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

by

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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. In this study, we test whether providing increasingly complex feeding enrichment decreases the duration of stereotypic behavior and increases enrichment interaction for three adult female sun bears (*Helarctos malayanus*) at Oakland Zoo in California. We compared the effects of two different feeding enrichment devices- presented to the bears at three complexity levels- on sun bear stereotypic behavior. After three weeks of baseline data collection when no complex enrichment was present, we introduced the complex enrichment three times a week per level over six weeks. In addition, we measured each bear's interaction with the enrichment devices to examine the effect of complexity on enrichment use. Providing increasingly complex enrichment decreased the duration of stereotypic behavior when compared to the baseline phase. Across the six weeks, the duration of stereotypic behavior was significantly less on the complex enrichment days compared to the days when complex enrichment was absent. Increasing enrichment complexity had variable effects on enrichment use. Our results indicate that providing complex enrichment decreased the duration of stereotypic behaviors, however, the effects of complex enrichment did not carry over on the days when the enrichment was no longer present. These results suggest that providing increasingly complex enrichment may have a positive influence on the behavior of captive bears.

Keywords: stereotypy; stereotypic behavior; species-typical behavior; behavioral enrichment; animal welfare

Research Highlights

- The provision of increasingly complex enrichment devices decreased the duration of stereotypic behaviors in captive sun bears.
- Increasing the complexity of the enrichment devices variably affected the time the bears spent using the devices.

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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 (Mench, 1998; Clubb & Vickery, 2006). Stereotypic behaviors, also known as stereotypies, are a category of atypical behaviors that are performed repeatedly with no apparent function (Mason, 1991; Rose et al., 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 et al., 2001; Bergeron et al., 2008, p. 19; Fernandez et al., 2008), rhythmic head movements or swaying in elephants (Gruber et al., 2000; Rees, 2009), head-tossing, rocking or pacing in primates (Hugo et al. 2003; Lutz et al., 2003; Jacobson et al., 2016), and pacing or head swaying in bears (Carlstead et al., 1991; Vickery & Mason, 2004; Anderson et al., 2010).

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 and with the same causal factors being responsible for all forms of stereotypy (Broom, 1983; Carlstead, 1998; Rushen & Mason, 2006). 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 & Mendl, 1993; Mason & Latham, 2004). The literature presents various underlying reasons for the development of these behaviors. In some cases, stereotypy produces a calming sensation or "mantra" effect (Mason & Latham, 2004), or represents an inability to cope with environmental stress (Swaisgood & Shepherdson, 2006; Mason et al., 2007). In others, the stereotypy acts as a scar from a previous trauma or suboptimal environment (Mason & Latham, 2004; Swaisgood & Shepherdson, 2005), or otherwise signifies a reduced ability to respond to novel environmental stimuli or "perseveration" (Mason & Latham, 2004; Mason et al., 2007). Finally, sometimes, stereotypies are described as an anticipatory behavior when management routines are too predictable (van der Harst & Spruijt, 2007; Watters, 2014; Ward et al., 2018). Considering all of these underlying motivations for the development of stereotypic behaviors, zookeepers 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). Captive animals need opportunities to engage in a variety of behavioral and cognitive activities, such as the ability to work for food or the motivation to explore their environment, in order to encourage expression of species-typical behaviors as seen in their wild counterparts (Spinka & Wemelsfelder, 2011). Environmental enrichment has been shown to increase the occurrence of species-typical behaviors and decrease the frequency of undesirable (i.e., stereotypic) behaviors in a variety of species (e.g., American black bear, *Ursus americanus*: Carlstead et al., 1991; leopard cats, *Felis bengalensis*: Shepherdson et al., 1993; chimpanzees, *Pan troglodytes*: Bloomsmith & Lambeth, 1994; Amur tigers, *Panthera tigris altaica*: Jenny & Schmid, 2002; spectacled bear, *Tremarctos ornatus*: Renner & Lussier, 2002; cheetahs, *Acinonyx jubatus*: Quirke & O'Riordan, 2011a,b; fennec foxes, *Vulpes zerda*: Watters et al., 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; Watters, 2014; Ward et al., 2018). 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 & 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 (Mason & Latham, 2004; Vickery & Mason, 2004; Jacobson et al., 2016). 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 (Shepherdson et al., 1993; Bloomsmith & Lambeth, 1994; Morimura et al., 1999; Bassett & Buchanan-Smith, 2007; Schneider et al., 2013; Grandia et al., 2018; Barber, 2018). 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 becoming a more 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 et al., 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 et al., 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. The Malayan sun bear (*Helarctos malayanus*), native to the tropical rainforests of Southeast Asia, is the smallest of the eight bear species (Te Wong et al., 2002). Sun bears are opportunistic omnivores, however very little is known about their food habits in the wild. The few studies that have been conducted indicate that invertebrates (i.e., termites, beetles, beetle larvae) are their most important food source, and that they use their characteristically long tongues to extract these insects from small spaces or to obtain honey from tree cavities (Te Wong et al., 2002). They have long, sharp claws and strong teeth to help in digging, climbing, and tearing into logs. Given these characteristics, most sun bear feeding sites are in decaying wood, tree cavities, and tree stumps (Te Wong et al., 2002). Taking these species-typical behaviors and morphologies into consideration, we specifically designed 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), we also incorporate designs that include both freestanding 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. There are currently 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 nighthouse 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 non-invasive and approved by Sonoma State's Institutional Animal Care and Use Committee (IACUC approval number: 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 have holes drilled into them and there are three levels of increasing complexity. Each level consists of a different food item in order to maintain novelty of the objects as they increased in complexity each week:

- Level 1 – Holes are filled with peanut butter and the log is free-standing so the bears can pick it up and manipulate in any way they want (see Figure 1a).
- Level 2 – Same object as described in Level 1, but holes are filled with honey and there are dowels inserted in the holes, so the bears have to first pull out the dowels to obtain the honey (see Figure 1b).

- Level 3 – Same object as described in Level 2, but holes are filled with molasses and the log is attached to a structure in the exhibit, so the device is no longer free-standing (see Figure 1c).

Enrichment Device #2: PVC cross-shaped feeder

The PVC cross-shaped feeder is designed by the Malayan sun bear keepers at Oakland Zoo. These PVC feeders are constructed by interlacing PVC pipes. 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 Figures 1d-1f. The sun bears obtain food through holes that were drilled in the middle of these pipes. These holes are revealed when the pipes shown as black with black 'caps' are moved along the opposing pipes (Figure 1g). This device also consists of three levels of increasing complexity with three different food items to maintain novelty:

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

Enrichment Device Presentation Protocol

The study was conducted in three distinct phases.

Phase One: Baseline data collection was conducted for three weeks, from July 1 – 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.

Phase Two: Following Phase One, the honey-log enrichment device was introduced to the sun bears for three consecutive weeks, from July 22 to August 11, 2019. One week was assigned to each complexity level (see Table 1 and Figures 1a-c). To prevent competition, four replicates of the honey-log were provided for every presentation on the assigned days (Monday, Wednesday and Friday). The replicates were placed in a different location in the exhibit on each assigned day and each week. The sun bears received access to the device on the assigned days for approximately two hours beginning at 10am. After two hours, the complex enrichment devices were removed from the exhibit and regular randomized enrichment was added in order to fulfill the daily dietary needs of the bears. On the other days of the week, the keepers followed their regular randomized enrichment schedule. This alternating presentation is necessary to provide keepers with time to clean and refill the devices with food.

Phase Three: Following Phase Two, the PVC cross-shaped feeder device was introduced to the sun bears for three consecutive weeks, from August 12 to August 30, 2019. One week was assigned to each level (see Table 1 and Figures 1d-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 at every presentation.

Data Collection

Video-Camera Observations

Stereotypic behaviors (see Table 2) were recorded using multiple 4MP Weatherproof PoE Bullet IP Cameras (EZVIZ Inc.) that were installed in six different locations: four in the sun bear exhibit and two in the sun bear nighthouse. Video footage was accessed via the EZVIZ App on an iPhone (Apple Inc.). During Phase One, video footage was reviewed three times a week on Monday, Wednesday and Friday for all-occurrences (Altmann, 1974) of stereotypic behavior between 06:00:00 and 19:00:00, and the start time, end time, bear identity, and type of stereotypic behavior were recorded in each instance. A total of 31 hours of stereotypy were collected during Phase One. During Phases Two and Three, video footage was reviewed five times a week on all weekdays for all-occurrences of stereotypic behavior during three different time periods: pre-enrichment (one hour before the bears had access to the enrichment device), enrichment (two hours while the bears had access to the enrichment device), and post-enrichment (one hour after the enrichment devices had been removed). A total of 33 hours of stereotypy were collected during Phases Two and Three, combined.

