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Can Sea Lions' (*Zalophus californianus*) Use Mirrors to Locate an Object?

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Although California sea lions (*Zalophus californianus*) are capable of forming complex mental concepts, they have failed to demonstrate mirror self-recognition, a skill that requires both a mental representation of one's physical features and knowledge of a reflective surface. Many non-human species that do not recognize themselves in mirrors can nonetheless learn to use mirror reflections to locate and retrieve objects. A total of 7 sea lions housed at 2 separate facilities were tested on their ability to detect an object using a mirror. The results of a preliminary detection task in which sea lions were reinforced for looking at a mirror to locate an object suggested that 4 sea lions reliably learned to locate an object positioned below a mirror in one of three locations. A follow-up study was conducted to determine if 3 different sea lions could learn the task without training the animals to use the mirrors. Two of the 3 sea lions located a single object in 1 of the 3 locations statistically above chance when the mirrors were added to the task for the first time. With additional mirror exposure, 1 sea lion successfully achieved 100% accuracy in detecting familiar objects placed in 1 of 3 familiar locations. This sea lion also demonstrated her ability to detect an object via a mirror located in a novel, fourth position with 100% accuracy. When two novel objects were tested with four locations, the sea lion again performed well, detecting the objects 87.5%. The results suggest that sea lions have the ability to use mirrors to locate an object with minimal exposure to a mirror, but likely need additional experience with mirrors to efficiently use the properties of these reflective surfaces and understand that the image is a two-dimensional representation of a three-dimensional object.

The ability to use a mirror reflection has been suggested to require sophisticated cognitive skills, such as the ability to form representations, or an internal concept (e.g., Mitchell, 1993). Mirror self-recognition, or the ability to recognize oneself in a mirror spontaneously, is touted as the most sophisticated cognitive ability associated with mirrors as it requires both a mental representation of one's physical features and an ability to use the reflective properties of a mirror (Gallup, 1970; Gallup, Anderson, &

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Shillito, 2002). Humans acquire the ability to recognize themselves in mirrors between 18 and 24 months (Amsterdam, 1972), which corresponds with their matured capacity for object permanence and a more complex sense of self, including a greater range of emotions and language use (Gallup et al., 2002). While almost all humans acquire mirror self-recognition spontaneously (Gallup et al., 2002), only a handful of non-human animals have capable of recognizing themselves in a mirror: chimpanzees (*Pan troglodytes*, Gallup, 1970; Lin, Bard, & Anderson, 1992; Povinelli, Rulf, Landau, & Bierschwale, 1993), orangutans (*Pongo pygmaeus*, Suarez & Gallup, 1981), dolphins (*Tursiops truncatus*, Marino, Reiss, & Gallup, 1994; Sarko, Marino, & Reiss, 2002), an Asian elephant (*Elephas maximus*, Plotnik, de Waal, & Reiss, 2006), and magpies (*Pica pica*, Prior, Schwarz, & Güntürkün, 2008). Although many other species have failed to pass the mark test, which is the standard for mirror self-recognition, these same species, including parrots (*Psittacus erithacus*, Pepperberg, Garcia, Jackson, & Marconi, 1995), many monkey species (*Macaca sp,* Anderson, 1986; Itakura, 1987; Marchal & Anderson, 1993), and pigs (*Sus scrofa*, Broom, Sena, & Moynihan, 2009, but see Gieling, Mijdam, van der Staay, & Nordquist, 2014) are able to complete different types of mirror-based tasks.

As compiled by Pepperberg and her colleagues in 1995 mirror-based tasks can be divided into a series of tests that begin with the fewest cognitive demands and end with the greatest cognitive demands; these tasks include 1) mirror-image stimulation (i.e., the stimulation of subjects' reactions to a mirror image), 2) mirror-triggered searching (i.e., the stimulation of searching behavior in the presence of a mirror), 3) mirror-mediated object discrimination (i.e., the discrimination of objects located in familiar locations), 4) mirror-mediated spatial localization of objects (i.e., the localization of objects in novel places), 5) mirror-guided searching (i.e., the guiding of one's limbs to retrieve an object), and 6) mirror self-recognition (i.e., the recognition of oneself in a mirror image). Each task is standardized and has been adapted for different species. Research with African grey parrots (Pepperberg et al., 1995) had indicated that this species could complete the more difficult mirror-based tasks, including localization of objects in novel locations (i.e., Task #4 and Task #5), but did not recognize themselves in mirrors. These findings suggest that the lack of mirror self-recognition was not due to an inability to process information contained in a mirror image, but more likely related to the lack of a specific cognitive ability required for recognizing one's physical features in a mirror image (Gallup et al., 2002).

