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Foraging devices as enrichment in captive walruses (*Odobenus rosmarus*)

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ABSTRACT

Stereotypies in captive animals are typically defined as repetitive, invariant behavioral patterns with no obvious goal or function. They are often attributed to boredom or fear and treated by introducing occupational stimuli. The present work on captive walruses examined the relationship between walrus stereotypies and species-typical foraging behaviors engaged in by their wild counterparts. Two types of walrus stereotypies were studied: (a) patterned swimming around their pool, or (b) repetitive sucking of some item, typically their own flipper. We tested two enrichment devices under filled and empty conditions: large foam/rubber mats and hollow boomer balls, both with multiple holes in them. Both devices were designed to stimulate the use of flippers, vibrissae, and mouth suctioning of small food in the devices. Walruses in the devices with food conditions increased locomotion and device contact and decreased engaging in stereotypies. We conclude: (1) daily stereotypies in these captive walruses are based on incomplete behavioral foraging "loops" (2) providing stimuli supporting completed foraging sequences can reduce stereotypies and increase active foraging components.

Stereotypies in captive animals have been defined as voluntary movement patterns without obvious goal or function, performed repeatedly with relatively invariant form (Mason, 1991a; Mason and Latham, 2004; Nelson and Johnson, 1987; Ödberg, 1978). A variety of stereotypies have been documented in captive animals, including: pacing in ursids, felids, and other carnivores (Bashaw et al., 2007; Carlstead and Seidensticker, 1991; Clubb and Mason, 2003; Mason et al., 2007), swaying/weaving in elephants (Mason and Veasey, 2010; Schiffmann et al., 2019), self-injurious behaviors, such as self-biting and hair-plucking in primates (Chamove and Anderson, 1981; Hosey and Skyner, 2007), regurgitation and re-ingestion of food and coprophagy in apes (Baker and Easley, 1996; Stevenson, 1983), and oral stereotypies, such as mouthing and crib-biting in pigs and horses (Cooper and McGreevy, 2007; Lawrence and Terlouw, 1993).

Stereotypies are typically viewed as highly undesirable side-effects of holding animals in artificial environments. Researchers have argued that they reflect high levels of boredom and/or stress (Broom, 1986; Dawkins, 1990; Mason, 1991b; Mason and Rushen, 2006). In predators, stereotypies are often associated with a lack of ability to engage in species-typical predatory behavior. As a result, in the last few decades zoos and other captive animal settings have attempted to reduce stereotypies in carnivores by increasing opportunities for "natural" predatory behavior. For example, Markowitz and LaForse (1987) generated species-typical hunting behaviors in captive tigers (*Panthera tigris*) and servals (*Felis serval*) by presenting artificial moving prey stimuli. Similarly, hiding multiple daily rations of food around the enclosure of captive-born leopard cats (*Felis bengalensis*) decreased pacing and increased exploration (Shepherdson et al., 1993). Offering food hidden in manipulable objects once daily to an American black bear (*Ursus americanus*) reduced stereotypic pacing significantly when compared with feeding once daily in the den (Carlstead et al., 1991).

Walruses (*Odobenus rosmarus*) are large aquatic carnivores. However, unlike many other large carnivores, such as ursids and felids, the prey of walruses are typically small, relatively stationary bivalve mollusks (e.g., clams) located in "beds" along the ocean floor. Walruses must search underwater actively and extensively to locate this prey. Once they find them, walruses perform a sequence of specialized foraging behaviors, beginning with probing for shellfish using their vibrissae while disrupting the substrate with their flippers. As shellfish are revealed the walruses jet streams of water from their mouths into the sand, followed by vacuuming up the bivalves with their mouths. By sealing their mouth around the prey items to prevent air leakage, they pull the prey out of its protective shells using intensive concentrated sucking (Born et al., 2003; Kastelein and Mosterd, 1989; Kastelein et al., 1991a; Levermann et al., 2003; Nelson and Johnson, 1987).

Because of their large size relative to the size of their individual

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prey, walruses must spend a considerable part of their daily activity searching for and consuming food. Thus, while walruses are predators, their foraging behavior resembles the relatively continuous grazing-like activity of large herbivores. However, in captivity, walrus enclosures rarely provide opportunities to engage in typical free-ranging-grazing behaviors. Pools are provided but usually lack a sandy, manipulable substrate to search through. Food is typically presented by hand, either by small amounts during a training session, or as a large meal thrown in the pool all at once (Franks et al., 2010; Kastelein and Wiepkema, 1989).

Only a handful of previous studies have addressed stereotypies and enrichment in captive walruses. Kastelein and Wiepkema (1989) showed that offering a digging trough to captive walruses resulted in reduced stereotyped circle swimming. This outcome would be expected if swimming behavior were typically involved in their natural foraging behavior, but zoos have usually provided only a concrete pool without opportunities to sort out the food and/or manipulate some substrate. In subsequent work, Kastelein et al. (1991b) also found that time spent feeding/foraging per day was increased by delivering food periodically through food dispensers that were kept loose or anchored in the pool but required more effort by the walrus to get the food than when the walruses were simply fed by hand. In addition, Kastelein et al. (2007) used several different types of enrichment feeding devices to increase the time spent using those devices to forage in walrus calves, Kuczaj et al. (2002) tested novel introduction of a small barrel on the interactions with that device in an adult walrus, and Franks et al. (2010) examined the effects of enrichment, feeding times, and season on the stereotypic activity of four adult walruses.

The present research examined the effects of presenting two types of foraging devices to three captive walruses at the Indianapolis Zoo. Experiment 1 presented the walruses with two large, thick stall mats under conditions with and without food placed in multiple holes drilled through the mats; Experiment 2 provided two large plastic boomer balls, with holes that allowed food to be shaken or sucked out. We established baseline interaction with the food during two different time periods (morning and afternoon) and noted similarities and differences between the behavior of a juvenile walrus and male and female adult walruses.

Our basic hypothesis is that providing walruses enrichment in the form of the foraging devices that engage more aspects of their natural hunting and consuming behaviors (i.e. large mats or boomer balls with holes, which can be manipulated with the flippers and mouth) should reduce stereotyped search behavior as a function of supporting a set of search behaviors typically used in locating and consuming food items in the wild. Stereotypies should therefore be replaced with more typical contact with the foraging devices, as well as increased non-stereotypic active (searching) behaviors.

1. Experiment 1

In Experiment 1, two large foam/rubber stall mats with multiple holes were introduced to the aquatic part of the exhibit under two conditions: either empty, or with their crevices filled with food. We also examined differences in activity between morning and afternoon sessions, and differences in behavior among individual walruses. We expected stable overall activity within each subject, and, because of widely reported differences between the amounts of time juvenile mammals spend directly foraging vs. playing compared to adults, we expected the juvenile walrus to engage in more general activity (and fewer stereotypies).

2. Methods

2.1. Subjects and enclosures

Three wild-born Pacific walruses (*Odobenus rosmarus*) located at the Indianapolis Zoo were used in this study. Brutus, an 18-year-old adult male at the start of the study, was collected from the wild in May of 1987 (unknown exact date and location). Originally a Sea World Ohio animal, he was on breeding loan from Six Flags Ohio, but became a permanent animal at the Indianapolis Zoo shortly after arrival on Oct. 30th, 2003. He weighed 1076 kg at the time of the study. Aurora, a 10-year-old adult female at the start of the study, was collected from Gambel, Alaska on May 26th, 1995. She has lived at the Indianapolis Zoo since she was several weeks old. She weighed 521 kg at the time of the study. Nereus, a 2-year-old juvenile male at the start of the study, was found stranded alone in Alaska on July 5th, 2003. He was taken to the Alaska Sea Life Center for rehabilitation and then transported to Indianapolis on August 20th, 2003. He weighed 236 kg.

