j.beproc.2015.07.002