To date, sea lions (*Zalophus californianus*) have failed to pass the mark test when tested, showing only social-oriented behaviors and vocalizations toward the mirror reflection (Delfour & Marten, 2001; Schusterman, Gentry, & Schmook, 1967). A number of studies in which the cognitive abilities of sea lions have been tested clearly indicate that sea lions are capable of forming mental representations, including stimulus equivalence via symbols (Schusterman, Kastak, & Kastak, 2003), oddity matching (Hille, Dehnhardt, & Mauck, 2006), and cross-modal transitive relations (Lindemann-Biolsi & Reichmuth, 2014), while maintaining those complex mental representations for long periods of time (Kastak & Schusterman, 2002). The lack of mirror self-recognition by sea lions does not seem to be related to the ability to form mental representations; however, no study has addressed whether or not sea lions are able to use the reflective properties of a mirror functionally.

The purpose of the current series of studies was to determine if sea lions could use reflective surfaces to detect objects in a modified mirror-mediated discrimination task (Task #3, Pepperberg et al., 1995) and a modified mirror-mediated spatial localization of objects task (Task #4, Pepperberg et al., 1995). Experiment 1 was conducted with four sea lions housed at a facility in Mississippi, USA. Experiment 2, an extension of Experiment 1, was conducted with three sea lions housed in a facility in Texas, USA.

Experiment 1

Method

Subjects. Four California sea lions (*Zalophus californianus*), 2 females and 2 males, located at Marine Life Oceanarium, Gulfport, Mississippi, USA were tested for the first study. The sea lions ranged in age between 11 and 17 years at the time of the study. None of the sea lions had any experience with mirrors or reflective surfaces before the study began.

Apparatus. To test the sea lions on their ability to use mirrors to locate an object, a three-location PVC apparatus was constructed (Figure 1a). The apparatus included three individual .3 m x .3 m (12” x 12”) mirrors positioned at 45° angles to reflect the contents of the box located directly below each mirror. The apparatus was approximately 1.4 m wide x .6 m deep x 1.1 m tall (4.5 ft wide x 2 ft deep x 3.5 ft tall). The mirrors were attached to a foam board with a permanent adhesive and fitted into grooves within the PVC pipe. Foam board dividers were placed between each mirror and box and on each end of the apparatus to limit cross reflections from other mirrors. Finally, the apparatus was positioned so that the top of the box was level with each sea lions’ eyes when the sea lion sat in a relaxed position with all four flippers on the ground (Figure 1a).

The objects used for this study were two identical miniature basketballs (i.e., balls). The sea lions were very familiar with these balls as they were a commonly used environmental enrichment device. Data were collected with paper and pencil, and all test sessions were video-taped for reliability purposes.