All three walruses resided in an outdoor enclosure containing a large pool: 3.1 m deep, 20.4 m in length, 9.3 m in width, with a surface area of 428 m^2, and containing 370,861 L of water when filled. The walruses also could occupy a smaller land area. At 1700 h each day, walruses were taken from exhibit to a holding area about half the size of the outdoor enclosure. Walruses were typically fed 3–5 times per day, receiving most of their diet during training sessions. To avoid conflict with standard training times, all the experimental conditions (described below) were conducted at times between training sessions. Note also that each walrus had its own diet; Brutus ate 35 kg of food per day, Aurora ate 11 kg, and Nereus ate 7 kg per day. Their diet consisted of herring (*Clupea harengus*), capelin (*Mallotus villosus*), and clam (*Mercenaria mercenaria*). Experimental conditions took portions of their normal feed and added them to the devices used (no change in total diet occurred).

2.2. Materials

Two 1.5 m × 1 m × 10 cm stall mats were introduced at the onset of the morning observation. Mats were constructed of a synthetic foam rubber mix, similar to a gymnasium mat, and had 25 5 cm diameter holes drilled in each of them. Both mats floated in the water, partially submerged. They were either introduced alone (Mat Alone condition) or stuffed with 15 capelin, 5 herring and 5 clams each (Mat with Food condition). We used Zire 21™ PDA's, Timex Ironman™ repeatable countdown stopwatches, Event PC software (developed by Dr. James C. Ha at the University of Washington for this project), along with laminated ethogram reference cards, and a notebook to collect data.

2.3. Data collection and procedures

Before beginning experimental trials, we constructed an ethogram of walrus behaviors (with classes and definitions) (see Table 1). The behaviors observed were mutually exclusive, and the inclusion of the "Other" observation category made the ethogram exhaustive. We measured fifteen behaviors organized in 5 different classes. For the purposes of this paper, most of the data were analyzed and presented graphically in terms of the classes of behaviors observed. The ethogram was developed during a previous pilot study and modified for these experiments. Observations were conducted from July through October 2005.

Data were taken three times per week from July to September, and twice per week, from September through October. Morning sessions (between 1030 and 1200 h) and afternoon sessions (between 1345 and 1515 h) were conducted for one hr each day. All experimental conditions occurred during the morning observations (afternoon sessions were used only to compare morning vs. afternoon activity). Instantaneous time samples (Altmann, 1994) were taken every 15 s during each 1 h session, for a total of 240 samples per subject per session. Percentage of occurrence for each behavior within a session was then determined by dividing the # of instances of each response by the total # of instances possible for each session (240). All three walruses were always on exhibit and observed together, and individual observers

Table 1
Behaviors, classes of behavior, and definitions for each response in the ethogram.

Class	Behavior	Definition
Active	Non-Patterned Swimming (NS)	Swimming in an irregular or non-patterned way.
	Non-Patterned Swimming w/ Contact (NC)	Same as NS, but with contact to a pool surface by face/vibrissae.
	Land Active (LA)	Moving or exploring a surface/object on land.
	Mat Contact (MC)	Face-vibrissae contact on a foraging mat.
	Other Contact (OC)	Contact with a manipulable object other than the mat.
Social	Interacting w/ Other Walrus (IOW)	Any body contact with another walrus.
	Vocalization at Walrus (V)	Vocalizing while oriented towards another walrus. Vocalization must occur while oriented towards another walrus (non-oriented grunts do not count).
Inactive	Resting (R)	Bobbing/non-movement in the water.
	Land Resting (LR)	Same as R, but on land.
Stereotype	Circle Swimming (CS)	Swimming in a repetitive pattern, with at least 1 complete circle.
	Circle Swimming w/ Contact (CC)	Same as CS, but with contact to a pool surface by face/vibrissae.
	Flipper Sucking (FS)	Contact of face/vibrissae to flipper with a continued sucking motion (usually done while resting).
	Whistling (W)	Repetitive high-pitched whistling pattern, done in several consecutive bursts (previously observed in Brutus).
Other	Out of Sight (OS)	Walrus is not visible to the observer.
	Other (O)	Walrus engages in a behavior that does not meet the above behaviors.

collected data on each walrus during all conditions of the study.

Researchers conducted their observations from a non-public catwalk located above the exhibit. When mats were introduced, they were dropped by researchers into the pool from the catwalk. The mats, while large, were relatively light, and the walruses were used to receiving enrichment items dropped from the catwalk. Therefore, they kept a safe distance from the area in the pool when objects were dropped.

A within-subject reversal design (described below) was used with the following four conditions:

Baseline (BL) – No introduction of mat or food.

Mat Alone (M) – Two 1.5 m x 1 m x10 cm mats were introduced without food at the beginning of the morning observation.

Mat with Food (MF) – Each of the two presented mats contained 15 capelin, 5 herring, and 5 clams each (50 food items [˜2.5 kg] total) stuffed in the holes in the mats.

Food Alone (F) – The same amount of food inserted in the Mat with Food (MF condition), was dropped in the pool at the beginning of the morning session.

Following the second BL condition, the MF and M conditions were reversed to control for potential order effects. The order was BL/M/MF/BL/MF/M/F/F. Eight sessions were run per condition (four 1 h sessions for each of the two times a condition was presented), for a total of 32 sessions. Prior to collapsing the separately run days for each condition, data for each class of behavior were assessed by comparing the means and standard errors of the first 4 days of a condition to the same measures for the last 4 days run for that condition (return to condition). Except for one case (see Baseline vs. Mat Alone results below), each condition showed very similar results regardless of when it was run.

Because several researchers were used to collect the data, inter-observer agreement (IOA) was used to assess observer coding reliability. IOA was calculated based on total agreement (Poling et al., 1995) for each walrus during 28% of all sessions conducted. This produced a percentage of IOA for each of the classes of behaviors observed for each walrus. IOA was at least 80%, with two exceptions: IOA for Inactive behaviors for Brutus and Aurora were 60.9% and 66%, respectively. However, these behaviors occurred very infrequently (occurred for 2.5% of all IOA session intervals), and therefore, the lack of agreement in their occurrence was not considered important for this study.

2.4. Statistical analyses

The statistical program SigmaStat 3.1® was used for all analyses. Except for differences between morning and afternoon observations and between walruses (both of which compared classes based on the entire hour of observation), the data for the classes of behaviors observed were split into ½ hr bins (0–30 min, 31–60 min), and both ½ hr bins and subjects were analyzed separately. Statistical analyses were conducted on the number of days for each condition representing individual observations. Differences between morning and afternoon observations were analyzed using standard *t*-tests (two-tailed). Differences between the walruses' baseline levels of activity were analyzed using a standard repeated-measures ANOVA with subject as the blocking variable. When significant differences ($p < .05$) for the ANOVA's were found, post-hoc pairwise comparisons (using Student Newman-Keuls tests) were used to examine which of the three subjects significantly differed. For examinations of differences between the four conditions, planned *t*-tests (two-tailed) were done for the following conditions: BL – M, BL – MF, BL – F, and MF – F. For all the comparisons noted above, when the data did not pass normality and/or homogeneity of variance, the data were analyzed using a Mann-Whitney *U*test (nonparametric test). For all tests run, effect size was reported via Cohen's d (*d*).

