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ARTICLE

Effects of Complex Feeding Enrichment on the Behavior of Captive Malayan Sun Bears (*Helarctos malayanus*)

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ABSTRACT

All zoos grapple with challenges of keeping captive animals engaged in natural behaviors, especially for bears which prove to be among the more challenging species to keep stimulated. In captivity, a common indicator of poor welfare is the presence of stereotypic behaviors. This study tests whether providing complex feeding enrichment devices decreases the duration of stereotypic behavior and increases enrichment interaction for three adult female sun bears (*Helarctos malayanus*) at Oakland Zoo in California. This study uses two different enrichment devices presented at three complexity levels. After three weeks of baseline data collection when no complex enrichment is present, the complex enrichment is introduced three times a week per level over six weeks. Sun bear interaction with the enrichment devices is also measured to examine the effect of complexity on enrichment use. Providing complex enrichment decreased the duration of stereotypic behavior when compared to baseline. Across the six weeks, the duration of stereotypic behavior is significantly less on the complex enrichment days compared to non-complex enrichment days. The complex enrichment has variable effects on enrichment use. These results suggest that providing complex enrichment may have a positive influence on the behavior of captive bears.

KEYWORDS

Stereotypy; stereotypic behavior; species-typical behavior; behavioral enrichment; animal welfare

Introduction

In the wild, animals face a plethora of challenges and exposure to new stimuli due to natural variations and uncertainties in their environment (Spinka & Wemelsfelder, 2011). The failure of a captive environment to satisfy an animal's needs for information gathering can be a possible cause for the development of stereotypic behaviors, especially for generalists such as bears, who, in the wild, spend a lot of time exploring their environment (Clubb & Vickery, 2006; Mench, 1998). Stereotypic behaviors, also known as stereotypies, are a category of atypical behaviors that are performed repeatedly with no apparent function (Mason, 1991; Rose, Nash, & Riley, 2017). Stereotypies are often observed in animals living in captivity and can manifest in a variety of ways across different species: tongue rolling or object licking in ungulates (Bashaw, Tarou, Maki, & Maple, 2001; Bergeron, Badnell-Waters, Lambton, & Mason, 2008, p. 19; Fernandez, Bashaw, Sartor, Bouwens, & Maki, 2008), rhythmic head movements or swaying in elephants (Gruber, Friend, Gardner, Packard, & Beaver, 2000; Rees, 2009), head-tossing, rocking or pacing in primates (Hugo et al., 2003; Jacobson, Ross, & Bloomsmith, 2016; Lutz, Well, & Novak, 2003), and pacing or head swaying in bears (Anderson, Arun, & Jensen, 2010; Carlstead, Seidensticker, & Baldwin, 1991; Vickery & Mason, 2004).

The welfare impact of stereotypies on captive animals is widely debated across the literature because the performance of stereotypies has been assumed to be a sign of poor welfare with the same causal factors generalized for all forms of stereotypy (Broom, 1983; Carlstead, 1998; Rushen & Mason, 2006).

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However, the relationship between stereotypies and animal welfare is not straightforward because the stimuli leading to the development of the behavior may be unidentifiable or uninterpretable (Mason & Latham, 2004; Mason & Mendl, 1993). Stereotypic behaviors have been associated with multiple factors such as frustration, inability to cope with stress, or lack of stimulation (Mason, Clubb, Latham, & Vickery, 2007; Swaisgood & Shepherdson, 2006). In some cases, stereotypy produces a calming sensation or "mantra" effect for the animal (Mason & Latham, 2004). In others, the stereotypy acts as a scar from a previous trauma or suboptimal environment meaning that the performance of stereotypy is unaffected even in a new, enriched environment; signifying a reduced ability to respond to novel environmental changes (Mason et al., 2007; Mason & Latham, 2004; Swaisgood & Shepherdson, 2005). Finally, sometimes, stereotypies are described as an anticipatory behavior when management routines are too predictable (Van der Harst & Spruijt, 2007; Ward, Sherwen, & Clark, 2018; Watters, 2014) and condition the repetition of a behavior prior to delivery of something the animal finds rewarding or relieving (e.g., shifting into another space, food delivery, etc.). Many gaps exist in our knowledge of stereotypies, but more detailed analyses of these behaviors can help shed light on their impact on animal welfare (Mason & Latham, 2004). Considering all of the underlying factors for the development of stereotypic behaviors, animal managers are faced with the task of determining the best strategy to decrease the time the animals spend performing stereotypies and encourage the animals to engage in more species-typical behaviors.

The most common way of tackling stereotypic behaviors involves providing environmental enrichment (Mason et al., 2007). To fulfill their motivations, captive animals need opportunities to engage in a variety of activities, such as the ability to work for food (Spinka & Wemelsfelder, 2011). Environmental enrichment has been shown to increase the occurrence of species-typical behaviors and decrease the frequency of stereotypic behaviors in a variety of species (e.g., American black bear, *Ursus americanus*: Carlstead et al., 1991; leopard cats, *Felis bengalensis*: Shepherdson, Carlstead, Mellen, & Seidensticker, 1993; chimpanzees, *Pan troglodytes*: Bloomsmith & Lambeth, 1995; Amur tigers, *Panthera tigris altaica*: Jenny & Schmid, 2002; spectacled bear, *Tremarctos ornatus*: Renner & Lussier, 2002; cheetahs, *Acinonyx jubatus*: Quirke and O'Riordan, 2011a, 2011b; fennec foxes, *Vulpes zerda*: Watters, Miller, & Sullivan, 2011; laboratory rats, *Rattus norvegicus*: Abou-Ismail & Mendl, 2016).