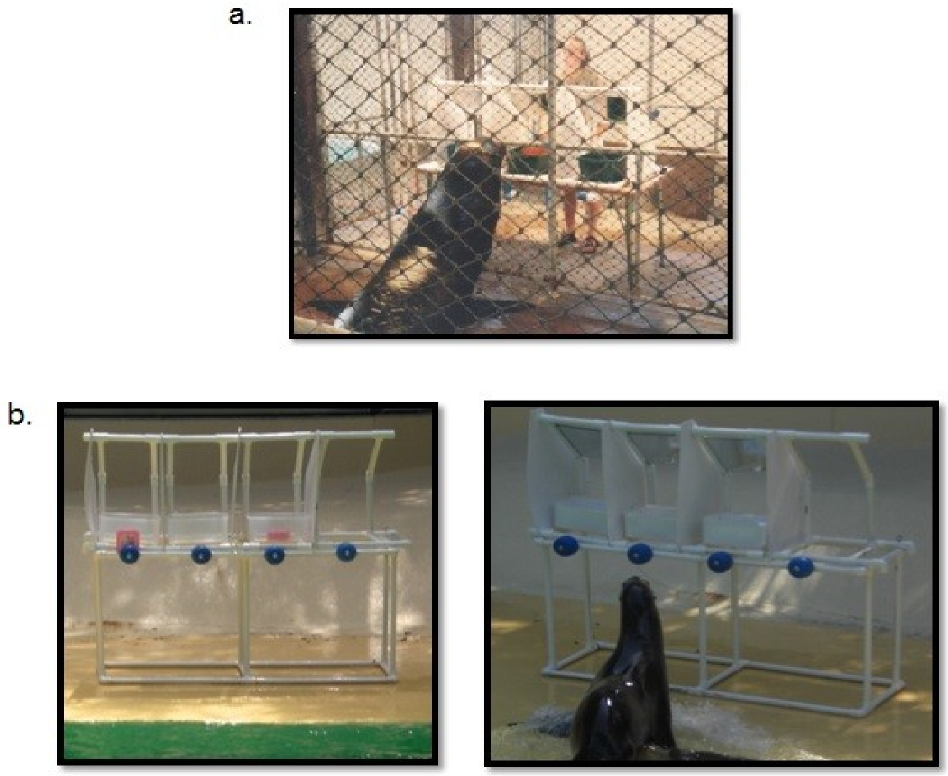

Figure 1. *Apparatus used at each facility.* **a.** Three-location mirror apparatus used at Marine Life Oceanarium. The image illustrates a training session in which the sea lion correctly selected the hidden object during a probe trial. During the session, the ball was not visible to animal unless he looked in the mirror. The angle of the photograph produced the illusion that the ball was visible above the top of the box. **b.** Three- and four-location mirror apparatus used at the Houston Zoo. The left picture shows the three-location apparatus with clear bins and no mirrors used during the training sessions. The pink box in front of the left-most box illustrates the first approximation while the pink box in the clear box of the right-most box illustrates the next approximation to locate the object. The right picture shows one of the sea lions correctly selecting the location of the object during a test session when the opaque boxes and mirrors were present during the three-location testing.

Procedure.

Training. All materials and procedures were approved by the University of Southern Mississippi IACUC and Marine Life's training and veterinary staff. The same procedures were used for all training and testing. To train the basic tasks, an errorless training approach was used to minimize errors. All trials in which a correct behavior was performed were reinforced (i.e., bridged) immediately with the word *Good* or a clicker followed by a fish (i.e., capelin, small herring, or squid). If no response or an incorrect response was given, the sea lion was recalled to the primary trainer by calling the sea lion's name and no primary reinforcement was provided. An accuracy response rate of 85% across five consecutive sessions[1] was selected for all training.

The sea lions were initially taught a detection task in the absence of the apparatus that used a match-to-sample methodology such that the sample (a miniature basketball) was shown and a single target (a second, identical miniature basketball) was provided[2]. Two people, a trainer and a research assistant,

[1] Sessions were comprised of 8-12 trials, depending on the specific sea lion. The 85% criterion was selected to accommodate 1-2 errors within a session, depending on the number of trials performed. The criterion was met when an animal could perform at this level within each session for five consecutive sessions.

[2] Although this initial detection task is not the typical match-to-sample discrimination task, it was used to establish the concept of matching a sample using an errorless training technique. All animals were trained with multiple objects

were placed across from one another separated by 2 m. The sea lion always started facing the trainer, so that the sea lion's back was to the research assistant. The trainer showed a ball to the sea lion and then cued the sea lion to find the second ball, which was held by the assistant (i.e., ball-to-ball task). The trainer used the term, *Find,* to release the sea lion from control and to move toward the second person with the ball. Following this initial training task, a unit of the mirror apparatus (one mirror/opaque box combination, Figure 1a) was placed next to the research assistant. The second basketball was held near or in front of the mirror unit by the research assistant, as the behavior was approximated and the sea lion learned the task to locate the second basketball. This step allowed the sea lions to become desensitized to the apparatus, to gain some experience with mirrors, and to learn the standardized procedure used for the remainder of the study. Sea lions were reinforced for correctly targeting on the basketball and recalled on mistakes or no responses.

Once sea lions located the ball at the single unit apparatus at the established criterion, the full apparatus was introduced. The ball was held above the front edge of the box by the research assistant and moved randomly to one of the three boxes for each trial until the sea lions located the ball at criterion. The sea lions were allowed to make only one choice, which was defined as moving to and stopping in front of a box, orienting their head directly at the box, and holding the position for at least two seconds. If the choice was correct, the sea lion was always reinforced with a secondary reinforcer, a verbal bridge of *Good* followed by a fish. Once the sea lions accurately located the ball at the front of the box, the ball was held in the air by the research assistant above the box halfway to the mirror. Following this task, the next step of training involved the ball held directly above the box, in front of the mirror, and then moved into the box while the sea lion was facing the apparatus and presumably watching the action. This condition was performed so that sea lions could learn that the ball may not always be visible as the three-dimensional object. Once the sea lions met criterion for this task, the next training step was introduced in which probe test trials occurred. A probe test trial consisted of the research assistant placing the ball into one of the three boxes while the sea lion was facing the trainer and under control so that the sea lion could not observe the object being placed into a box. The purpose of the probe trial was to determine if the sea lions were using the mirror reflection of the ball as opposed to the visible cue of the actual ball when placed in front of the mirror. As a research assistant had to remain behind the apparatus to move the location of the object, a standardized procedure was followed. The assistant stood behind the apparatus at the middle box and faced the sea lion at all times. The research assistant stared directly at the back of the apparatus and did not make eye contact with the sea lion being tested. Three to four probe test trials were included in each training session until the sea lions correctly identified 85% of the probe trials within each session for five consecutive sessions.