3. Results

3.1. Morning vs. afternoon activity

Fig. 1 shows the mean percentage of occurrence during morning Baseline (BL) sessions (8 days) and during all afternoon sessions (11 days) for all five classes of behavior (Active, Social, Inactive, Stereotypy and Other) across all four conditions (BL, M, MF, and F). No significant differences were found between morning and afternoon for each class of behavior (all t-values were < 2.11). These observations suggest that the walruses showed stable classes of behavior throughout their daily time on exhibit.

3.2. Differences among the walruses

A repeated-measures ANOVA with subjects as the blocking variable was performed comparing differences in classes of behaviors across the three walruses' morning Baseline (BL) observations. Active behaviors showed significant differences among walruses ($F_{2,21} = 25.74$, $p < .001$, $d = 1.00$). Nereus (the juvenile) spent more time in Active behaviors compared to Brutus ($p < .001$) and Aurora ($p < .001$). Stereotypies also showed significant differences among walruses ($F_{2,21} = 30.160$, $p < .001$, $d = 1.00$), with Nereus showing less time engaging in Stereotypies than either Brutus ($p < .001$) and Aurora ($p < .001$). Finally, the occurrence of Other behaviors showed differences among walruses ($F_{2,21} = 28.908$, $p < .001$, $d = 1.00$), with Nereus spending more time in Other behaviors than did Brutus ($p < .001$) or Aurora ($p < .001$). These differences were related to Nereus' significantly greater level of activity. Because he spent more time unpredictably moving about the exhibit, he was also more difficult to track and more likely to move into areas unobservable, resulting in an

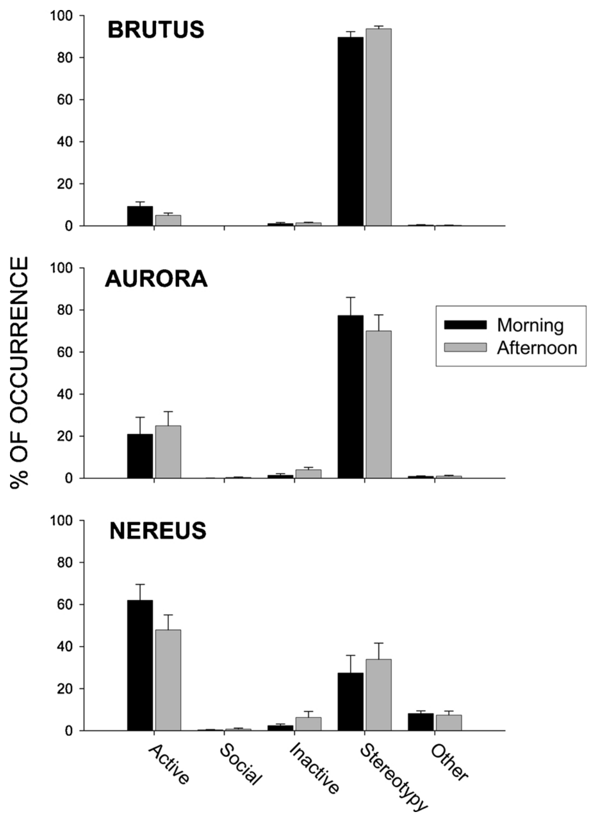

Fig. 1. Mean percentage of occurrence (with SE bars) between morning Baseline sessions (8 days) and all Afternoon sessions (11 days) for all five classes of behavior (Active, Social, Inactive, Stereotypy, and Other) across all four conditions (BL, M, MF, and F). The top graph shows the classes of behavior for Brutus, the middle graph for Aurora, and the bottom graph for Nereus.

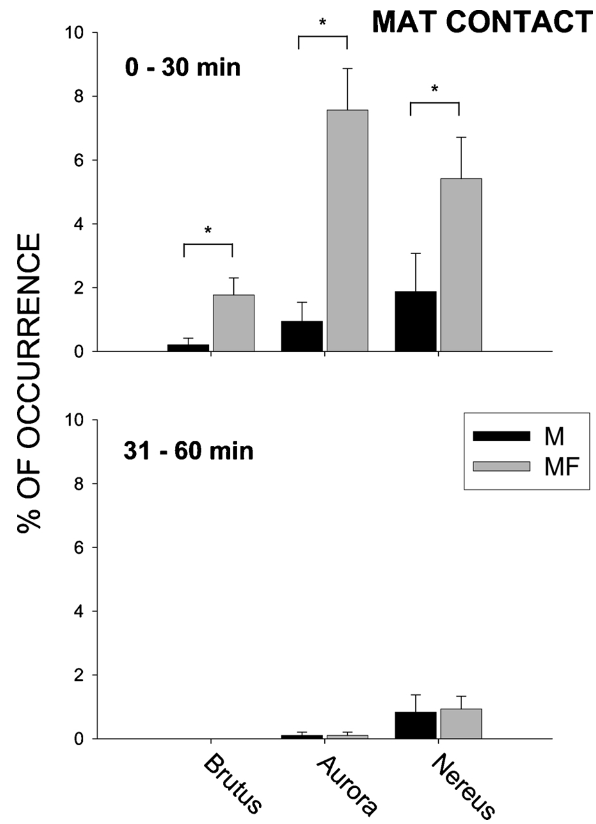

Fig. 2. Mean percentage of occurrence (with SE bars) for Mat Contact behaviors across the Mat Alone (M) and Mat with Food (MF) conditions. The top graph shows the first ½ hr after the mat was introduced, and the bottom graph the second ½ hr. Asterisks and solid lines indicate significant differences between two conditions ($p < .05$).

"Out of Sight" coding (only Out of Sight behaviors were observed for the Other class of behaviors for all walruses throughout the study).

3.3. Mat contact

Fig. 2 represents the mean percentage occurrence for Mat Contact (one of the behaviors in the Active class of behaviors) across the Mat Alone (M) and Mat with Food (MF) conditions. The top graph shows the first ½ hr after the mat was introduced, and the bottom graph shows the second ½ hr. During the first ½ hr, all three walruses contacted the mat during the MF condition significantly more than in the M (Mat Alone) condition (for Brutus, $U = 47_{14}$, $p = .028$, $d = .857$; for Aurora, $t_{14} = \pm 4.628$, $p < .001$, $d = .992$; for Nereus, $U_{14} = 44.5$, $p = .010$, $d = .695$). There were no significant differences during the second ½ hr between the two conditions for any of the three walruses. In short, all 3 walruses paid little attention to the mats without food in them, regardless of whether they once had food in them (all food in the mats were typically consumed within the first ½ hour). However, when food was present in the mat, all 3 walruses increased their contact.

3.4. Individual effects observed in the first ½ hour of all conditions

Fig. 3 displays the mean percentage of occurrence for the first ½ hr of observation for all five classes of behavior (Active, Social, Inactive, Stereotypy, and Other) across all four conditions (Baseline, Mat Alone, Mat with Food, and Food Alone). The top graph represents Brutus' results, the middle graph Aurora's results, and the bottom graph Nereus' results.

