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RESEARCH ARTICLE

A Comparative Study of the Speeds Attained by Captive Cheetahs During the Enrichment Practice of the "Cheetah Run"

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The enrichment practice of the "cheetah run" is becoming increasingly popular within zoological institutions as a method to enrich captive cheetahs. A lure moving at speed represents an artificial prey item that the cursorial cheetah can pursue, therefore allowing it to perform an important hunting behavior within a captive setting. This study was conducted in order to highlight how employing different forms of this type of enrichment may influence its efficacy. This is important in relation to the future development of an optimum type of "cheetah run" enrichment which maximizes the potential beneficial effects and therefore positively impacts upon cheetah welfare in captivity. Video recordings were carried out at three separate institutions (Fota Wildlife Park, Ireland; Ann van Dyk Cheetah Centre, South Africa; Cheetah Conservation Fund, Namibia). Randomization tests were carried out to compare the highest speeds attained between males and females, trained and untrained cheetahs and also between the three institutions. Females and trained individuals reached significantly higher speeds compared with males and untrained individuals, respectively. The only significant difference between the three institutions was between the Ann van Dyk Cheetah Centre and the Cheetah Conservation Fund, where cheetahs at the Ann van Dyk center reached significantly higher speeds. The current study represents the first detailed study of any aspect of the "cheetah run" across multiple institutions. It also includes the first quantification of the speed of cheetahs in captivity in relation to differing enrichment practices. Zoo Biol. 32:490–496, 2013. © 2013 Wiley Periodicals, Inc.

Keywords: cheetah; enrichment; lure; speed

INTRODUCTION

Felids are a difficult species group to enrich successfully and continually in captivity due to their natural suites of hunting behaviors and high levels of inactivity in captivity [Skibiel et al., 2007]. The complexity of their hunting behaviors, which include stalking, chasing, and killing of prey, lend themselves well to enrichment based upon feeding, but it remains difficult to provide fully for this complex array of behaviors within the captive setting. Cheetahs (*Acinonyx jubatus*) are highly visual predators and instinctively react to small moving objects. Consequently, the practice of lure-coursing or the "cheetah run" is a popular form of enrichment for cheetahs in captivity. In addition to its primary function as cheetah enrichment, it offers an opportunity for public education and funding opportunities [Ziegler-Meeks, 2009]. Training has been described as any planned and targeted procedure whereby a zoo keeper encourages the performance of specific behaviors [Szolkalski et al., 2012]. Animal training using positive reinforcement techniques serves as an important animal management tool in zoos to reduce problematic behaviors, to increase animal activity levels, to enhance psychological well-being, and to facilitate safe veterinary and husbandry procedures through voluntary

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cooperation [Desmond and Laule, 1994; Kreger and Mench, 1995; Bloomsmith et al., 1998].

Cheetahs are cursorial, diurnal predators. They are the fastest land animals in the world, capable of speeds up to $29\,m\,sec^{-1}$ or $103\,km\,hr^{-1}$ [Sharp, 1997]. They stalk their prey up to a certain distance and then, with an explosive burst of speed over 300–400 m [Marker, 2002], attempt to chase and kill the prey item. Cheetahs are markedly different in anatomy and behavior from other felids. They have a slight build, long, thin legs, a narrow chest, and a small domed skull [Caro, 1994]. According to Ewer [1973], the main adaptations that allow a cheetah to run at such high speeds are a lightweight thinly-boned skull, flat face, reduced muzzle length (that allows the large eyes to be positioned for maximum binocular vision), enlarged nostrils and extensive air-filled sinuses. Cheetahs also have 50% heavier thigh muscles than would be expected for a typical quadrupedal mammal of the same body mass [Alexander, 1993]. Blunt, slightly curved and semi-protractile claws contribute to added traction during a cheetah's high speed chases [Londei, 2000].

To date, no research has empirically examined or compared any aspect of the various forms of the "cheetah run" employed in zoological institutions. The overall aim was to enhance understanding of this form of enrichment, with a view to improving design of future enrichment programs. The specific objectives of this research were to (1) use slow motion video footage to measure the speed of captive cheetahs provisioned with this form of enrichment in three separate zoological institutions and, (2) assess how sex, provision of training, and institution influence the highest speeds observed.