*Testing***.** Each sea lion was given 15 test trials spread across three to four sessions. Test trials consisted of placing the ball in a randomly determined box while the sea lion was stationed with the trainer so that the sea lion was facing the trainer under control and unable to see which box in which the ball was placed. The research assistant wore reflective sunglasses and turned away from the apparatus once the ball was in the box until the sea lion had made a choice and returned to the trainer thus controlling for any possible cues by the assistant. The trainer could see the reflection of the ball and was therefore able to bridge verbally, which was followed by fish reinforcement for each correct choice or recall for an incorrect choice. Test sessions included three to four test trials that were intermixed with eight visible trials in which the ball was placed above the box or visible to the sea lion without the aid of a mirror. Each test session began with four visible trials, followed by one test trial, one visible trial, two test trials, two visible trials, one test trial, and one visible trial. The placement of the ball was randomly determined within the session but counterbalanced across trials and sessions.

The four visible trials were used to assess the sea lions' readiness to perform the task. If the sea lion missed one of the visible trials, then the session was not conducted. If the sea lion was correct on all of the visible trials, the session was continued until all the trials were completed.

Results

Training. The number of training trials and sessions differed for each sea lion (Table 1). The variations in training time were due to a number of factors including individual differences in learning ability, training history, motivational state during

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during the training procedure in preparation for a follow-up task that ultimately used a traditional match-to-sample discrimination task with one or more distractors.

sessions, physiological issues (e.g., illness, breeding season), and facility constraints (e.g., other training obligations, available space). Table 1 summarizes the number of sessions and trials needed for each animal to meet the established criterion.

Testing. Once each sea lion reached the 85% detection criterion of the probe trials for five consecutive sessions, the formal testing procedure was instituted. The results of the test trials are presented in Figure 2. KIA and TOR detected and located the ball using the mirrors on every test trial (i.e., 15/15 each). SPA missed one of his 15 test trials for a 93% detection rate. The missed trial occurred in his final test session. When he was sent to the apparatus, he went straight to the middle box without looking at any of the mirrors. Finally, JAN missed two of her 15 test trials for a detection rate of 87%. Although she ultimately selected the correct location on both trials, she did not choose either location as her first choice, and both trials were coded as incorrect. The results of four separate multinomial tests indicated that all the sea lions detected the object using the mirror reflection in all tested locations at levels significantly above chance, $p < 0.001$.

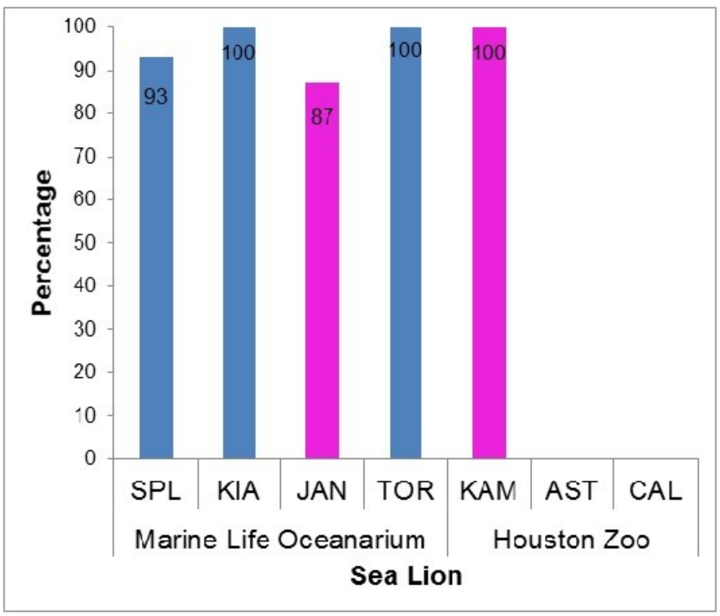

Figure 2. *Performance of sea lions on mirror test trials following established criteria for each study.* Blue bars represent male sea lions. Pink bars represent female sea lions. Chance was 33%.

Table 1
Number of Sessions and Trials per Sea Lion during Training and Testing in Experiment 1

	SPL	KIA	JAN	TOR
Session Type	*F*	*F*	*F*	*F*
No Probe Trials				
Sessions	14	8	12	8
Visible trials	205	105	172	127
Probe trials				
Sessions	14	20	22	36
Visible trials	170	126	186	225

Probe Trials	32	59	59	173
Total trials	202	185	245	398

Note. Sessions involving visible trials included the ball being visible to the sea lions and never placed in the opaque box without the sea lion watching. When probe trials were initiated, the sea lions were unable to watch the ball being placed in one of three locations. Instead, they could only use the mirror reflection to locate the object. The mirrors were present for all sessions and trials. The five consecutive sessions in which the sea lions met criterion to determine testing are included in the session numbers presented. Formal testing trials are not included in these frequencies (*F*).

Reliability. The first author and a second independent rater coded the selections of each sea lion for all test trials. Reliability between the two coders was calculated using Cohen's kappa. With 59 agreements out of 60 trials, a kappa of .975 was attained.