3.5. Brutus

For Brutus, Active behaviors significantly increased from Baseline (BL) during the Mat with Food (MF) condition ($U_{14} = 42$, $p = .005$, $d = .544$, $d = .544$) and during the Food Alone (F) condition ($U_{14} = 47$, $p = .028$, $d = .857$). The difference between MF and F was not significant, although the increase in Active behaviors during the MF condition ($M = 32.8\%$, $SD = 19.8$) was higher than the increase in Active behaviors observed in the F condition ($M = 20.3\%$, $SD = 13.5$). There was also a significant increase in Inactive behaviors for Brutus when comparing BL to the F condition ($U_{14} = 49.5$, $p = .050$, $d = .998$). Finally, there were significant decreases in Stereotypies from BL to the MF condition ($U_{14} = 96$, $p = .002$, $d = 1.0$) and to the F condition ($U_{14} = 89.5$, $p = .021$, $d = 1.0$). Like the effects seen in Active behaviors, the MF condition was not significantly different from the F condition. However, the MF condition ($M = 61.8\%$, $SD = 27.6$) did produce a greater reduction in Stereotypies compared to the F condition ($M = 73.2\%$, $SD = 20.0$).

3.6. Aurora

For Aurora, Active behaviors increased significantly from Baseline (BL) during the Mat with Food (MF) condition ($t_{14} = \pm 2.166$, $p = .048$, $d = .422$) and the Food Alone (F) condition ($U_{14} = 47$, $p = .028$, $d = .857$). There were significant increases in Social behaviors for Aurora from BL to the MF condition ($U_{14} = 44$, $p = .010$, $d = .664$) and to the F condition ($U_{14} = 44$, $p = .010$, $d = .664$). A significant increase in Other behaviors from F to the MF condition ($U_{14} = 89$, $p = .028$, $d = 1.0$) was also observed. The increase in Social behaviors during the two food conditions was a result of Aurora contacting Nereus

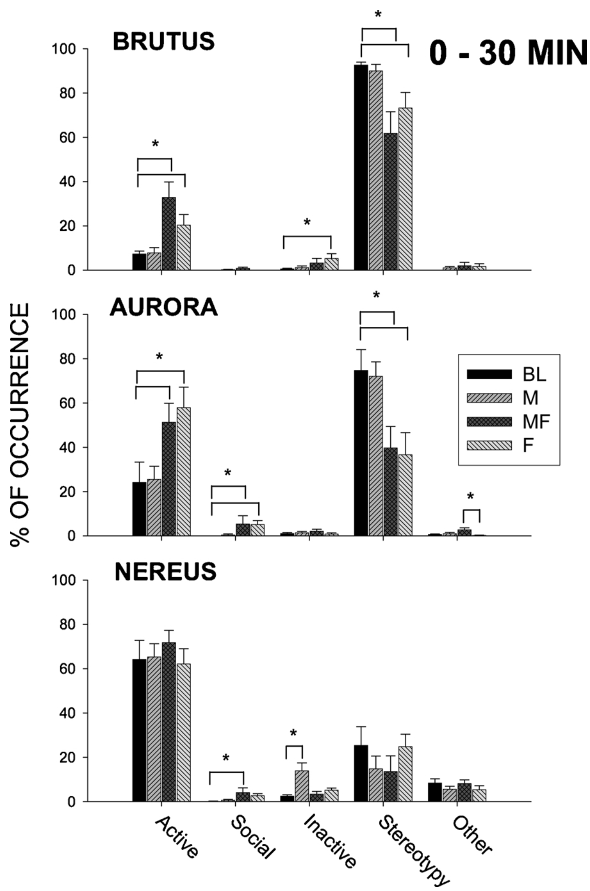

Fig. 3. Mean percentage of occurrence (with SE bars) in the first ½ hr for all five classes of behavior (Active, Social, Inactive, Stereotypy, and Other) across all four conditions (Baseline [BL], Mat Alone [M], Mat with Food [MF], and Food Alone [F]). The top graph shows the classes of behavior for Brutus, the middle graph for Aurora, and the bottom graph for Nereus. Asterisks and solid lines indicate significant differences between two conditions (p < .05).

more when foraging for food. These contacts did not appear to be aggressive in nature, but simply resulted from foraging near another walrus (presumed unintentional physical contact). The reasons for the difference in Other behaviors are not clear, although it may have been a result of the mats partially obstructing our ability to observe Aurora while foraging during the MF condition. Finally, Stereotypies decreased from BL to the MF condition ($t_{14} = \pm 2.492$, $p = .021$, $d = .604$) and from BL to the F condition ($t_{14} = \pm 2.776$, $p = .015$, $d = .677$). Like the effects seen in Active behaviors, the MF condition was not significantly different from the F condition.

3.7. Nereus

Unlike the two adult walruses, Nereus maintained a high level of Active behaviors and low level of Stereotypies during Baseline (BL), and exhibited no significant differences for these behaviors during the Mat with Food (MF) or Food Alone (F) conditions. There was a significant increase in Social behaviors from BL to the MF condition ($U_{14} = 42.5$, $p = .005$, $d = .574$). This matched Aurora's increase in social behaviors during this condition and was a result of the two walruses likely unintentionally contacting each other while attempting to obtain food from the mats. Again, these contacts did not appear to be aggressive in nature.

3.8. Effects observed in the second ½ hour

Fig. 4 shows the mean percentage of occurrence for the second ½ hr for all five classes of behavior (Active, Social, Inactive, Stereotypy, and Other) across all four conditions (Baseline, Mat Alone, Mat with Food, and Food Alone). The top graph represents Brutus' results, the middle graph Aurora's results, and the bottom graph Nereus' results.

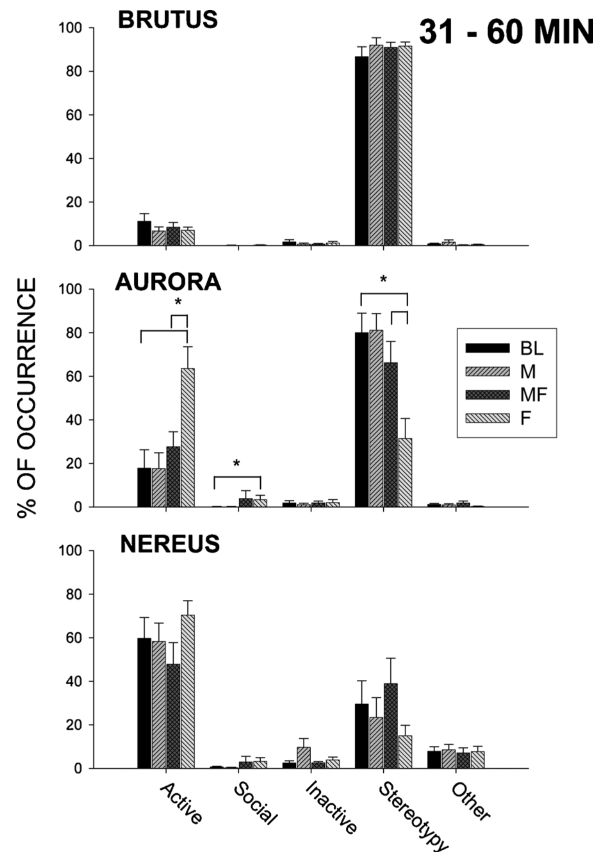

Fig. 4. Mean percentage of occurrence (with SE bars) in the second ½ hr for all five classes of behavior (Active, Social, Inactive, Stereotypy, and Other) across all four conditions (Baseline [BL], Mat Alone [M], Mat with Food [MF], and Food Alone [F]). The top graph shows the classes of behavior for Brutus, the middle graph for Aurora, and the bottom graph for Nereus. Asterisks and solid lines indicate significant differences between two conditions (p < .05).

3.9. Brutus and nereus

Both Brutus and Nereus showed no significant differences for any of the conditions during the second ½ hr. These results, along with the previous Mat Contact data, suggest that any enriching functions of the Mat with Food (MF) and Food Alone (F) conditions were short-lived for Brutus, presumably because most, if not all, of the food was consumed in the first ½ hr.