The topography of stereotypic behaviors (i.e., form, timing, and location), has been linked to the motivation behind the behavior. For example, pacing around the time of predictable husbandry events or in areas where the animal can view food arrival has been linked to anticipation of upcoming interaction with a keeper and expectation of a food reward (Van der Harst & Spruijt, 2007; Ward et al., 2018; Watters, 2014). Presumed anticipatory stereotypies have been observed in many captive bear species (e.g., American black bears: Carlstead et al., 1991; European brown bears, *Ursus arctos arctos*: Montaudouin & Le Pape, 2004; Malayan sun bears, *Helarctos malayanus*: Vickery & Mason, 2004; sloth bears, *Melursus ursinus*: Anderson et al., 2010; and polar bears, *Ursus maritimus*: Cless & Lukas, 2017). In addition, a higher prevalence of locomotory and oral stereotypies exhibited by an animal suggests it has limited ability to respond to stimuli or to perform species-typical behaviors, such as foraging (Jacobson et al., 2016; Mason & Latham, 2004; Vickery & Mason, 2004). Since bears are easily prone to developing stereotypies due to their complex feeding behaviors and extensive foraging activities, providing bears with opportunities to exhibit feeding behaviors as they would in the wild can reduce the performance of some stereotypic behaviors (Carlstead et al., 1991; Forthman et al., 1992; Vickery & Mason, 2003; Wagman et al., 2018).

Many environmental enrichment studies manipulate the predictability of food, either temporally or spatially, to address feeding and foraging behaviors, increase animal activity, and decrease atypical behaviors (Bassett & Buchanan-Smith, 2007; Barber, 2018; Bloomsmith & Lambeth, 1995; Grandia, van Dijk, & Koene, 2018; Morimura & Ueno, 1999; Schneider, Nogge, & Kolter, 2014; Shepherdson et al., 1993). Although these studies prolong feeding and foraging activities, they lack the integration of cognitive challenges that encourage decision-making, problem-solving, and learning skills (Clubb & Mason, 2007; Meehan & Mench, 2007).

Introducing enrichment objects that conceal food is a common approach in zoo husbandry practices. Studies of captive grizzly bears (*Ursus arctos horribilis*) show that they spend more time manipulating concealed foods even in the presence of unconcealed foods, a phenomenon known as contrafreeloading (McGowan, Robbins, Alldredge, & Newberry, 2010). In addition, manipulating the complexity of a feeding enrichment object to increase an animal's interaction with that enrichment has been shown to decrease stereotypic behaviors. For example, when captive sloth bears were presented a food-filled wobbling box that had holes drilled only on the four sides of the box instead of the bottom, researchers reported an increase in active, foraging, and investigative behaviors as well as a decrease in stereotypies (Veeraselvam, Sridhar, Jayathangaraj, & Perumal, 2013). In another study, an American black bear and sloth bear were presented with a log that had holes filled with honey which were then plugged with wooden dowels. The researchers observed a reduction in total time spent performing stereotypic behavior and an increase in investigative and foraging behaviors (Carlstead et al., 1991). In these studies, the enrichment objects were specifically designed so that the bears would spend more time manipulating the device and thereby have less time available to engage in stereotypies. Although Carlstead et al. (1991) and Veeraselvam et al. (2013) examined the effects of "complex" feeding objects, they did not investigate how changing the level of complexity (i.e., increasing levels of difficulty) of an enrichment device affects captive animal behavior. In fact, to our knowledge, there are no known reported efforts to explore the effects of increasing complexity of the same enrichment devices over time in the scientific literature.

In this study, we examine the effects of increasingly complex enrichment on the stereotypic behavior of three captive Malayan sun bears housed at Oakland Zoo using two different feeding enrichment devices designed to have three levels of increasing complexity. Taking the species-typical behaviors and morphologies of sun bears into consideration, this study uses enrichment devices with small holes to encourage the bears to use their long claws and tongues to acquire food. Since sun bears prefer to lay on their dorsal side to manipulate enrichment objects by using their front and back paws (D. Minier, unpublished data, January 2019), enrichment designs include both free-standing and anchored objects to challenge the bears. We hypothesize that more complex enrichment devices would reduce sun bear stereotypic behavior and increase sun bear enrichment use to a greater extent than less complex devices.

Methods

Study site and animals

This project was conducted at The Conservation Society of California and Oakland Zoo, located in Oakland, California. Oakland Zoo is accredited by the Association of Zoos and Aquariums (AZA) of the United States and houses more than 700 native and exotic animals. At the time of this study, there were three adult female Malayan sun bears living at Oakland Zoo. Ting Ting (29 years old) is the oldest of the three bears and was born in the wild in 1990. Bulan (13 years old) and Pagi (11 years old) were both born at the San Diego Zoo (in 2006 and 2008, respectively) to the same mother. By January 2011, all three bears were on exhibit together at Oakland Zoo. The sun bear enclosure includes an enclosed indoor holding area and a spacious outdoor enclosure. The outdoor space is 1,300-sqm in size and includes a variety of climbing structures, log piles, dense bushes, a large eucalyptus tree, palm trees, and a pool. Stereotypic behaviors (i.e., pacing, head rolling) have been observed in all three bears. This project was noninvasive and approved by Sonoma State's Institutional Animal Care and Use Committee (IACUC approval # 2018–65).

Complex enrichment devices

Enrichment device #1: Honey-log

The design of the honey-log is inspired by Carlstead et al. (1991) and the natural feeding sites of Malayan sun bears. These honey-logs were approximately 50 cm × 25 cm and had six holes (3 cm

wide) drilled around the circumference of the logs. There were three levels of increasing complexity; each level contained a different food item in order to maintain novelty of the objects as they increased in complexity each week:

(1) Level 1 – Holes were filled with peanut butter and the log was free-standing so the bears could pick it up and manipulate in any way they want (see Figure 1(a)).
(2) Level 2 – Same object as described in Level 1, but holes were filled with honey and there were wooden dowels inserted in the holes, so the bears have to first pull out the dowels to access the honey. Wooden dowels are approximately 4 cm long (see Figure 1(b)).
(3) Level 3 – Same object as described in Level 2, but the holes were filled with molasses and the log was attached to a structure in the exhibit, so it was no longer free-standing (see Figure 1(c)).