Brief Discussion

The results of this initial study suggested that sea lions learned to use the information provided by a mirror image to locate or detect a hidden object although each sea lion varied in the number of trials they needed to learn the task. Using a familiar set of locations and a familiar object, the sea lions reliably selected the location containing the hidden object. As indicated by the initial probe trials incorporated during training sessions, the sea lions did not immediately use the mirror reflection functionally as the ball was not successfully located on these early hidden trials. The sea lions required 32 to 172 probe trials before meeting criteria of detecting the hidden object with the mirrors present. Despite performances well above chance (i.e., 33%) and only three incorrect test trials out of 60 trials across all four sea lions, it is unclear if the sea lions fully understood the nature of the mirror reflection and the one-to-one correspondence between the mirror image and the object. None of the sea lions used the mirrors on the initial mirror-mediated object detection trials presented during the training sessions, suggesting that the mirror reflections were not inherently used or understood by sea lions. With the standardized protocols, it is unlikely that the sea lions detected the object using unintentional cues presented by the humans involved in the study. This conclusion is validated by the inability of the sea lions to correctly locate the hidden ball during the initial probe trials. However, it is possible that the sea lions performed well because they were trained to detect an image that was different from two other images at locations with which they were familiar, precluding the need to understand the functionality of a mirror reflection. Another interpretation for the results may have been that the animals formed a conditioned association or used a simple rule to detect the object as it was the same object across trials in familiar locations. Ultimately, due to the training paradigm in which the sea lions were reinforced for looking up at the ball positioned in front of the mirror, it is unclear if the sea lions used the mirror reflection functionally, as a two-dimensional representation of the three-dimensional object being reflected, or if they completed the task using some form of associative learning.

To address the limitations of Experiment 1, Experiment 2 was conducted using a modified training paradigm intended to control for the possible explanation that the original sea lions were trained or acquired an association to detect the non-visible object without functionally using the mirror reflection. The possibility of associative learning was also controlled by using four objects that were novel to the sea lions at the beginning of the study and testing two novel stimuli at the conclusion of the study. Finally, the sea lions completed a transfer task that included a novel location to test a mirror-mediated spatial localization task instead of the simpler, mirror-mediated object discrimination.

Experiment 2

Method

Subjects. Three sea lions, 2 females and 1 male, located at the Houston Zoo were trained for the mirror task by their respective trainers. They ranged in age from two to seven years. None of the sea lions had any experience with mirrors or reflective surfaces before their participation in the study.

Apparatus. To test the sea lions on their ability to use mirrors to locate an object, a four-location PVC apparatus was constructed (Figure 1b). The apparatus initially included three individual .3 m x .3 m (12” x 12”) mirrors positioned at 45° angles so that the object in the box was reflected in the mirror directly above the box. The apparatus was approximately1.4 m wide x .6 m deep x 1.1 m tall (4.5 ft wide x 2 ft deep x 3.5 ft tall). Only three locations were used for the initial training and testing. The mirrors were attached to a foam board with a permanent adhesive and fitted into grooves within the PVC pipe. Foam board dividers were placed between each mirror and box and on each end of the apparatus to limit reflections from other mirrors. Finally, the apparatus was positioned so that the top of the box was level with each sea lions’ eyes when the sea lion sat in a relaxed position with all four flippers on the ground (Figure 1b, right panel).

Objects used for the study included an intact blue nylon rope, a rectangular pink sandwich box, a miniature yellow and orange Nerf© football, and a small yellow dustpan and broom. All objects were completely novel to the sea lions upon initiation of the study. Two additional novel objects were also tested: a *K* and a *star.* A video camera and a laptop computer were used for data collection.

Procedure. All animal training and testing was conducted by the trainers assigned to the sea lions participating in the project and approved by the St. Mary’s University IACUC and the Houston Zoo research board. Each animal was trained and tested individually. Two sea lions, KAM and AST were ultimately trained and tested by one trainer although AST began with a different trainer. The third sea lion was trained and tested on the detection task by her primary trainer.

Desensitization training. All animals were desensitized to the three-location apparatus and objects using a procedure developed by each sea lion’s trainer. This process generally involved the presentation of the novel items to each sea lion while under control during a training session, such as having the sea lion move near the object or apparatus or allowing the sea lion to investigate the new object or apparatus. After animals did not show any hesitation or fear in the presence of these novel items, the sea lions transitioned to the training phase of the study.