METHODS

Study Sites

This research was carried out at Fota Wildlife Park (Fota) in Ireland, the Ann van Dyk Cheetah Centre (AvD) in South Africa, and the Cheetah Conservation Fund (CCF) in Namibia. There were differences between institutions in relation to the schedule of provision of the run and the shape and length of the run track (Table 1). At each institution, cheetahs were subject to no more than one enrichment run session per day. Cheetahs at AvD were run twice a week

TABLE 1. Cheetah runs at each institution

Institution	Schedule	Average no. of run sessions/ week/cheetah	Shape of run	Distance
Fota Wildlife Park	Daily (subject to weather)	5		Start to finish: approx. 70 m
Ann van Dyk Cheetah Centre	Twice a week per cheetah	2		Start to finish: approx. 480 m
Cheetah Conservation Fund	Non-regular (subject to visitor bookings)	1		Full circuit: approx. 800 m

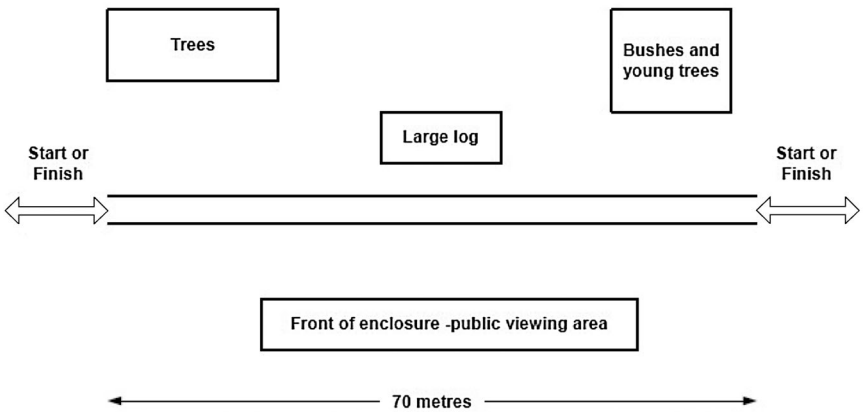

Fig. 1. Diagram of run course at Fota Wildlife Park. The lure is bi-directional. Distance is approximate.

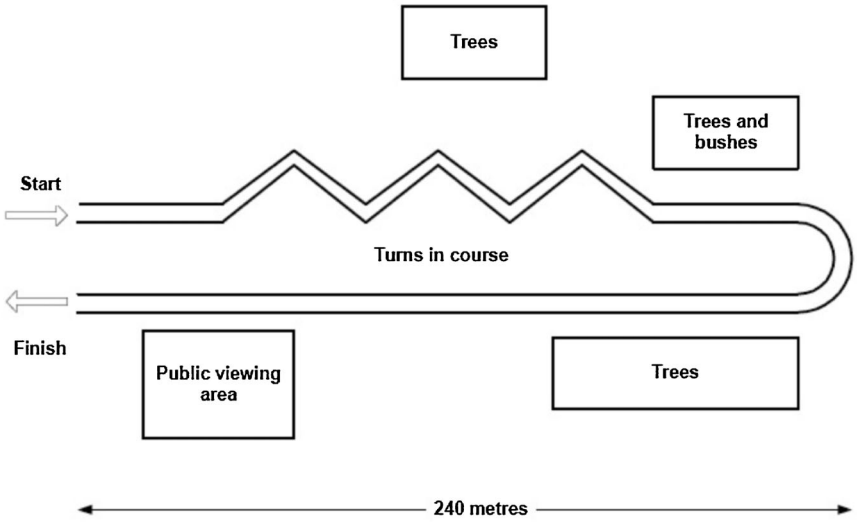

Fig. 2. Diagram of run course at the Ann van Dyk Cheetah Centre. The run is unidirectional. Distance is approximate.

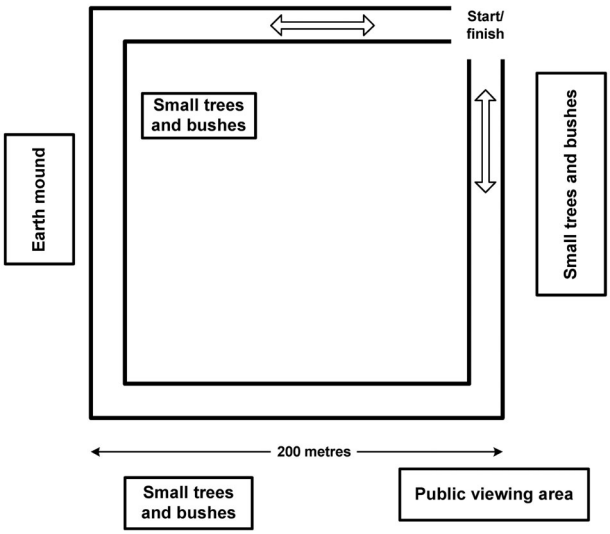

Fig. 3. Diagram of run course at the Cheetah Conservation Fund in Namibia. The run is bi-directional. The run course was located in a sub-section of a large 2 ha enclosure. Distance is approximate.

while at Fota and the CCF, cheetahs were run five times and one time per week, respectively. Figures 1–3 highlight the detailed shapes, distances, surrounding vegetation, and public viewing areas present within the "cheetah run" enclosures. Each run course was set up on flat grassy terrain. The AvD and CCF employed a system similar to those used for coursing greyhounds, which has become increasingly popular within zoos for coursing cheetahs. The system consists of a car starter motor operated by a hand held trigger switch, a string with a lure (a rag or white plastic), and is powered by a car battery. Pulleys are used in order to set out the course of the lure. Fota Wildlife Park employed a device which suspends food (whole rabbit or chicken) from a wire held 3 m off the ground. The food hangs just above the ground and its support is powered by a mechanism controlled by an operator in a tower overlooking the cheetah enclosure. The systems at each institution allow the operator to control the speed and direction of the lure.