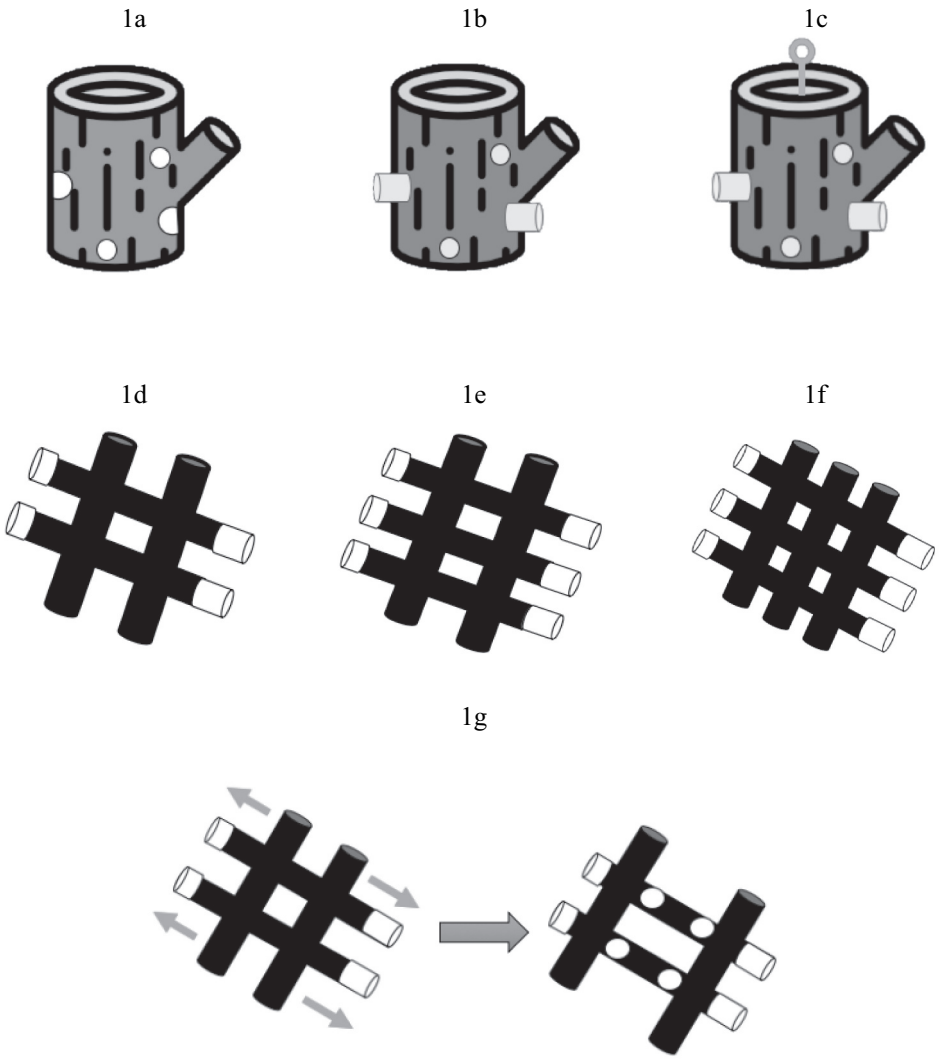

Figure 1. Honey Log Complex Enrichment Device (Figure 1a-c): Yasmeen Ghavamian modified Icon made by Freepik from www.flaticon.com. Complex enrichment devices: (a) Honey-Log Level 1; (b) Honey-Log Level 2; (c) Honey-Log Level 3; (d) PVC Cross-Shaped Feeder Level 1; (e) PVC Cross-Shaped Feeder Level 2; (f) PVC Cross-Shaped Feeder Level 3; (g) gray arrows show direction of movement of PVC Cross-Shaped Feeder.

Enrichment device #2: PVC cross-shaped feeder

The PVC cross-shaped feeder was designed by the Malayan sun bear keepers at Oakland Zoo. These PVC feeders were constructed by interlacing PVC pipes that were approximately 100 cm × 12 cm. The pipes filled with different food items were capped to allow for easy cleaning inside and out. These pipes are shown as black with white "caps" in Figure 1(d–f). The sun bears obtained food through two sets of holes (3 cm wide) that were drilled into the middle of these pipes. These holes were revealed when the pipes shown as black with black "caps" were moved along the opposing pipes (Figure 1(g)). This device also consisted of three levels of increasing complexity with three different food items to maintain novelty:

(1) Level 1 – Two white capped pipes have holes with sliced apples inserted. The two black capped pipes could move back and forth to reveal holes (see Figure 1(g)), and the object was free standing so the bears can pick it up and manipulate in any way they want (see Figure 1(d)).
(2) Level 2 – Same object as described in Level 1, but holes were filled with sliced avocado. A third white capped pipe was added so that there were three pipes with food (see Figure 1(e)).
(3) Level 3 – Same object as described in Level 2, but the holes were filled with sliced peaches. A third black capped pipe was added so that there were three moveable pipes (see Figure 1(f)).

Enrichment device presentation protocol

This study was conducted in three distinct phases (see Table 1).

Phase One: Baseline data collection was conducted for three weeks, from July 1 2019 to July 21 2019, prior to the introduction of the complex enrichment devices. During this phase, the keepers followed their regular, randomized enrichment schedule for the sun bears; daily diet is typically only provided in enrichment. Regular enrichment are devices such as cardboard boxes, paper bags, plastic toys, puzzle feeder balls, and kongs which are provided based on a randomized schedule to maintain novelty and interest. No changes to the randomized schedule for environmental enrichment were made outside of device presentation for these trials.