Clear boxes-no mirrors present training. This training phase began with individually introducing the sea lions to the apparatus on the *beach* or dry area of their habitat (Figure 1b). The pace and activities of the training sessions were determined by the trainers and the animals’ interest and motivation. A set of approximations was used to teach the animals the basic task. First, the trainer showed a sea lion the pink sandwich box (visible in Figure 1b, left panel) and then said *Match*, pointing the sea lion to the second pink box located on the apparatus in front of a clear box (Figure 1b, left panel, left-most box). The object was moved randomly from one box to another to teach the animal to *follow* the object. Once the animals began to understand the concept of locating the target object at the apparatus, the object was moved inside of the box, as shown by the right panel in Figure 1b. Each object was introduced gradually into the single object match–to-sample paradigm so that the number of objects increased until all four were rotated between. All correct choices were reinforced with a secondary reinforcer (*Good* or a whistle) first and followed with fish.

The next step in the training phase was to teach the sea lions their starting position, choosing position, and their ending position. Although the sea lions started next to the apparatus positioned on the beach (Figure 1b, left panel), they were ultimately tested using a starting position located across the pool on a floating dock, a distance of 7.6 m (approximately 25 ft). This starting position required multiple approximations before finally attaining the final starting position on floating dock, opposite of the apparatus.

During these training stages, the animals were exposed periodically to a mirror disk in their holding pools outside research sessions involving the apparatus. This mirror exposure was provided for two reasons. First, the sea lions had no mirror experience and some exposure was needed to desensitize them to the reflective surface. Moreover, it was important for the experience to be provided in a context that differed from the apparatus so that the two contexts remained independent.

Once all of the initial training was completed, the sea lions were exposed to the complete sequence of the detection task, which was standardized across all three sea lions. The sea lion began in a laid out position on the floating dock, facing away from the apparatus while targeting on the trainer's hand. The sea lion's trainer also looked down at the sea lion and away from the apparatus to avoid providing any eye cues to the sea lion. While the sea lion and the trainer were in this position, one of the three boxes was baited randomly with a randomly selected object by the research assistant located on the beach with the apparatus. After the research assistant baited the box, she moved away from the apparatus to a hidden location. A second research assistant informed the trainer which object to present (e.g., Football, Box, Broom, or Rope) to the sea lion. The research assistant also stared at a fixed point to minimize the possibility of providing cues to the sea lion. The trainer then showed the selected object to the sea lion and said *Match*, which was the sea lion's signal to leave the dock, enter the water, swim to the beach, and select the box with the matching object located inside of a clear box. The trainer looked only at the sea lion during this time. Once the sea lion had jumped into the water at the cue of *Match*, the second research assistant verbally informed the sea lion's trainer of the object's location. If the sea lion chose correctly, as indicated by the sea lion targeting on the buoy target below the box with the object, the trainer bridged the sea lion and provided a fish upon the sea lion's return to the dock. If the sea lion was incorrect, the trainer called the sea lion back to the dock for another trial or behavior. All training sessions were videotaped and recorded on paper by both research assistants – the one on the beach and the one behind the floating dock. Trials with a single object placed in one of the three clear boxes were conducted until each sea lion had achieved a criterion of 100% accuracy across eight sessions of four trials each. The sea lion was only able to make one choice and the first target physically touched was considered his or her choice.

Four different, and initially novel, objects were used throughout the training process to control for any preferences. These objects and their locations were randomized across trials so that the same object or the same location could not be used more than two times in a row and all locations and objects had to be used across eight trials to control for search patterns or other simple rule formations.

Initial testing: Opaque boxes-mirrors present. To determine if the sea lions were capable of immediately using a reflective surface to detect an object, each sea lion was given eight test trials with opaque boxes in which the mirrors were present for the first time. Using a randomized sequence, each object was used twice and each location was used a minimum of two trials. The same standardized procedure established during training was used for all test trials. To succeed on this task, the sea lion had to use the reflected image in the corresponding mirror to detect which opaque box held the specific object as the sea lions were unable to detect an object located in the opaque boxes when the mirrors were not present. If the sea lions spontaneously used the mirror image to detect the object, they were expected to locate the objects at an accuracy rate above chance (i.e., 33%).

Final testing: Opaque boxes-mirrors present. Since none of the sea lions performed at the 85% criterion established by the sea lions in Experiment 1, each sea lion was given additional experience with the mirrors to learn to accurately locate the object to be matched. The same standardized procedure was used for these trials as had been used for the initial testing and training. A criterion of 85% accuracy within a session for four consecutive sessions was established to test the sea lions a second time with the opaque boxes and mirrors present. The sea lions were to receive a total of 32 mirror trials. These trials were spread across eight sessions with four trials per session, using the same standardized procedure established in the training phase. Each sea lion's performance was compared to chance (i.e., 33%) using a multinomial test.

Transfer to novel location: Desensitization. To desensitize the animal to the appearance of a fourth box and mirror while maintaining the novelty of this location and informing the sea lion that the fourth box was part of the task, three desensitization sessions of four trials each were conducted. These sessions included the opaque boxes and mirrors. An object was placed in one of the three original locations used, so that the fourth location remained empty but available to investigate for all 12 trials.