3.10. Aurora

Active behaviors significantly increased from Baseline (BL) during the Food Alone (F) condition ($U_{14} = 46.5$, $p = .021$, $d = .823$). The F condition also showed significantly greater Active behaviors when compared to the Mat with Food (MF) condition ($t_{14} = \pm 2.955$, $p = .010$, $d = .743$). Aurora also significantly increased Social behaviors from BL to the Food condition ($U_{14} = 46$, $p = .021$, $d = .790$). Again, these increased Social behaviors resulted primarily from inadvertent contact with Nereus while foraging near him. Finally, Aurora significantly decreased Stereotypies from BL to the Food (F) condition ($t_{14} = \pm 3.791$, $p = .002$, $d = .938$). Like the effects seen in Active behaviors, The F condition showed significantly fewer Stereotypies when compared to the Mat with Food (MF) condition ($t_{14} = \pm 2.591$, $p =$

.021, $d = .603$).

4. Experiment 1 conclusions

While both the Mat with Food (MF) and Food Alone (F) conditions appeared to have similar effects in increasing Active behaviors and reducing Stereotypies in the two adult walruses, there were differences that could be viewed as recommending alternative enrichment strategies for each walrus. For Brutus, while both conditions were effective at increasing Active behaviors and reducing Stereotypies, and no significant differences were found between the two treatments, the MF condition did show greater mean differences from Baseline for both measures. In contrast, Aurora's effects observed in the second ½ hr (Fig. 4) exhibited that the F condition was more effective than the MF condition at maintaining increased Active behaviors and decreased Stereotypies.

One possible reason for this difference between Brutus and Aurora is that, while the MF condition maintained food in one area (predominantly on or around the mats), the F condition dispersed the same amount of food around the pool (i.e., it was not contained within a device). This difference appeared to interact with the form of stereotypies. Brutus spent 71% of his stereotypies engaged in flipper sucking, whereas Aurora spent 91.9% of her stereotypies engaged in a form of circle swimming. As a result, restricting food to the mats (MF) may have been better suited to disrupt stereotypies for Brutus, who engaged mostly in a stationary stereotypy. In contrast, scattering food around the pool (F) may have been better suited for interfering with the movement-based stereotypy displayed most frequently by Aurora.

5. Experiment 2

In Experiment 1, the two adult walruses primarily exhibited two different forms of stereotypies during an experimental session with food available: locomotor circle swimming for Aurora and stationary flipper sucking for Brutus. Circle swimming, functionally, appears more directly related to movement-based foraging activity, while the reason for flipper sucking by Brutus was less clear. However, observations of walrus foraging in the wild showed extensive use of their flippers while foraging, including digging/stirring up the sandy bottom in searching for shellfish (Levermann et al., 2003). Because of this, we decided to introduce boomer ball feeding devices that would be more directly manipulable (compared to the mats) with a walrus's flippers, as well as easily moved around the exhibit.

6. Methods

6.1. Subjects and enclosures

The subjects and enclosure were the same as used during Experiment 1.

6.2. Materials

Two 61 cm diameter balls were used during morning observations. The balls, commonly referred to as boomer balls and typically used for enrichment, were made of a hollow, hard polyethylene plastic with 6 holes (5-4 cm diameter holes and 1–10 cm diameter hole) drilled through the surface. Both balls floated rather than sinking to the bottom, although they could be easily dragged underwater by a walrus. The balls were introduced both empty and with food in them (see conditions described below). All additional materials were the same as Experiment 1.

6.3. Data collection and procedures

The ethogram was the same as used during Experiment 1. Observations were conducted from November 2005 through April 2006. Data were taken two times per week throughout the study. Only morning sessions were observed to keep the present experiment within the same circadian time frame as Experiment 1 (1030 to 1200 h). Observation length, method, place of occurrence, and foraging device introduction were the same as Experiment 1. As with Experiment 1, a within-subject reversal design (order described below) was used, but only for the two following conditions:

Ball Alone (B) – Two 61 cm diameter Plastic balls were introduced at the beginning of each observation.

Ball with Food (BF) – Both balls introduced with 15 capelin, 5 herring, and 5 clams each (50 food items total) placed inside the balls.

Because the mat alone and baseline conditions showed little difference in Experiment 1, and after observing that the Ball Alone (B) condition showed a similar trend, we only used B and BF conditions for Experiment 2. The, sessions were semi-randomized between B and BF conditions (1–5 sessions per condition) to test for both habituation (reduced responding due to familiarly with the boomer balls) and carryover effects (continued responding to a boomer ball without food because of its previous containment of food). A total of 28 sessions were observed, 10 B, and 18 BF conditions. The reversals were run in the following order (with # of sessions in parentheses):

BF(2) - B(1) - BF(5) - B(2) - BF(4) - B(2) - BF(2) - B(2) - BF(2) - B(1) - BF(2) - B(2) - BF(1)

Interobserver agreement (IOA) was calculated based on total agreement (Poling et al., 1995) for 21.4% of all sessions conducted. This produced a percentage of agreement for each of the classes of behaviors observed and for each walrus. All measures of total agreement were above 80%, with two exceptions. IOA for Other behaviors for Brutus and Aurora were 44.4% and 50%, respectively. However, these behaviors occurred very infrequently (occurred for 2.0% of all IOA session intervals), and therefore, the lack of agreement in their occurrence was not considered important for this study.

6.4. Statistical analyses

SigmaStat 3.1® was again used for all statistical analyses, with all data again split into ½ hr bins and both bins and subjects analyzed separately. For examinations of differences between the two conditions, standard *t*-tests (two-tailed) were used. In addition, *t*-tests (two-tailed) were used to compare the BF to either the MF or F condition from Experiment 1, and Ball Contact with Mat Contact from Experiment 1. When the data did not pass normality and/or homogeneity of variance, the data were analyzed using a Mann-Whitney *U*test (nonparametric test). For all tests run, effect size was reported via Cohen's d (*d*).

To examine potential habituation effects, line plots of Ball Contact percentages during their first ½ hr of introduction were plotted for all 18 days the Ball with Food (BF) condition was implemented.

7. Results

7.1. Ball contact

Fig. 5 shows the mean percentage of occurrence for Ball Contact across the Ball (B) and Ball with Food (BF) conditions. The top graph shows the first ½ hr after the boomer balls were introduced, and the bottom graph shows the second ½ hr the boomer balls were present. During the first ½ hr, all three walruses significantly increased their Ball Contact during the BF condition compared to the B condition (for Brutus, $U_{26} = 61$, $p < .001$, $d = .545$; for Aurora, $U_{26} = 55$, $p < .001$, $d = .669$; for Nereus, $U_{26} = 58$, $p < .001$, $d = .606$). During the second ½ hr, only Aurora continued to significantly contact the boomer balls more during the BF condition than the B condition ($U_{26} = 90.5$, $p = .010$). While Brutus and Nereus still contacted the boomer balls in the second ½ hr, the contact did not differ significantly between the B and BF conditions. As with the mats in Experiment 1, all 3 walruses paid