Phase Two: Following Phase One, the honey-log enrichment device is introduced to the sun bears for three consecutive weeks, from July 22 2019 to August 9 2019. One week was assigned to each complexity level (see Table 1 and Figure 1(a–c)). This device was presented on three weekdays: Monday, Wednesday, and Friday. To prevent competition, four replicates of the honey-log were provided for every presentation. The replicates were placed in different locations in the exhibit on each assigned day and each week. The sun bears had access to the device on the assigned days for approximately two hours beginning at 10 am. No other enrichment was available to the bears during this time. After two hours, the complex enrichment devices were removed from the exhibit and regular, randomized enrichment was added in order to fulfill the daily caloric needs of the bears. On

Table 1. Schedule of trials, resulting in a total of nine weeks of observation. During Phases 2 and 3, complex enrichment devices were only present on Monday, Wednesday, and Friday.

Phase	Date	Complex Enrichment Device
1	July 1 2019–July 21 2019	Baseline
2	July 22 2019–July 26 2019	Honey-Log Level 1 (HL1)
	August 29 2019–August 2 2019	Honey-Log Level 2 (HL2)
	August 5 2019–August 9 2019	Honey-Log Level 3 (HL3)
3	August 12 2019–August 16 2019	PVC Feeder Level 1 (PVC1)
	August 19 2019–August 23 2019	PVC Feeder Level 2 (PVC2)
	August 26 2019–August 30 2019	PVC Feeder Level 3 (PVC3)

non-trial days of the week (Tuesday, Thursday, Saturday, and Sunday), the keepers follow their regular, randomized enrichment schedule. This alternating presentation is necessary to provide keepers with time to clean and refill the devices with food. The food in the complex enrichment devices were items from the highly preferred category of the bears' standard rotational diet. During the study, these highly preferred items were only provided when the complex devices were available.

Phase Three: Following Phase Two, the PVC cross-shaped feeder device is introduced to the sun bears for three consecutive weeks, from August 12 2019 to August 30 2019. One week is assigned to each complexity level (see Table 1 and Figure 1(d–f)). The presentation of this device follows the same format as the honey-log device (outlined in Phase Two), with the exception that only three replicates of the PVC cross-shaped feeder were provided for every presentation.

Data collection

Stereotypic behavior: Video-camera observations

Stereotypic behaviors (i.e., pacing and head roll; see Table 2) were recorded by YG using multiple 4MP Weatherproof PoE Bullet IP Cameras (EZVIZ Inc.) that are installed in six different locations where stereotypy has been previously observed: four in the sun bear exhibit and two in the sun bear indoor holding area. Bears have access to the indoor holding area at all times, except for one hour of the day when the keepers clean the holding area. Video footage was accessed via the EZVIZ App on an iPhone (Apple Inc.).

During Phase One (baseline, no complex enrichment), footage was reviewed three times a week on Monday, Wednesday and Friday. These observations started at 06:00:00 and ended at 19:00:00. The observational protocol consisted of all-occurrence sampling (Altmann, 1974) to record durations of stereotypic behavior, with start time, end time, bear identity, and type of stereotypic behavior noted for each event.

During Phases Two (enrichment device #1) and Three (enrichment device #2), video footage was reviewed five times a week, Monday through Friday, for all-occurrences of stereotypic behavior. The same protocol as described for Phase One (above) was used here, with one exception. On enrichment trial days (Monday, Wednesday, and Friday) observations were conducted during these time periods: (a) pre-enrichment (one hour before bears had access to the complex enrichment devices), (b) during enrichment (two hours while bears had access to the complex enrichment devices), (c) post-enrichment (one hour after the complex enrichment devices had been removed). On the non-trial days (Tuesdays and Thursdays), these same time periods apply when the bears' had access to regular enrichment.

Enrichment device use: In-person observations

YG and one trained observer conducted in-person observations of complex enrichment device use three times a week at 10 am on Monday, Wednesday and Friday during Phases Two and Three. Observers achieved above 90% inter-observer agreement in recording data. Observational data is collected on an iPhone (Apple Inc.) using the website application software ZooMonitor (Ross et al., 2016). Observation sessions were 60 minutes long with 30-second intervals, during which bear

Table 2. Ethogram describing behaviors observed and used in analysis.

Behavior	Description
Stereotypic	
Pacing	Bear walks invariant path (1–2 body lengths) on a log or the ground.
Head Roll	Bear is stationary with continuous swaying of the head in repetitive, circular motion.
Device Use	
Device Use	Bear is within one head's length of device and investigates the device without physical contact. Bear physically manipulates the device with nose or paws including holding, moving, picking up and tossing the device, and consuming food item.

identity and complex enrichment use were recorded using one-zero sampling (Altmann, 1974). Within an interval, a sun bear must have interacted with a complex enrichment device for 15 continuous seconds or more to be scored as device use. Device use included both noncontact investigation and physical manipulation (see Table 2). The number of intervals that included an occurrence of device use was divided by the total of 120 sample intervals to give a percentage of the hour the sun bears spent interacting with a complex enrichment device.

External stimuli: Keeper presence and visitor attendance

To examine the effects of keeper presence, the sun bear keepers recorded when they entered and left the exhibit area during the study. When YG recorded stereotypic behavior (see above), keeper presence was recorded as a yes or no: "yes" if a keeper is present during the stereotypy, "no" if a keeper is not present. To examine the effects of visitor presence, Oakland Zoo provided YG with visitor attendance data for the duration of the study. Visitor attendance is defined as the number of people that enter through the front gates of the zoo, including all guest ticket sales and group education programs. Weather was not investigated as an external stimulus because a previous study on these same sun bears at Oakland Zoo indicated that temperature did not have a significant effect on pacing behavior (Barber, 2018).

Statistical analyses

JMP Pro 14 (SAS Institute Inc., Cary, NC, USA) was used for all statistical analyses. The effects of complex enrichment on sun bear stereotypic behavior and complex enrichment use were evaluated using linear mixed models. Since multiple data points were collected from each bear multiple times, bear identity was used as a random effect with a restricted maximum likelihood (REML) method to yield estimates of the variance components. Phase was also included as a factor. Only Phase One data was used to examine the effects of keeper presence and visitor attendance on the duration of sun bear stereotypic behavior to determine if either variable influenced the occurrence of stereotypy to be included as covariates in the other models comparing stereotypy with enrichment complexity.