Transfer to novel location: Testing. One session of eight trials was performed to test the transfer of the mirror task from three familiar locations to four locations. The fourth location was considered the novel location. Each object was presented two times in each box using a randomly determined order.

Transfer to novel objects: Testing. Two test sessions of eight trials each for a total of 16 trials was performed to test the transfer of the mirror task from four familiar objects placed in three familiar locations to two novel objects placed in one of the four locations. Each novel object was tested two times in each of the four locations. Location and object were randomly selected and counterbalanced within each session.

Results

Training. The number of training trials and sessions differed for each sea lion. Like Experiment 1, the variation in training time was influenced by individual differences in learning ability, training history, motivational state during sessions, physiological issues (e.g., breeding season), and facility constraints (e.g., other training obligations, pool maintenance). Table 2 summarizes the number of sessions and trials needed for each animal to meet the established criteria.

Initial testing. To determine if the sea lions were capable of immediately using a reflective surface to detect an object, each sea lion was given eight test trials with opaque boxes and the mirrors present for the first time. KAM and CAL each detected five out of the eight objects on the initial test trials, which was statistically significant using a multinomial test for each, $p = .027$. AST detected three out of eight objects on his initial test trials, which was not significantly above chance, multinomial test, $p = .097$ (Table 2).

While two of the three sea lion's performances, body postures, and eye gazes appeared to indicate that they were able to use the mirrors to detect the non-visible objects the first time the mirrors were available, they did not do so reliably or at the selected criterion of 85% accuracy. Additional sessions were conducted to ensure that the sea lions were using the mirrors. Each sea lion developed his or her own superstitious rule following a series of incorrect responses and needed different amounts of sessions and trials to achieve the final criterion needed to be formally tested (Table 2). Ultimately, only one of the three sea lions reached the final criterion to be formally tested.

Final Testing. The results of the final test trials are presented in Figure 2. KAM detected and located an object using the mirrors on every test trial for 100% accuracy on 32 test trials. This sea lion successfully detected each object tested across all locations with a performance that was significantly above chance, $p < 0.001$, as indicated by a multinomial test.

Table 2

Number of Sessions and Trials per Sea Lion during Training and Testing in Experiment 2

	KAM	CAL	AST
Session Type	*F*	*F*	*F*
Training Sessions	22	14	10
Trials	140	66	45
Initial Mirror Session	1	1	1
Trials	8	8	8
Post-Test Mirror Sessions			7
Clear Box Trials	67	17	--
Sessions	10	4	--
Opaque Box-Partially Visible Trials	--	--	38
Sessions			9
Opaque Box Trials	116	--	77
Sessions	25	--	16

Note. Training sessions included all sessions in which sea lions learned the basic matching task in the presence of the apparatus with clear boxes and no mirrors. The initial mirror session was the attempt to determine if sea lions immediately understood how to use a mirror reflection. Post-test mirror sessions included all of the sessions conducted before the sea lions met the criterion established for final mirror testing – 4 consecutive sessions of 100% object detection with mirrors and opaque boxes present. *F* – frequency.

Transfer to Novel Location. To strengthen the results of the detection task, the sea lion was asked to transfer her use of the mirror to a novel location. KAM detected each object on all eight trials for 100% accuracy. Interestingly, KAM showed some hesitation when she initially encountered the object in the fourth location but ultimately selected the location correctly.

Transfer Task with Novel Stimuli. To further control the influence of simple rule learning associated with familiar objects, two novel objects were also tested using all four locations. Out of 16 additional trials, KAM correctly located a novel object 14 times for an 87.5% accuracy rate.

Reliability. The first author and a second independent rater coded the selections of each sea lion for all test trials. Reliability between the two coders was calculated using a Cohen's kappa. No disagreements occurred between the author and the rater for a total of 156 agreements out of 156 trials, 100.0% agreement, or a kappa of 1.

Brief Discussion

This replication and extension study supported the outcomes of Experiment 1. To control for the possibility of training the sea lions to use a mirror reflection, the sea lions in Experiment 2 were never reinforced in the presence of the mirror during training of the detection task. Rather, the mirrors were presented and tested once the sea lions demonstrated their knowledge of the detection task using clear boxes and a visible object. In Experiment 2, the sea lions also located four different objects, with which they were unfamiliar initially, instead of a single object, with which they were very familiar. This change should have controlled for the possibility of triggering a conditioned association of find the image with this one object (Pepperberg et al., 1995). However, as these four stimuli were the training stimuli, two additional novel stimuli were tested, with the results indicating that familiarity with the stimuli did not enhance the detection accuracy. Finally, a standardized procedure was again incorporated to reduce the possibility of external cues provided by the humans to the sea lion during the training and testing sessions. With these confounds from Experiment 1 controlled, the performance of two of the three sea lions during the initial exposure to the mirrors with the apparatus and a hidden object indicated that the sea lions may have used the mirrors spontaneously to locate the object present significantly more than expected by chance (i.e., 33%). However, it was clear that despite this initial success the sea lions did not appear to use the mirror reflection reliably as they were unable to consistently locate the object with the same accuracy as the sea lions in Experiment 1. Additional trials in which the sea lions were reinforced for locating the hidden object when the mirror was present and recalled for incorrect choices were provided to each sea lion until they reached the criterion of 85% accuracy within each session across four consecutive sessions. While this information provided some feedback to the sea lions, it allowed the sea lions the opportunity to spontaneously learn the relationship between the mirror and the object to be detected. The sea lions were not shaped or taught to use the mirrors as they may have been in Experiment 1.