In-Person Observations

Two trained observers conducted in-person observations of complex enrichment device use three times a week on Monday, Wednesday and Friday during Phases Two and Three. Observational data were collected using ZooMonitor, a mobile application software, on an iPhone (Apple Inc.). Observation sessions were 60 minutes long with 30-second intervals, during which we recorded complex enrichment use using one-zero sampling (Altmann, 1974). Within an interval, a sun bear had to interact with a complex enrichment device for 15 seconds or more to be recorded for device use (see Table 2). The number of intervals that included an occurrence of device use was divided by the total of 120 sample intervals to result in a score, or a percentage of the hour the sun bears spent interacting with a complex enrichment device.

External Stimuli

To examine the effects of keeper presence, the sun bear keepers kept a record of when they entered the exhibit area and when they left the exhibit area. In addition, to examine the effects of visitor presence, visitor attendance data was received from Oakland Zoo. Visitor attendance is defined as the number of people that enter through the front gates of the zoo, including all guest ticket sales and summer programs.

Statistical Analyses

We used JMP Pro 14 (SAS Institute Inc., Cary, NC, USA) to perform all statistical analyses. For all analyses, we used a Linear Mixed Model since the effects of complex enrichment on sun bear stereotypic behavior and complex enrichment use were evaluated using models that contained bear identity as a random effect. Since bear identity is a random effect, we used a restricted maximum likelihood (REML) method to yield estimates of the variance components. Only Phase One data were used to examine the effects of keeper presence and visitor attendance on the duration of sun bear stereotypic behavior before the introduction of the complex enrichment devices. This analysis was conducted in order to determine if keeper presence and visitor attendance should be included as covariates in the final model. For analyses comparing Phase One to Phases Two and Three, the three time periods used in data collection for Phases Two and Three were extracted from Phase One (see Data Collection – Video Camera Observations). 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 α = 0.05

Results

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 = 0.4826). The number of visitors attending the zoo significantly affects the duration of sun bear stereotypic behavior ($F_{1,3443}$ = 73.26, p < 0.0001). 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 = 0.0197), which means 98% of the variation is due to other factors. Bear identity accounts 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 ($F_{2,4642} = 23.68$, $p < 0.0001$). Without looking at the different levels, both the honey-log and the PVC cross-shaped feeder were equally efficient at reducing stereotypic behavior (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 ($F_{6,4637} = 11.36$, $p < 0.0001$). 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

During the week, the presence of complex enrichment devices had a significant effect on the duration of sun bear stereotypic behavior ($F_{7,4740} = 11.14$, $p < 0.0001$). 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 (Figure 4). Bear identity accounted for 53.2% of the variance in stereotypy duration.

Effects of Complex Enrichment on Enrichment Use

Increasing the complexity of the enrichment devices had a significant effect on sun bear enrichment use ($F_{5,43} = 2.6169$, $p = 0.0375$). 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

In zoos, performance of stereotypic behaviors is concerning because these behaviors have been linked to poor welfare and associated with multiple factors such as coping, frustration, stress or lack of stimulation. However, not all stereotypies are equal and most importantly, not all stereotypies can be treated the same way. Many gaps exist in our knowledge of stereotypies, but more detailed analyses of these behaviors and the effects of different environmental enrichment can help shed light on their impact on animal welfare (Mason & Latham, 2004).

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 was 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.

A higher prevalence of locomotory stereotypies (i.e., pacing) occurring in a location associated with food arrival (i.e., an animal's 'nighthouse' or along cage sides), can suggest an animal has limited ability to perform species-typical behaviors, such as foraging (Mason & Latham, 2004; Vickery & Mason, 2004; Jacobson et al., 2016). In the wild, bears (including sun bears) spend a considerable amount of their time foraging because of natural fluctuations in food availability (Carlstead et al., 1991; Vickery & Mason, 2004; Te Wong et al., 2004; Schneider et al., 2013). 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 reported that providing enrichment devices reduced the stereotypic behavior of various captive bear species (Carlstead et al., 1991; Forthman et al.,1992; 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; Vickery & Mason, 2003, Veeraselvam et al., 2013; Krebs & Watters, 2017). 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 and tongue as they would in the wild to reach food from small spaces such as tree cavities and termite mounds (Te Wong et al., 2002).