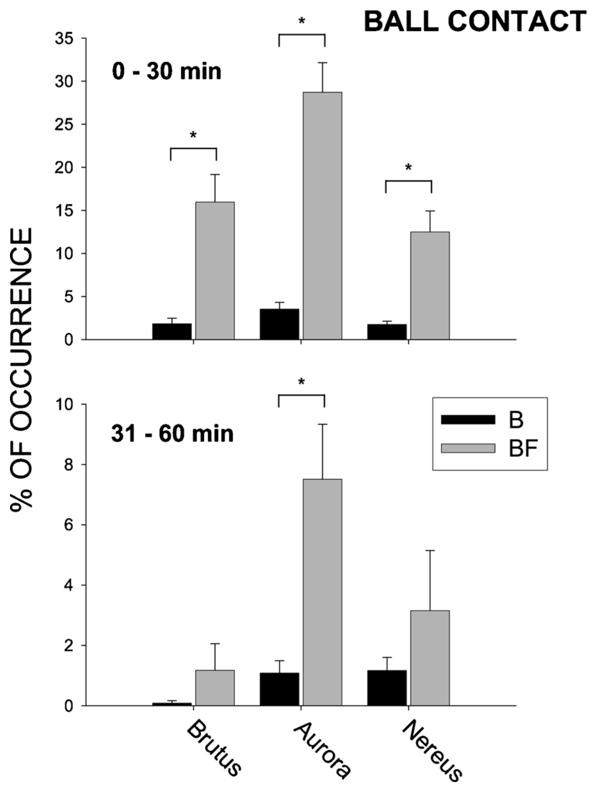

Fig. 5. Mean percentage of occurrence (with SE bars) for Ball Contact behaviors across the Ball Alone (B) and Ball with Food (BF) conditions. The top graph shows the first ½ hr after the ball was introduced, and the bottom graph the second ½ hr. Asterisks and solid lines indicate significant differences between two conditions (p < .05).

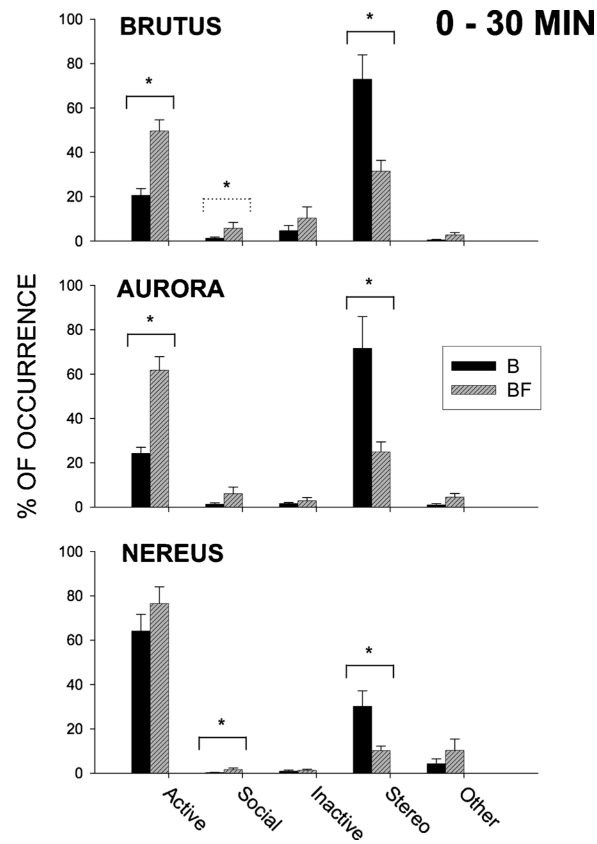

Fig. 6. Mean percentage of occurrence (with SE bars) in the first ½ hr for all five classes of behavior (Active, Social, Inactive, Stereotypy, and Other) across both conditions (B and BF). The top graph shows the classes of behavior for Brutus, the middle graph for Aurora, and the bottom graph for Nereus. Asterisks and solid lines indicate significant differences between two conditions (p < .05).

little attention to the boomer balls without food in them, and only one of the walruses (Aurora) contacted the boomer balls more than incidentally after the first ½ hr of their introduction.

Within the first ½ hr, all 3 walruses showed significantly greater contact of the Ball with Food (BF) compared to the Mat with Food (MF) conditions (for Brutus, $U_{24} = 40.5$, $p < .001$, $d = 1.0$; for Aurora, $U_{24} = 36$, $p < .001$, $d = 1.0$; for Nereus, $U_{24} = 68$, $p = .028$, $d = .407$). Also, Aurora continued to contact the boomer balls during the BF condition significantly more than the B condition in the second ½ hr, which was not the case with the mats.

7.2. Individual effects observed in the first ½ hour

Fig. 6 displays the mean percentage of occurrence for the first ½ hr for all five classes of behavior (Active, Social, Inactive, Stereotypy, and Other) across both conditions (Ball Alone and Ball with Food). The top graph represents Brutus' results, the middle graph Aurora's results, and the bottom graph Nereus' results.

7.3. Brutus, BF vs. B

The Ball with Food (BF) condition significantly increased Active behaviors ($U_{26} = 71$, $p < .001$, $d = .350$), and produced an increase that approached significance in Social behaviors ($U_{26} = 106.5$, $p = .068$, $d = .302$) when compared to the Ball Alone (B) condition. Stereotypies significantly decreased when comparing the BF condition to the B condition ($t_{26} = \pm 5.241$, $p < .001$, $d = 1.0$). These results suggest that the BF condition was an effective enrichment tool for Brutus during the first ½ hour of its introduction.

7.4. Brutus, BF vs. MF

The Mat with Food (MF) condition from Experiment 1 appeared to be the most successful condition for Brutus in terms of increasing Active behaviors and decreasing Stereotypies. As a result, we compared the MF condition with the Ball with Food (BF) condition to see if there was a significant difference between the two conditions. The BF condition was significantly better at increasing Active behaviors ($t_{24} = \pm 2.113$, $p = .045$, $d = .419$) and decreasing Stereotypies ($t_{24} = \pm 3.2$, $p = .004$, $d = .845$) compared to the MF condition.

7.5. Aurora, BF vs. B

There was a significant increase in Active behaviors, comparing the Ball with Food (BF) condition to the Ball Alone (B) condition ($U_{26} = 68$, $p < .001$, $d = .407$). Stereotypies significantly decreased when comparing the BF condition to the B condition ($t_{26} = \pm 5.580$, $p < .001$, $d = 1.0$).

7.6. Aurora, BF vs. F

The Food Alone (F) condition from Experiment 2 appeared to be the most successful condition for Aurora in terms of increasing Active behaviors and decreasing Stereotypies. However, a comparison of the F condition with the Ball with Food (BF) condition showed no significant differences during the first ½ of observation for the two conditions.

7.7. Nereus, BF vs. B

The Ball with Food (BF) condition compared to the Ball Alone (B) condition showed a significant increase in Social Behaviors (U_{26} = 103, p = .046, d = .237), and a significant decrease in Stereotypies (U_{26} = 189.5, p = .035, d = .130). In both Experiments 1 and 2, Nereus maintained a high level of Active behaviors and low level of Stereotypies during non-food conditions. Unlike the Mat with Food (MF) and Food Alone (F) conditions for Nereus, the BF condition was able to reduce Stereotypies relative to Baseline during the first ½ hr of its introduction.

7.8. Nereus, BF vs. MF, BF vs. F

For Nereus, neither the Mat with Food (MF) or Food Alone (F) conditions from Experiment 1 significantly increased Active Behaviors or decreased Stereotypies when compared to Baseline. As a result, we compared both MF and F conditions with the Ball with Food (BF) condition to see if there was a significant difference for BF between the MF or F conditions. No significant differences were observed for the first ½ hr of observation between the BF and MF conditions. However, the BF condition showed a significant decrease in Stereotypies when compared to the F condition (U_{24} = 148, p = .028, d = .194).