Out of the three sea lions, one sea lion successfully detected 100% of the objects during the formal testing period once she was reliably locating the hidden objects. The other two sea lions did not complete the training for this task due to two unanticipated factors (CAL: trainer sabbatical; AST: sea lion illness). The accurate performance of the sea lion on the detection of a hidden object in three familiar locations suggests that she was using the information provided by the mirror reflection in a functional manner. The use of the mirror was supported by the research assistant’s description of the sea lion’s eyes rolling up toward the mirror as she scanned the mirrors before making her choice. However, it was still unclear if the sea lion understood the nature of the mirror reflection or if she was working from a conditioned rule she had established for familiar locations and objects as may be the case in an object-mediated discrimination task, which this task simulated (Pepperberg et al., 1995). To determine if the sea lion could adapt her functional knowledge of a mirror reflection to locate an object in a novel location, the sea lion was tested with a fourth, novel location. The results of the transfer test demonstrated that the sea lion was able to locate an object placed in the novel location immediately and 100% accurately. The results of this transfer test were validated with a final test of mirror use in which the sea lion detected two novel stimuli with 87.5% accuracy across all four locations, suggesting that the sea lion was able to use the mirror images functionally without the aid of any conditioned associations with familiar objects.

General Discussion

Ultimately, six out of seven sea lions of varying ages and training histories were able to use a mirror to locate a hidden object placed in one of three familiar locations at detection rates significantly above chance. Using a mirror apparatus with three fixed locations, the sea lions correctly detected hidden objects through the information provided by a mirror image and not by any external cues as the sea lions were unable to find a hidden object when the mirrors were absent. The modification of the training protocol from Experiment 1 to Experiment 2 controlled the possibility that the sea lions were trained to use the mirror image rather than doing so spontaneously, which is a critical aspect of mirror image processing (Gallup et al., 2002). The results of two of the three sea lions in Experiment 2 performing significantly above chance supports the interpretation that sea lions are capable of spontaneously processing information from a mirror image functionally, but must have some additional experience with mirrors to do so efficiently, much like human children and primates (Amsterdam, 1972; Anderson, 1984; Gallup, 1970; Gallup et al., 2002). The transfer task in Experiment 2 to a novel location approximated the task of a mirror-mediated spatial localization task, which theoretically requires a more advanced cognitive ability of understanding the function of a mirror as a reflection of an object in an environment that can only be seen and obtained through the use of a mirror (Anderson, 1986; Pepperberg et al., 1995). The success of the sea lion on this transfer task as well as a second transfer task in which two novel objects were tested provided additional support that sea lions, as evidenced by one sea lion, are able to use a mirror image as the source of information for correctly detecting the object, and not some other external cue. These results are similar to other animals such as Asian elephants (Povinelli, 1989), African grey parrots (Pepperberg et al., 1995), and monkeys (Anderson, 1986; Itakura, 1987; Marchal & Anderson, 1993).

Unfortunately, it remains unclear if the sea lions fully understood the nature of the mirror reflection as a two-dimensional representation of the three-dimensional object being reflected, or if they had learned a rule to select an image that was different from the other available images. Additional testing is necessary to begin to parse out the actual knowledge of a mirror reflection. Thus, a mirror-mediated object match-to-sample task in which the sea lions must discriminate between objects using mirror reflections to detect the location of a target object would help clarify the question of the presence of a rule-based strategy. While this task is cognitively more complex, it still does not require that sea lions to understand that the reflection is a two-dimensional representation of a three-dimensional object. A test in which sea lions are asked to discriminate between two different types of two-dimensional representations (e.g., a photograph of the object vs the reflected image in a mirror) may elucidate this issue. Despite the uncertainty about *how* they do it, the results reported here for the first time demonstrate that sea lions can use reflective information from a mirror to detect an object that is present, contributing uniquely to the current knowledge of mirror image processing by different animals. Future research should continue to explore the degree to which different species understand the nature of mirror reflections and the cognitive abilities necessary to achieve the different levels of processing.

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