As an animal spends more time foraging for food hidden in enrichment objects, less time is available to engage in stereotypic behaviors (Carlstead et al., 1991; Veeraselvam et al., 2013). Furthermore, presenting an animal with an object that requires it to learn how to obtain a reward should also result in a decrease in time spent engaging in stereotypic behaviors. This is because increasing the complexity of an enrichment object will increase the time an animal spends with an object and thereby decreasing the time spent engaging in stereotypies. In addition, animals are driven to gather information about their environment (Carlstead et al., 1991; Mench, 1998; Inglis et al., 2001). Therefore, 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. The observed decrease in stereotypic behavior suggests that introducing a new complexity level each week was effective at changing the 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 overall activity budget changes in animals.

Another important factor we examined was how complex enrichment days compared to the days the complex enrichment was absent. We designed this study to avoid habituation to the enrichment based on other studies that reported intermittent presentation of enrichment recovered interest toward an enrichment device (Carlstead et al., 1991; Anderson et al., 2010; Wagman et al., 2018). Looking across a single week, the duration of stereotypic behavior was significantly less on the days the complex enrichment devices were 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 was in accordance with the findings of Veeraselvam et al. (2013) who reported that during a post-enrichment period when sloth bears no longer had access to enrichment objects, there was 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.

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). In this study, we examined the effect increasing enrichment complexity had on sun bear enrichment use. We predicted that increasing enrichment complexity would increase the percentage of time the sun bears would spend engaging with the enrichment device, but this prediction was only true for the PVC cross-shaped feeder and not for the honey-log. Since these results might have been influenced by the different food 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.

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 & Seidensticker, 1991; Vickery & Mason, 2004; Rushen & Mason, 2006). 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; Watters, 2014; Ward et al., 2018). In this study, the presence of keepers had no effect on the duration of sun bear pacing behavior suggesting that this stereotypic behavior is not anticipatory. In addition, an animal may engage in stereotypy as a stress-response associated with loud disturbances, such as large crowds (Mason, 1991; Shyne, 2006; Clubb & Vickery, 2006; Barber, 2018). 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 accounted for 2% of the variance, indicating that sun bear stereotypic behavior was not linked to a stress-related motivation. This indicates that the underlying motivations or processes contributing to the performance of the sun bear stereotypic behavior is more complicated and is likely due to multiple factors (e.g., habits, coping mechanism, perseveration: Mason & Latham, 2004).

For example, bear identity accounted for nearly 40% of the variance in stereotypic behavior suggesting significant individual differences between the three sun bears. Each sun bear has its own personal history (e.g., Ting Ting was born in the wild sold into the pet trade, and raised in captivity; while Bulan and Pagi were both born and raised in captivity), which likely contributed to the differences in the properties of their stereotypies (i.e., form, timing, location). Individual variation has also 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 were 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 (Vickery & Mason, 2003, 2005; Mason & Latham, 2004; Clubb & Vickery, 2006). 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 is an effective way to decrease the duration of stereotypic behaviors that are a concern for zoological institutions and can be a valuable technique for increasing the well-being of sun bears in captivity. Given this finding, zoos might benefit by investing time and money into building devices that increase in complexity.

Conclusions

Creating more opportunities for captive animals to exhibit species-typical behaviors and introducing enrichment complexity into zoo husbandry routines may reduce the duration of stereotypic behaviors. However, depending on personal history and early development, captive animals can exhibit significant individual variation in their stereotypic behavior and response to enrichment. Examining the basic properties of stereotypies and how they may have developed is necessary to determine the most effective method for tackling these behaviors. Continued research into the relationship between stereotypy, enrichment, and animal welfare can benefit zoo management regimes.