For analyses comparing Phase One to Phases Two and Three, the three time periods in data collection for Phases Two and Three (pre-, during, and post-enrichment) were matched to data collected in the same time periods in Phase One. In addition, each of the complexity levels were considered sub-phases. Model residuals were visually assessed for normality and residual plots were assessed for homoscedasticity. Distributions of residual duration of stereotypic behavior were highly skewed, so the response variable duration was log transformed. Evidence for a significant interaction of complex enrichment on sun bear stereotypic behavior or complex enrichment use was further investigated by comparing least square means using student t-tests. Statistical significance was assessed using $\alpha = 0.05$

Results

With a total of 108 observation hours in Phase One, 31 hours of stereotypic behavior were recorded. With a total of 120 observation hours in Phases Two and Three, 33 hours of stereotypic behavior were recorded.

Effects of external stimuli

The presence of keepers had no effect on the duration of sun bear stereotypic behavior ($F_{1,3443} = 0.49$, $p = 0.483$). The number of visitors at the zoo significantly affected the duration of sun bear stereotypic behavior ($F_{1,3443} = 73.26$, $p < 0.001$). Even though the effect of visitor attendance is statistically significant, it is not biologically significant, accounting for only 2% of the variance in stereotypic behavior ($r^2 = 0.019$), which means 98% of the variation is due to other factors. Bear

identity accounted for 39.7% of the variance in stereotypy duration, which suggests strong individual differences. For these reasons, keeper presence and visitor attendance were not included as covariates in other analyses.

Effects of complex enrichment on stereotypic behavior

Enrichment devices: Honey-log vs. PVC cross-shaped feeder

Complex enrichment devices had a significant effect on the duration of sun bear stereotypic behavior ($F_{2,4642} = 23.68$, $p < 0.001$). With all complexity levels combined, there was no significant difference between the honey-log and the PVC cross-shaped feeder (Figure 2). Bear identity accounted for 50.8% of the variance in stereotypy duration.

Increasing complexity of devices

Increasing the complexity of the enrichment devices had a significant effect on the duration of sun bear stereotypic behavior ($F_{6,4637} = 11.36$, $p < 0.001$). As the complexity of the honey-log increased, the duration of stereotypic behavior decreased (Figure 3). As the complexity of the PVC cross-shaped feeder increased, the duration of stereotypic behavior increased (Figure 3). Bear identity accounted for 50.0% of the variance in stereotypy duration.

Complex enrichment days vs non-complex enrichment days

The presence of complex enrichment devices had a significant effect on the duration of sun bear stereotypic behavior ($F_{7,4740} = 11.14$, $p < 0.001$). The duration of stereotypic behavior decreased on the days the complex enrichment devices were present compared to the days the complex enrichment devices were absent, except for the first level of the honey-log (Figure 4). Bear identity accounted for 53.2% of the variance in stereotypy duration.

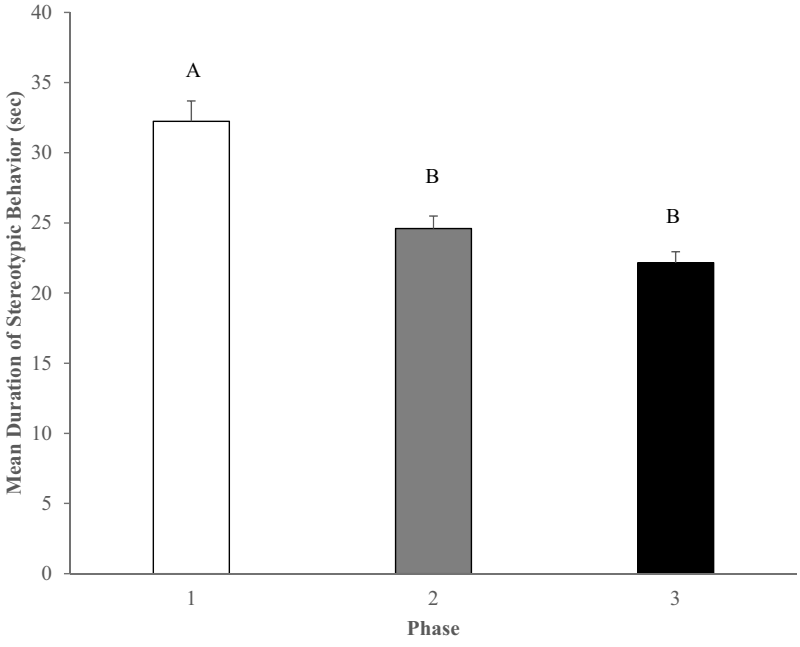

Figure 2. Mean duration of stereotypic behavior for all individuals throughout the baseline and complex enrichment phases, with all complexity levels combined. Phase 1 = Baseline, Phase 2 = all Honey-Log levels, Phase 3 = all PVC Cross-Shaped Feeder levels. The letters denote significant differences assessed using the Least Square Means which controls for the variation between individual bears. The phases not sharing a letter are significantly different from one another.