7.9. Effects observed in the second ½ hour

Fig. 7 displays the mean percentage of occurrence for the second ½ hr for all five classes of behavior across both the Ball Alone (B) and Ball with Food (BF) conditions. The top graph represents Brutus' results, the middle graph Aurora's results, and the bottom graph Nereus' results.

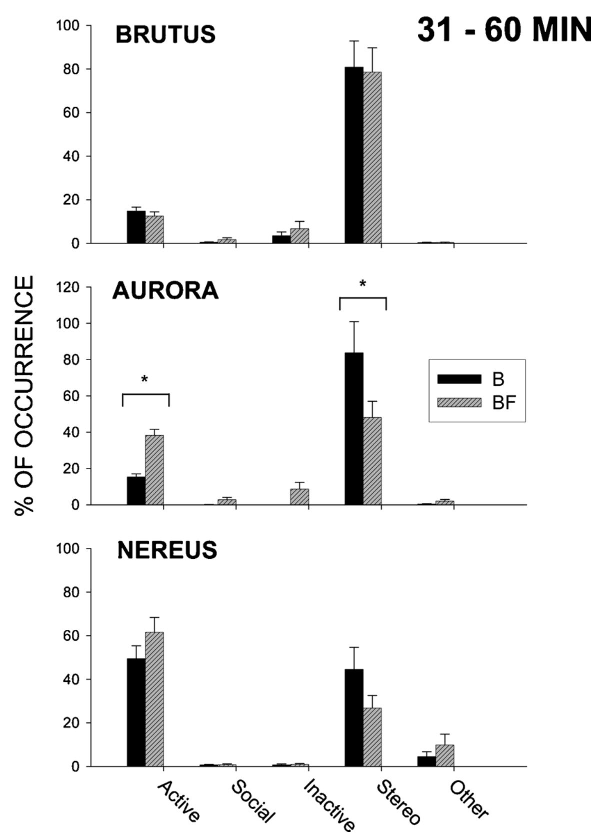

Fig. 7. Mean percentage of occurrence (with SE bars) in the second ½ hr for all five classes of behavior (Active, Social, Inactive, Stereotypy, and Other) across both conditions (B and BF). The top graph shows the classes of behavior for Brutus, the middle graph for Aurora, and the bottom graph for Nereus. Asterisks and solid lines indicate significant differences between two conditions ($p < .05$).

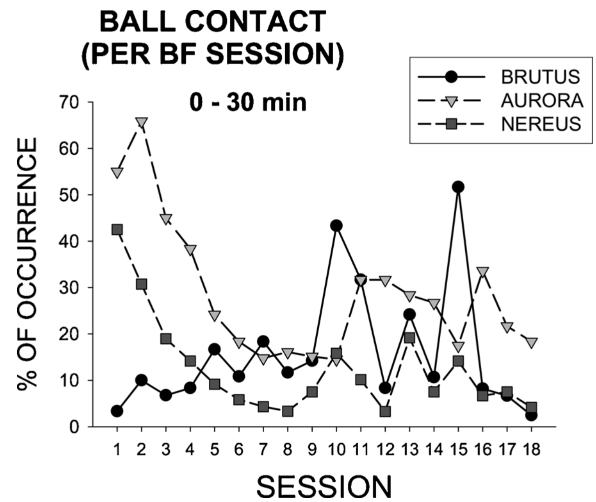

Fig. 8. Percentage of ball contact per session during the first ½ hr of the BF condition.

The only significant differences observed when comparing the Ball with Food (BF) condition to the Ball Alone (B) condition in the second ½ hr were an increase in Aurora's Active behaviors (U_{26} = 99.5, p = .031, d = .173) and a decrease in Stereotypies (t_{26} = ± 3.192, p = .004, d = .846). Likewise, only Aurora exhibited a significant difference in comparisons between either the BF and Mat with Food (MF) or Food Alone (F) conditions in the second ½ hr; the BF condition exhibited a significant decrease in Active behaviors when compared to the F condition (t_{24} = 2.211, p = .037, d = .463).

7.10. Ball contact across BF sessions

Fig. 8 shows the percentage of Ball Contact per session (18 total sessions) during the first ½ hr of the Ball with Food (BF) condition.

7.11. Aurora and nereus

For both Aurora and Nereus, rapid habituation was observed, with the first 2 sessions representing the highest percentage of contact (Aurora, 55 and 65.8%; Nereus, 42.5 and 30.7%, respectively) and steadily decreasing to 14.5% during session 10 for Aurora, and 3.3% during session 8 for Nereus. However, following these sessions, both walruses continued to show spikes in Ball Contact for the rest of the BF sessions, and neither showed a continued decline in Ball Contact that dropped below their session 10 (for Aurora) and 8 (for Nereus) percentage of occurrence.

7.12. Brutus

In contrast, Brutus showed an initial reluctance to contact the boomer balls, but gradually increased Ball Contact across the first several sessions, and after session 9, showed interspersed spikes in Ball Contact activity for the remainder of the sessions. Following session 15 (the session with his highest percentage of contact; 51.7%), he continued to show a level of Ball Contact activity similar to that observed during his first several sessions.

8. Experiment 2 conclusions

Overall, the Balls with Food (BF) condition was more effective than the Mat with Food (MF) condition at producing device contacts for all three walruses during the first ½ hour of a device's introduction. This extended to the second ½ for Aurora, who continued to contact the balls. In addition, two of the walruses (Brutus and Nereus) showed significantly greater Activity and less Stereotypies during the BF condition compared to the MF condition. For the third walrus, Aurora, BF was as effective at increasing Activity and reducing Stereotypies as the Food Alone (F) condition. These results indicate that the boomer balls functioned better as potential food-containing enrichment items for the walruses than the mats, and thus were functionally more appropriate for eliciting foraging behavior in the walruses.

Additionally, while for 2 of the 3 walruses, there was rapid habituation to the ball devices, all walruses continued to show considerable interest in the boomer balls with food. This suggests that food-based enrichment should continue to maintain interest, if food continues to be available. Rather than an animal habituating to an item that previously alleviated "boredom", enrichment should continue to maintain foraging activity while it gives an animal a reason to forage. In other words, animals may discover ways of extracting food faster, but a foraging-motivated animal should continue to interact with a foraging device for as long as they can obtain food from the device.

9. General discussion

9.1. Stereotypies across the day

As reported in Experiment 1, all three walruses showed a stable level of responding in all five classes of behavior across both morning and afternoon sessions. This suggests that adult walruses maintained a moderate to high, unchanging level of stereotypies throughout their daily time on exhibit. This contrasts with observations of other captive carnivores, such as polar bears and ocelots, in which stereotypies and general activity typically increase markedly in the hours before a large daily feeding (Wechsler, 1991; Weller and Bennett, 2001).

Two possible reasons for the different distributions of stereotypies and other classes of behavior in the walruses are: (1) they were fed 3–5 times a day, unlike the common practice of feeding a large daily feed for many species of captive carnivores (i.e., ursids and felids), and (2) walruses in the wild are an atypical large predator, in that they spend most of the day steadily consuming small prey, rather than capturing large prey once a day, or less.

9.2. Stereotypies as a function of multiple feedings

If several daily feedings are responsible for the walruses' stable foraging behavior across the day (compared to that shown by other large carnivores), it might be argued that walruses should show less stereotypies than single or large daily meal carnivores. Increasing number of feedings in other large carnivores has been shown to reduce stereotypies compared to one feeding a day (Shepherdson et al., 1993). However, the two adult walruses in this study still engaged in large amounts of stereotypies, summing to over 80% of their total possible behaviors during baseline conditions.