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Tables

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 1st - July 21st	Baseline
2	July 22nd - July 26th	Honey-Log Level 1 (HL1)
	July 29th - August 2nd	Honey-Log Level 2 (HL2)
	August 5th - August 9th	Honey-Log Level 3 (HL3)
3	August 12th - August 16th	PVC Feeder Level 1 (PVC1)
	August 19th - August 23rd	PVC Feeder Level 2 (PVC2)
	August 26th - August 30th	PVC Feeder Level 3 (PVC3)

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

Behavior	Description
Stereotypic	
Standard Pace	Bear walks repeatedly in the same short path (1-2 body lengths), on a log or the ground

Head Roll	Bear’s feet don’t move with continuous swaying of the head around in repetitive motion
Device Use	
Device Use	Bear investigates the device without touching or manipulating the device; Bear uses nose and/or paws to physically manipulate device; Bear consumes reward

Figures

Figure 1. Complex enrichment devices: (1a) honey-log Level 1; (1b) honey-log Level 2; (1c) honey-log Level 3; (1d) PVC cross-shaped feeder Level 1; (1e) PVC cross-shaped feeder Level 2; (1f) PVC cross-shaped feeder Level 3; (1g) grey arrows show direction of movement of PVC cross-shaped feeder

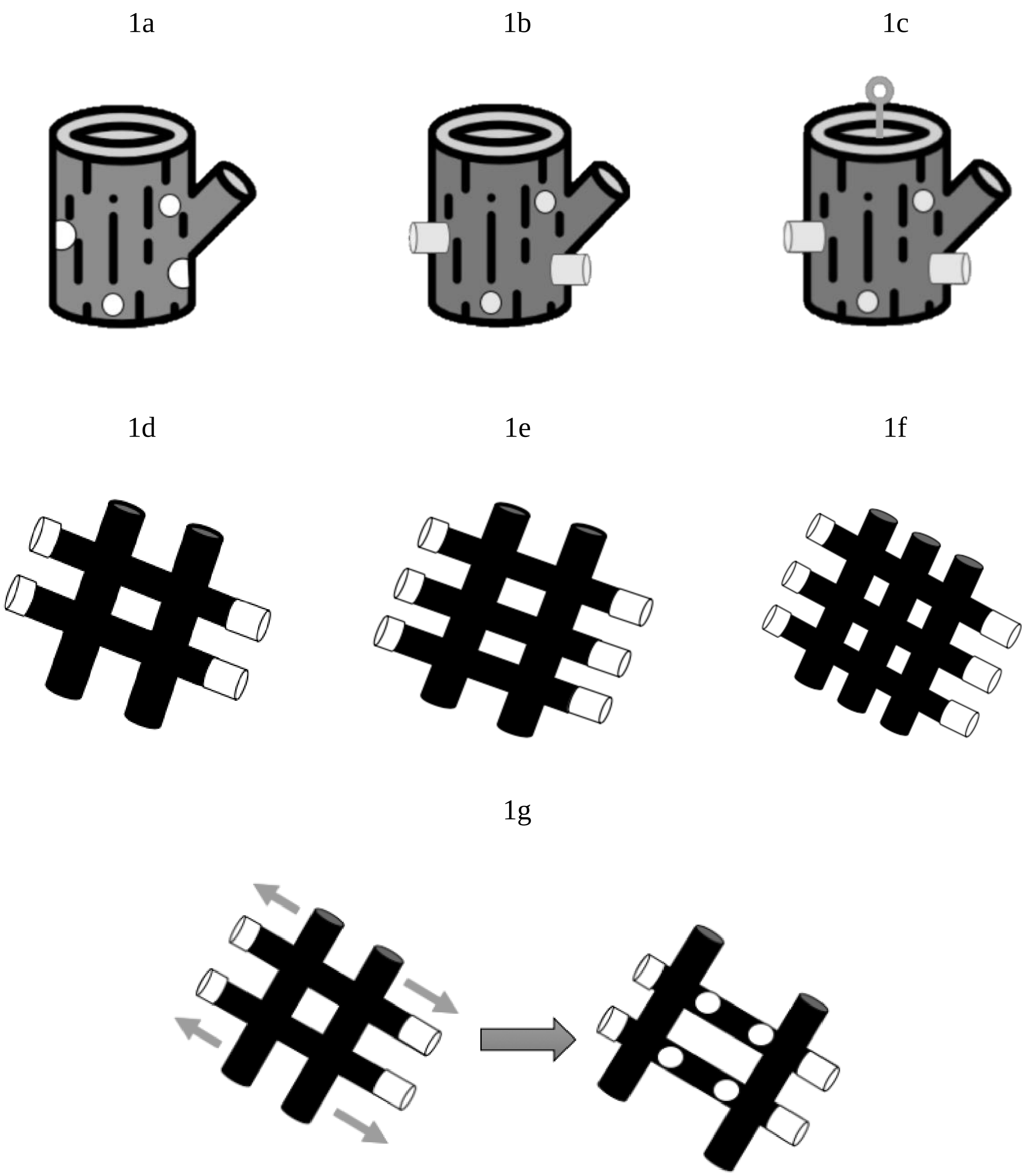

Figure 2. Mean duration of stereotypic behavior throughout the baseline and complex enrichment phases, without looking at the different complex enrichment levels. Phase 1 = baseline, Phase 2 = all honey-log levels, Phase 3 = all PVC feeder levels. The letters denote significant differences assessed using the Least Square Means which controls for the variation between individual bears. The phases not sharing a letter are significantly different from one another.