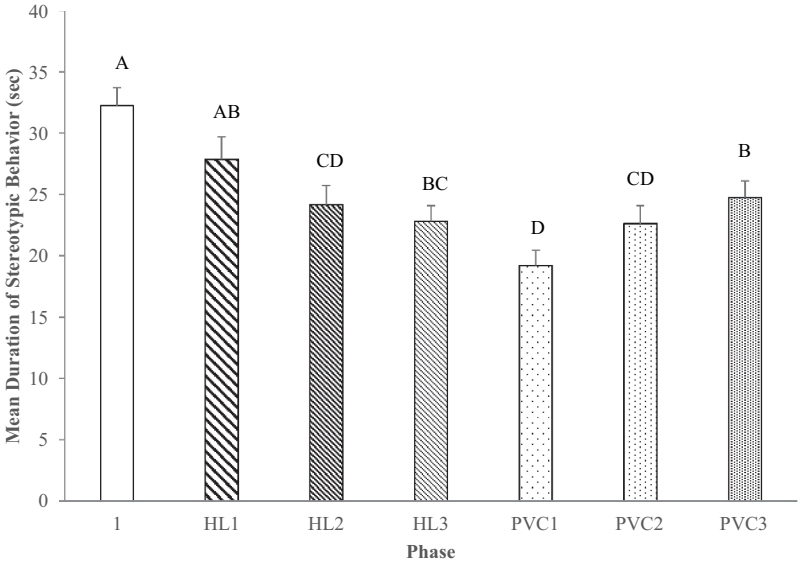

Figure 3. Mean duration of stereotypic behavior for all individuals throughout the baseline and complex enrichment phases. Phase 1 = Baseline, HL1 = Honey-Log Level 1, HL2 = Honey-Log Level 2, HL3 = Honey-Log Level 3, PVC1 = PVC Cross-Shaped Feeder Level 1, PVC2 = PVC Cross-Shaped Feeder Level 2, and PVC3 = PVC Cross-Shaped Feeder Level 3. The letters denote significant differences assessed using the Least Square Means which controls for the variation between individual bears. The phases not sharing a letter are significantly different from one another.

Effects of complex enrichment on enrichment use

Increasing the complexity of the enrichment devices had a significant effect on sun bear enrichment use ($F_{5,43}$ = 2.617, p = 0.038). As the complexity of the honey-log increased, enrichment use decreased (Figure 5). As the complexity of the PVC cross-shaped feeder increased, enrichment use increased (Figure 5).

Discussion

We investigated the effects of two complex feeding enrichment devices on the behavior of captive sun bears and examined whether increasing the complexity of these devices would decrease stereotypic behavior and increase enrichment use. As predicted, our results demonstrate that providing complex enrichment decreases stereotypic behavior. Although increasing the complexity of each device produced contrasting trends for the duration of stereotypic behavior, stereotypic behavior is still significantly lower compared to baseline. As we increased the complexity of the enrichment devices, enrichment use increased for one device, but unexpectedly, decreased for the other.

In this study, providing complex feeding enrichment devices significantly reduced the duration of sun bear stereotypic behavior when compared to baseline. These results are similar to those of other researchers who report that providing enrichment devices reduces the stereotypic behavior of various captive bear species (Carlstead et al., 1991; Forthman et al., 1992; Renner & Lussier, 2002; Veeraselvam et al., 2013; Wagman et al., 2018). The complex enrichment devices used in this study increased the complexity of the sun bears' environment by providing problem-solving opportunities to stimulate their naturalistic behaviors and reduce the performance of stereotypic behaviors (Carlstead et al., 1991; Krebs & Watters, 2017; Veeraselvam et al., 2013; Vickery & Mason, 2003). By hiding food in manipulatable enrichment devices, we were able to provide the sun bears with more opportunities to engage in natural feeding and foraging behaviors by using their long claws

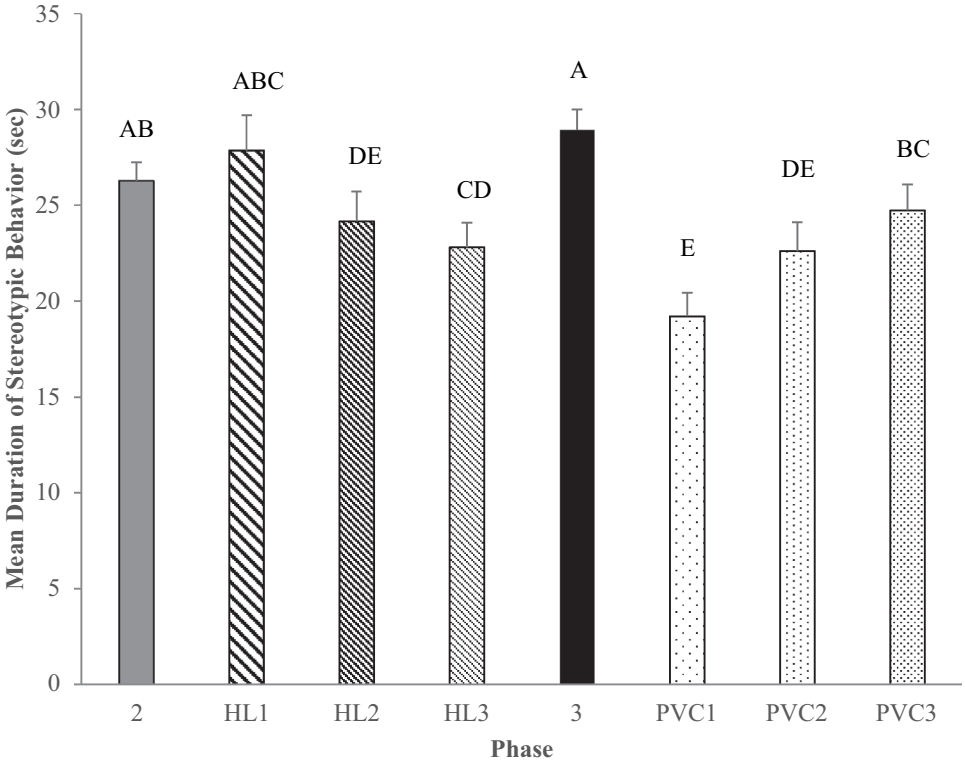

Figure 4. Mean duration of stereotypic behavior for all individuals throughout the complex enrichment phases. Complex enrichment days are Monday, Wednesday and Friday. Non-complex enrichment days are Tuesday and Thursday. Phase 2 = non-complex enrichment days in Phase 2, HL1 = Honey-Log Level 1, HL2 = Honey-Log Level 2, HL3 = Honey-Log Level 3, Phase 3 = non-complex enrichment days in Phase 3, PVC1 = PVC Cross-Shaped Feeder Level 1, PVC2 = PVC Cross-Shaped Feeder Level 2, and PVC3 = PVC Cross-Shaped Feeder Level 3. The letters denote significant differences assessed using the Least Square Means which controls for the variation between individual bears. The phases not sharing a letter are significantly different from one another.

and tongue as they would in the wild to reach food from small spaces, such as tree cavities and termite mounds (Te Wong, Servheen, & Ambu, 2002).