It's possible that multiple feedings only produce temporary relief from stereotypies, or that hiding of the food or unpredictable timed deliveries (as opposed to the food delivered during training sessions at predictable times) are necessary. Alternatively, the key differences with other carnivores may be that walruses have evolved to maintain a high level of foraging across the whole day in the wild to maintain their body weight on their relatively small individual prey, which would account for their high frequency of adult stereotypies observed throughout the day in this study.

It is worth noting that feeding multiple times a day as opposed to once a day should be beneficial for the welfare of walruses in general, especially given that multiple daily feedings are more representative of how they consume food in the wild. However, as a treatment to reduce stereotypies, multiple feedings probably should not be particularly successful with walruses. Walrus stereotypies revolve around local search and specialized behaviors for repeatedly extracting prey items, rather than extensive locomotion between prey items (Born et al., 2003; Levermann et al., 2003). Their foraging appears more similar to herbivore grazers in its high level of specialized feeding behavior and sustained local search and acquisition.

9.3. Young vs. adult stereotypies and establishment/emancipation

Nereus engaged in considerably less stereotypies compared to the two adult walruses. Other studies have found similar differences between captive juvenile and adult stereotypies (Mountaudouin and Le Pape, 2004; Schoenecker et al., 2000). Some researchers have suggested that less stereotypies in young animals are due to the shorter amount of time the animal has spent in captivity (Cooper and dberg, 1991; Mason, 1993). These researchers argue that stereotypies initially become established within captive environments, and then eventually becomes emancipated from its original causes, presumably because it has occurred within that context for a lengthy period. While the mechanism(s) producing this effect have not been clearly described, it is presumed that this is somehow a result of being captive.

An alternative explanation for lower levels of stereotypies in juvenile mammals is that they spend less time attempting to physically catch prey and more time playing (Fagen, 1981; Loizos, 1966). A simple test of this alternative hypothesis to the establishment/emancipation of stereotypies would be to compare either: (1) wild-caught adults compared to captive-bred adults, or (2) younger adults compared to older adults. In both cases, the establishment/emancipation hypothesis should predict that the younger/recently captive animals would not display stereotypies as often as the older/captive bred animals. However, the alternative, foraging-based hypothesis would predict that, following habituating to the novel aspects of a captive environment, the younger/recently captive animals would engage in stereotypies on average similarly to the older/captive bred animals.

9.4. Mats vs. boomer balls

For all the walruses, the boomer balls used in Experiment 2 appeared to be more effective than the mat as an enrichment device eliciting contact. They were also more effective at reducing stereotypies and increasing general activity for Brutus during the first ½ hr after their introductions. Initially, the mats were selected as a foraging device because of their thick texture and size, thus providing a potential substrate functionally similar to the ocean floor for the walruses to use while foraging. However, after obtaining the results of Experiment 1 and observations of the use of flippers for foraging by walruses in the wild, we implemented the boomer ball experiment. The boomer balls as foraging devices allowed each walrus to use extensive flipper manipulations to obtain food from the devices, as well as use them in either a stationary or movable manner.

9.5. Treatment effect and form of stereotypies

As noted in Experiment 1, there were considerable differences in what conditions were effective for each walrus, particularly between the two adult walruses, and these differences were once again observed in Experiment 2. One explanation is that the form of the stereotypies the two adult walruses displayed dictated what type of foraging activity they were more likely to engage in, and therefore what type of treatment would be more effective. For Aurora, who engaged predominantly in locomotion-based stereotypies, the Food Alone (F) condition was more effective than the Mat with Food (MF) condition, since the F condition was more likely to spread the food across the exhibit.

While the Ball with Food (BF) condition elicited significantly greater contact than the MF condition did, and while Aurora was often observed to push the ball around the exhibit, which still allowed her to engage in a locomotion-based foraging activity, it was not as effective as the F condition in the second ½ hr for maintaining Active behaviors.

Brutus, however, engaged predominantly in flipper sucking, a stationary stereotypy, and showed greater increases in Active behaviors and greater decreases in Stereotypies during the MF condition. It was still apparent that during the first ½ hr, the BF condition was very successful at eliciting contact, increasing Active behaviors, and reducing Stereotypies when compared to the MF condition for Brutus. Brutus, in comparison to Aurora, was often observed to grip one of the boomer balls between his flippers and slowly rotate the ball while periodically sucking on the holes.

9.6. Exhibit/enrichment history

Aurora, as noted in Experiments 1 and 2, was the only walrus to show effects of food introduction that lasted beyond the first ½ hr. In addition, Aurora showed the highest level of contact to both the mats and boomer balls and was the only walrus that maintained significantly greater contact with the boomer balls into the second ½ hr after their introduction. One possible reason for this was that Aurora spent almost her entire life at the Indianapolis Zoo, where she received enrichment and training several times a day throughout most of her life. Brutus, as noted previously, was maintained in a smaller pool for much of his captive life, where he was reported to have received less training and enrichment, as well as less ability to move about freely. In addition, Brutus was previously rewarded by zookeepers for sucking on his flipper. This was done to minimize Brutus sucking on or mouthing other parts of his exhibit, which could cause damage to himself and/or the exhibit.

As a result, it's possible that the limited ability to engage in movement-based activity combined with being rewarded for flipper sucking resulted in Brutus engaging in more flipper sucking stereotypies than circle swimming stereotypies compared to Aurora. Regardless of the proximate functional relevance to the form of the stereotypies observed, we still observed (1) a similar percentage of stereotypies for both adult walruses, and (2) an ability to reduce the stereotypies with the use of food and food-related stimuli.

9.7. Stereotypies and foraging

Overall, both experiments supported the hypothesis that the walruses' stereotypies are functionally related to species-typical foraging activities, and that the use of food and items containing food are ideal for deterring their stereotypies and increasing "naturalistic" foraging behaviors. While these manipulations were experimental designs intended to examine the relationship of such stimuli to foraging activity (and therefore only examined a fraction of the effects on overall daily activity), they provide some insight and evidence about how to attain the long-term zoo goal of decreasing and deterring stereotypies and other aberrant behaviors throughout the life of walruses and other exhibited animals.

It should be noted that caution is warranted in generalizing these results beyond that of captive walruses in similar exhibits. However, it is equally arguable that within-subject methods such as those used in this study are necessary for identifying internally valid mechanisms involved in stereotypies, as well as identifying the function of any behavior. Future studies on stereotypies could focus on both providing within-subject analyses (internal validity), in combination with between-subject generalizability (external validity) to better capture both the proximate and ultimate mechanisms involved in stereotypies across a wide range of individuals, species, and captive settings.

Based on this and other enrichment studies, a key to developing foraging devices that are effective in reducing stereotypies is the fit between the device and the set of behaviors the animal typically uses in foraging. Stereotypies can be viewed as an animal's way of telling you what kinds of behaviors and sensory motor mechanisms are available in those circumstances, and therefore, how that animal is likely to interact with its exhibit and the items introduced into their enclosure. For instance, repetitive licking in a giraffe suggests that devices requiring considerable mouth and tongue manipulations to get food would help reduce that stereotypy. Viewed in this way, stereotypies are a source of information about the animal's foraging tendencies and abilities. Discovering how to engage those mechanisms and behaviors appears important in both increasing species-typical foraging repertoires and reducing stereotypies. Thus, we can at the same time improve the welfare of the animals, educate the observers, and help form a better model of how that animal functions in its ecological niche.

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