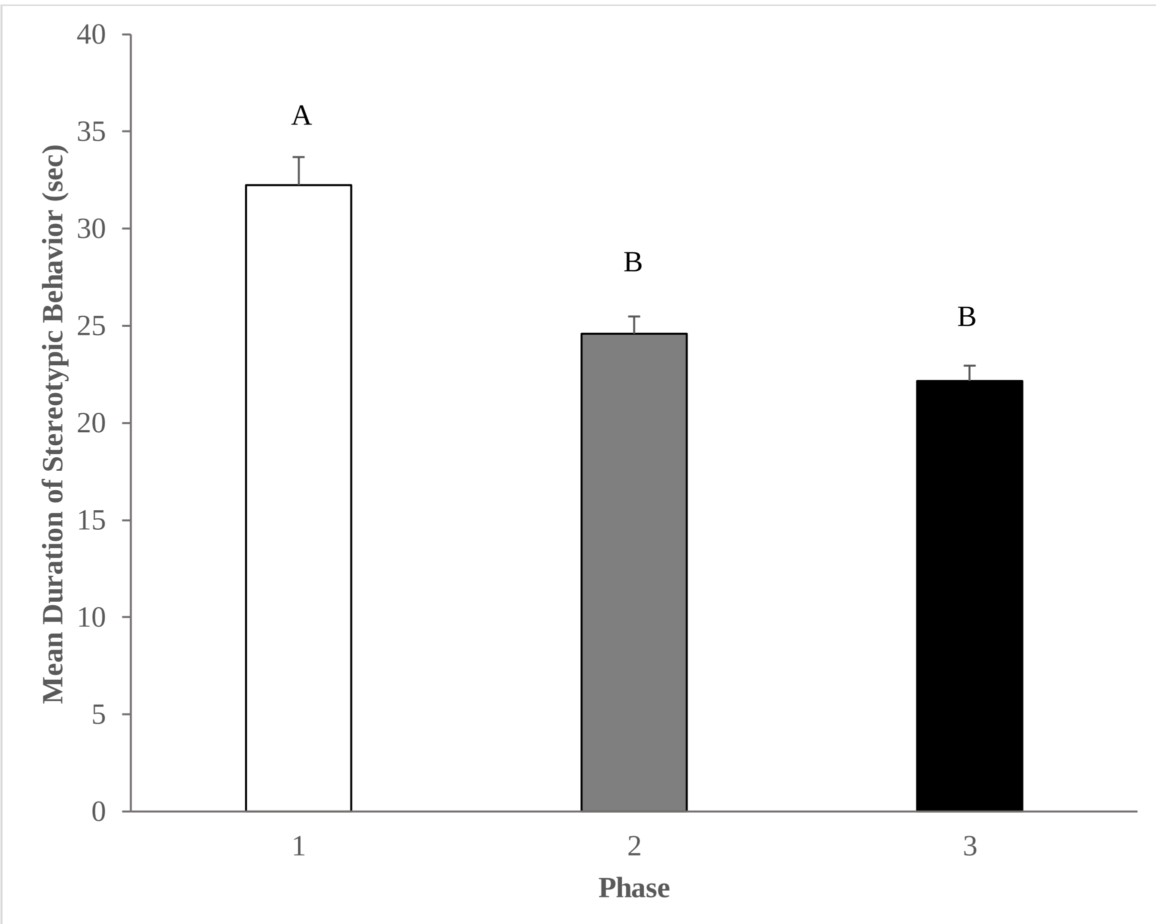

Figure 3. Mean duration of stereotypic behavior throughout the baseline and complex enrichment phases. Phase 1 = baseline, HL1 = honey-log Level 1, HL2 = honey-log Level 2, HL3 = honey-log Level 3, PVC1 = PVC cross-shaped feeder Level 1, PVC2 = PVC cross-shaped feeder Level 2, and PVC3 = PVC cross-shaped 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.