Captive animals should expect change and challenges as they would in the wild. Altering a captive animal's environment and making it more challenging is often accomplished by introducing new and different forms of enrichment. We took a different approach and instead increased the complexity of the same device over multiple weeks to assess the effects on the sun bears' behavior. We are unaware of previous studies that introduce enrichment objects with multiple levels. Our results indicate that increasing the complexity of the same enrichment devices significantly reduced the duration of stereotypic behavior when compared to the baseline phase, except for the first level of the honey-log device. Although the honey-log device is a novel enrichment item, the first level of the device is no different than routine, rotational enrichment the bears normally receive (i.e., the enrichment medium was novel but the tactic to retrieve food items was similar to other forms of enrichment). This may explain why the first level of the honey-log device did not significantly reduce stereotypic behavior. The observed decrease in stereotypic behavior with increasing levels of complexity suggests that introducing a new complexity level each week was effective at changing the task environment, by providing a new challenge for the bears and maintaining novelty (e.g., different food introduced in each level), while satisfying their motivation to forage. Although we focused on changes in stereotypic behavior specifically, future studies should explore both stereotypic and foraging behaviors to determine the magnitude of overall activity budget changes in animals.

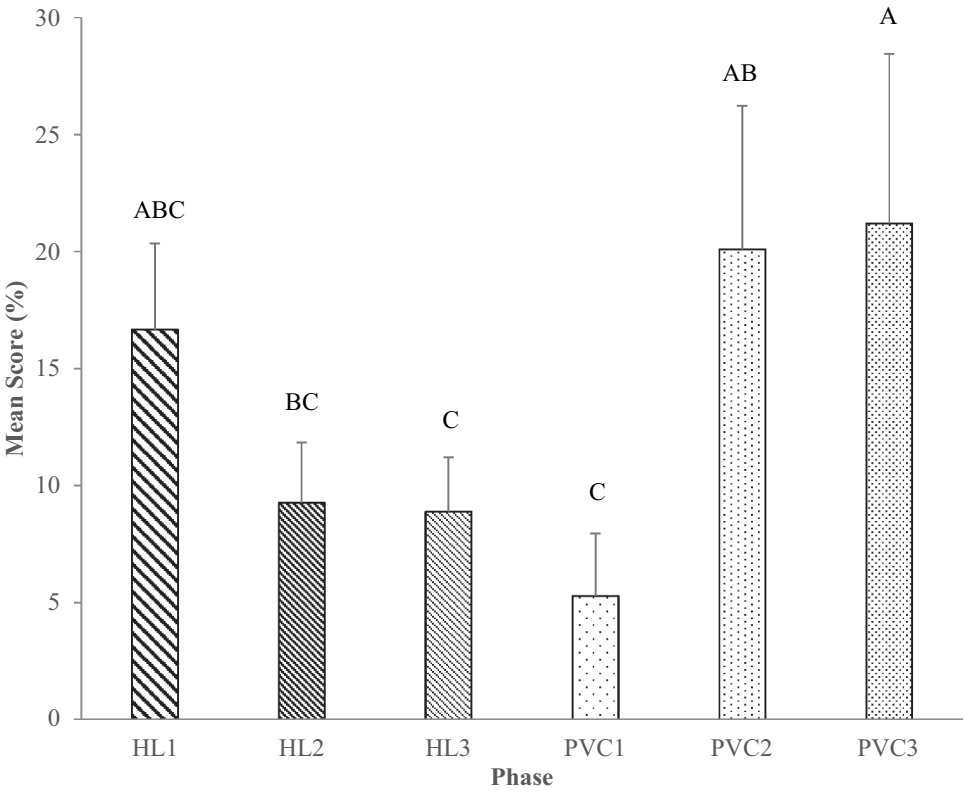

Figure 5. Mean score of complex enrichment use for all individuals throughout the complex enrichment phases. HL1 = Honey-Log Level 1, HL2 = Honey-Log Level 2, HL3 = Honey-Log Level 3, PVC1 = PVC Cross-Shaped Feeder Level 1, PVC2 = PVC Cross-Shaped Feeder Level 2, and PVC3 = PVC Cross-Shaped Feeder Level 3. The letters denote significant differences assessed using the Least Square Means which controls for the variation between individual bears. The phases not sharing a letter are significantly different from one another.

This study was designed to avoid habituation to the enrichment devices based on other studies that report intermittent presentation of enrichment recovered interest toward an enrichment device (Anderson et al., 2010; Carlstead et al., 1991; Wagman et al., 2018). Looking across a single week, the duration of stereotypic behavior was significantly less on the days the complex enrichment devices are present (except for level one of the honey-log) compared to the days when none of the complex enrichment devices were present. This indicates that the effects of complex enrichment do not carry over on the days when the enrichment is no longer present, suggesting that the effects of enrichment are short-term. This result is in accordance with the findings of Veeraselvam et al. (2013) who report that during a post-enrichment period when sloth bears no longer have access to enrichment objects, there is an increase in abnormal (i.e., stereotypic) behaviors. Therefore, in order to have lasting effects on stereotypic behavior in the long term, zoos should manipulate their enrichment programs to maintain a continuously complex environment.