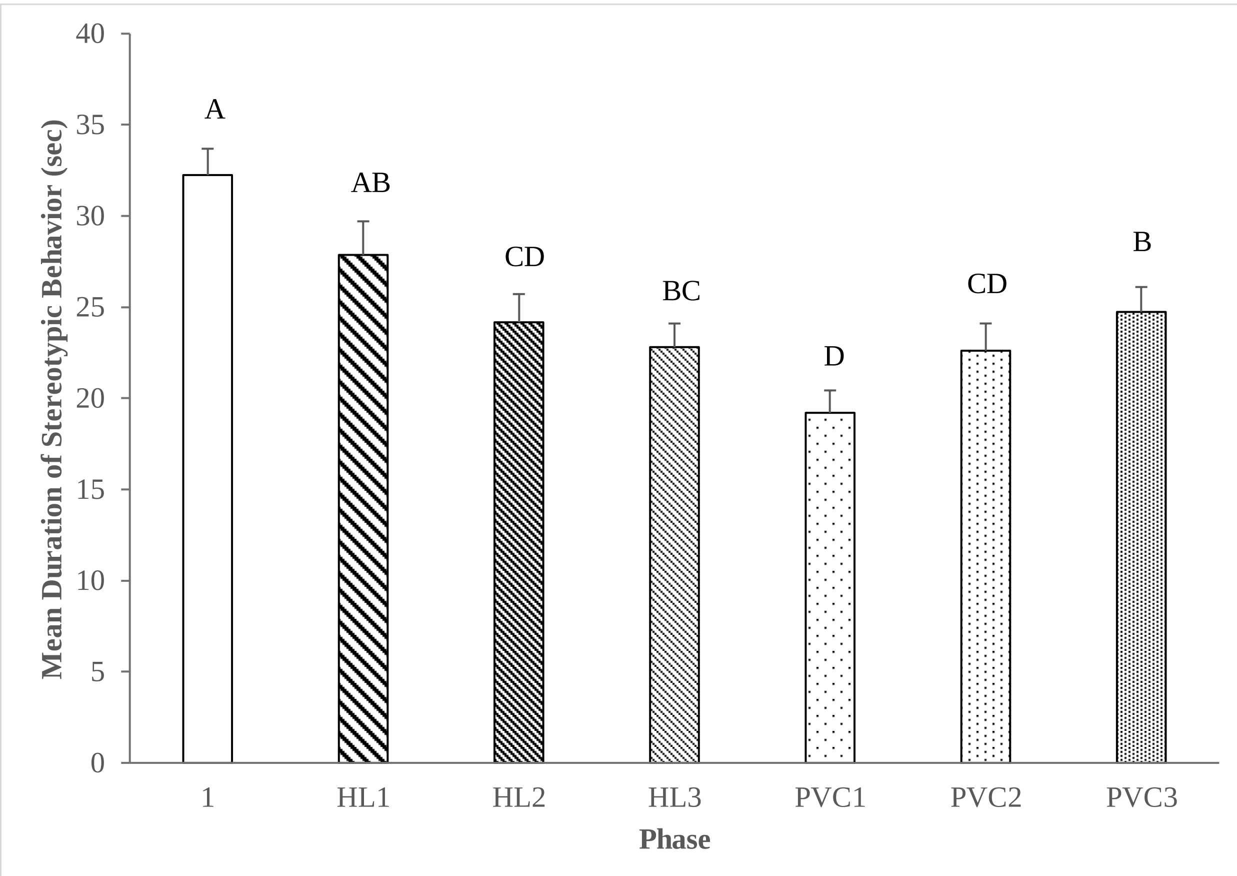

Figure 4. Mean duration of stereotypic behavior throughout the complex enrichment phases. Complex enrichment days are Monday, Wednesday and Friday. Non-complex enrichment days are Tuesday and Thursday. Phase 2 = non-complex enrichment days in Phase 2, HL1 = honey-log Level 1, HL2 = honey-log Level 2HL3 = 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.