In this study, we also examined the effect increasing enrichment complexity has on sun bear enrichment use. Enrichment devices designed to be more challenging so that an animal has to perform a new behavior in order to attain the same goal (i.e., food), should increase the time an animal spends manipulating the device (Carlstead et al., 1991; Veeraselvam et al., 2013). We predicted that increasing enrichment complexity would increase enrichment use, but this prediction was only true for the PVC cross-shaped feeder and not for the honey-log. We also saw an increase in stereotypic behavior as the complexity of the PVC cross-shaped feeder increased, suggesting

a positive correlation between stereotypy and enrichment use. We can speculate that this increase in stereotypy and enrichment use is indicative of frustration or anxiety because the challenge exceeds the abilities of the bears or is evidence of boredom because the challenge does not meet the skill levels of the bears (Meehan & Mench, 2007). This is in direct contrast with the results of increasing the complexity of the honey-log device in which we see a decrease in stereotypic behavior and decrease in enrichment use. These results may suggest that the sun bears mastered the honey-log challenge, providing sufficient environmental stimulation and reward, and thereby, reducing the performance of stereotypies. Even though both enrichment devices provided opportunities for the bears to express natural foraging behaviors, with each increasing level there was a new task to test the bears' learning and cognitive skills. Moreover, as described by Meehan and Mench (2007), animals are intrinsically motivated to engage in challenging tasks, but the appropriateness of that task is dependent on an individual's skills. The present study offers promise for using this novel approach of increasing enrichment complexity for targeting stereotypic behaviors, nevertheless, future studies need to be aware that the appropriate level of challenge and the reliable indicators to determine the effectiveness of that challenge will be dependent on the individual animal (Meehan & Mench, 2007).

We also investigated the relationship between two types of external stimuli, keeper presence and visitor attendance, on the stereotypic behavior of the sun bears because previous studies have highlighted the importance of understanding the underlying causes of these behaviors in order to treat and reduce such behaviors (Carlstead et al., 1991; Rushen & Mason, 2006; Vickery & Mason, 2004). The highly predictable nature of traditional zoo husbandry routines can create the potential for animals to learn the timing of events or use cues such as keeper presence connected with food delivery, which can lead to the development of anticipatory behaviors, such as pacing, swaying and other stereotypies (Carlstead, 1998; Ward et al., 2018; Watters, 2014). In this study, the presence of keepers had no effect on the duration of sun bear stereotypic behavior suggesting that the stereotypy exhibited by the sun bears is not anticipatory in nature. On the other hand, an animal may engage in stereotypy as a stress-response associated with loud disturbances, such as large crowds (Barber, 2018; Clubb & Vickery, 2006; Mason, 1991; Shyne, 2006). The results of this study indicate that visitor attendance did have a detectable effect on the duration of sun bear stereotypic behavior, but it only accounts for 2% of the variance, indicating that sun bear stereotypic behavior is not linked to a stress-related motivation. This demonstrates that the underlying motivations or processes contributing to the performance of the sun bear stereotypic behavior is more complicated and is likely multifactorial (e.g., habits, coping mechanism, perseveration: Mason & Latham, 2004).

Each sun bear has its own personal history (e.g., Ting Ting was born in the wild, sold into the pet trade, and rescued by sanctuary; while Bulan and Pagi were both born and raised in zoos), which likely contributed to the differences in the properties of their stereotypies (i.e., form, timing, and location). These individual differences are apparent in this study as bear identity accounts for nearly 40% of the variance in stereotypic behavior. Individual variation has been linked to perseveration, another reason for the complications in reducing stereotypic behavior. In a study of captive Asiatic black bears and Malayan sun bears, highly stereotypic individuals are reported to be more perseverative than less stereotypic individuals, suggesting that in some individuals the behavior is highly persistent and linked to a reduced ability to respond to new stimuli (Clubb & Vickery, 2006; Mason & Latham, 2004; Vickery & Mason, 2003, 2005). If individual variation in perseveration exists, stereotypic behavior can take much longer to reduce in some individuals, even with an enriched environment.

We found that increasing the complexity of feeding enrichment can be a valuable technique for increasing the well-being of sun bears in captivity. However, the limitations of this study should be investigated further. Since the present study is one of the first to manipulate the same feeding enrichment devices for more complexity and taking into account that the sample size is three bears, care must be taken with the generalizability of these results. Even though there is an overall decrease in sun bear stereotypic behavior compared to baseline, increasing enrichment complexity had variable effects on both stereotypic behavior and enrichment use, and thus should not be recognized

as a general solution for all individuals. Since these results may be influenced by the different food items inside the devices, we recommend future studies change one variable at a time in order to elucidate the effects of food and the effects of complexity. Even though novelty is regarded as an important aspect of environmental enrichment (Carlstead et al., 1991; Renner & Lussier, 2002), the type and amount of food available may have an influence on bear behavior (Forthman et al., 1992; Schneider et al., 2014; Veeraselvam et al., 2013).

Furthermore, due to time constraints, this study was only nine weeks in length and due to access limitations, bear behavior was observed during specific hours of the day. Implementing a longer trial period and increasing hours of observation should provide more insight on the level of perseveration for the stereotypic behavior and allow for the effects of different food items to be recognized. However, this can introduce another possible external factor: weather. In the present study, weather was unlikely to be a significant factor in the sun bears' behavior because historical data show the weather at Oakland Zoo is stable during the study period, and a previous study of similar length conducted during the same time of year showed that temperature did not have a significant effect on the bears' pacing behavior (Barber, 2018). For a longer study that spans several months, or those conducted at zoos that experience greater shifts in weather, researchers must be cognizant of seasonal differences in animal behavior (Te Wong, Servheen, & Ambu, 2004).

Conclusions

The results of this study indicate that introducing enrichment complexity into zoo husbandry routines can create more opportunities for captive animals to exhibit species-typical and problem-solving behaviors and may help reduce stereotypies. However, the relationship between enrichment and stereotypy is complex. Individuals may respond differently according to the type of enrichment challenge presented and depending on their own developmental history. While this area of study is still growing, integrating appropriate challenges into zoo management regimes may be an important tool for targeting the performance and development of stereotypic behaviors in captive animals.

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