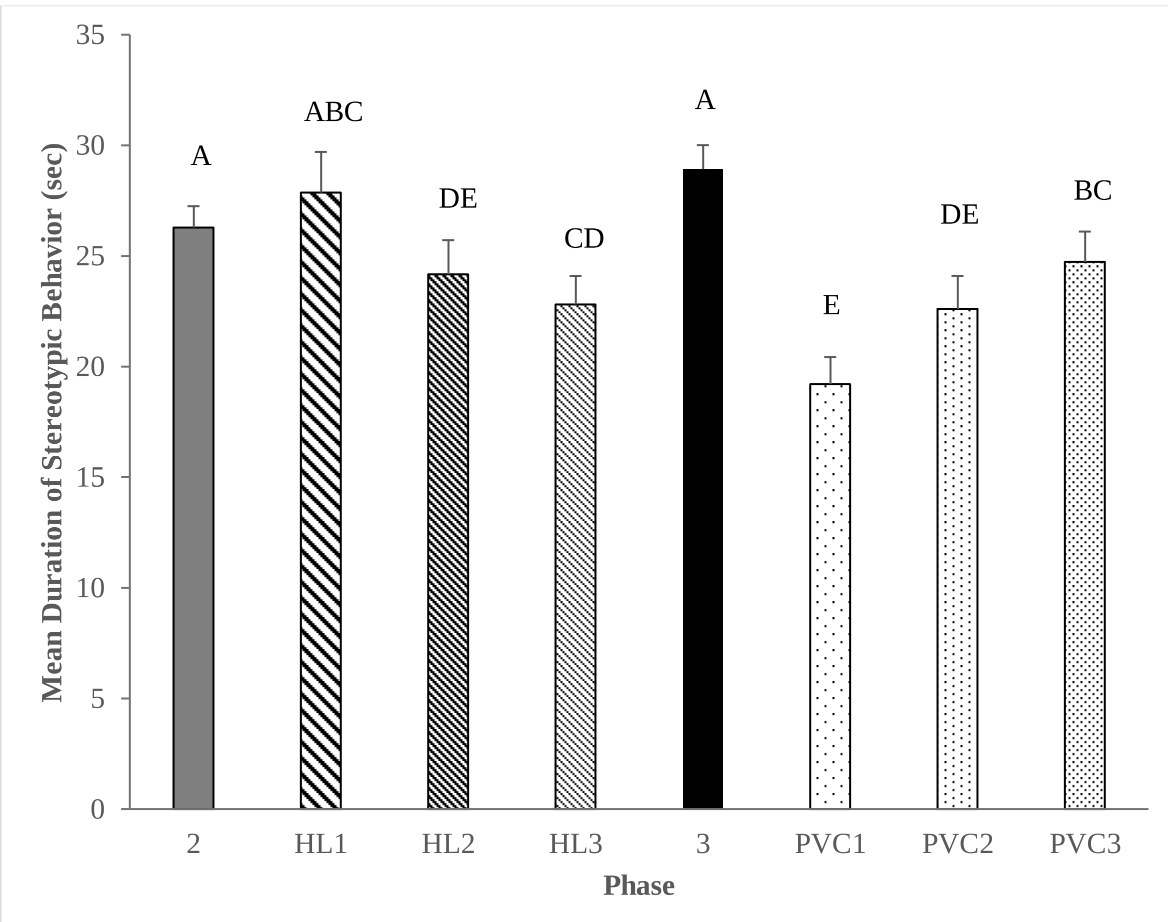

Figure 5. Mean score of complex enrichment use throughout the complex enrichment phases. HL1 = honey-log Level 1, HL2 = honey-log Level 2, HL3 = honey-log Level 3, PVC1 = PVC cross-shaped feeder Level 1, PVC2 = PVC cross-shaped feeder Level 2, and PVC3 = PVC cross-shaped feeder Level 3. The letters denote 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.