Fota incorporated a straight line, bi-directional system. The AvD incorporated a uni-directional system with a number of turns in the middle and at the end of the run. Both of these institutions used dedicated enclosures for this enrichment practice, both of which were similar in size. In contrast, at the CCF, a bi-directional system was set out in a square shape. In contrast to Fota and AvD, this run was of much greater size and set up within a sub-section of a very large 2 ha enclosure.

Study Animals

Fifteen cheetahs were the subjects of this study (Table 2). The age of the cheetahs ranged from 1 to 8 years

TABLE 2. Cheetahs investigated in this study

Cheetah	Sex	Age	Training	Institution
Graca	Female	7	Yes	AvD
Phantom	Female	3	Yes	AvD
Roy	Male	2	Yes	AvD
Big girl	Female	8	Yes	AvD
Charlotte	Female	4	Yes	AvD
Shaka	Male	7	Yes	AvD
Impie	Female	5	No	Fota
Zulu	Female	5	No	Fota
Hermoine	Female	5	No	CCF
Harry	Female	5	No	CCF
Tiny	Female	1	No	CCF
Little C	Male	3	No	CCF
Ron	Male	5	No	CCF
Blonde	Male	2	No	CCF
Smart	Male	2	No	CCF

AvD, Ann van Dyk Cheetah Centre; Fota, Fota Wildlife Park; CCF, Cheetah Conservation Fund.

of age. Of these, nine were female and six were male. Six of the cheetahs had been trained and nine had not (Table 2). Trained cheetahs had been previously conditioned via positive reinforcement to return to the operator to receive a food reward after pursuing the lure. Cheetahs were only rewarded when they pursued the lure for the entire length of the run track. They showed interest in the lure from the beginning of training, but initially, the noise of the pulleys and motor often distracted or frightened them during a run. This was the main reason for the cheetahs not pursuing the lure. Once they became accustomed to these sounds, they began to pursue the lure consistently and return to the operator for their food reward.

Data Collection

Video recordings were made using a Casio Elixim EX-FH100 digital camera mounted on a tripod. In all cases the camera field of view was fixed throughout the recording. Cheetahs were recorded at 240 frames/sec for later analysis. At Fota Wildlife Park, videos were recorded from three points along the length of the cheetah run enclosure. Three videos were recorded from each point during April and May 2010. As the cheetahs at Fota were maintained in the same enclosure during the run, footage for the two animals was collected simultaneously. A total of nine videos were recorded for each cheetah. At the AvD, videos were recorded from three points along the length of the enclosure. Three videos were recorded from each point for each cheetah during June and July 2010. A total of nine videos were recorded for each cheetah. All cats were run separately at the AvD. At the CCF, videos were recorded from two points within the enclosure (two sides of the square run). Two separate groups of four cheetahs were run at the CCF, one group of four males and another of three females. Three videos at each point were carried out for each group during August and September 2010. A total of six videos were recorded for each cheetah. The researchers had no control over when certain cheetahs were run or how they were run in relation to groupings. This was at the discretion of each individual institution. The gait of the cheetahs was measured during each run. Galloping was defined as when all four feet were off the ground during each stride. Trotting was defined as a gait in which diagonal pairs of legs moved forwards together. In this study, sprinting involved a similar gait to that of trotting but at a faster speed. Walking refers to the normal ambulatory movement of the cheetahs at slow speed.

Data Analysis

Motion Analysis Tools-DX9-Shareware Version 2.7.3 was used to analyze the video footage. A known length on the body of each cheetah, in this case, the distance between the tip of the nose and the base of the tail was used as a linear scale marker. For each cheetah and each video, speed was measured from the point when the tip of the nose came into field of view to the moment the tip of its nose left the field of view. This procedure was carried out for each video clip collected during the study. The highest speed observed from all video footage for each individual cheetah was used during the analysis.

A randomization test using 1,000 re-randomized pseudosamples was used to compare the highest speeds observed between males and females [Todman and Dugard, 2001; Plowman, 2008]. The same procedure was carried out in order to compare the highest speeds observed between trained and untrained cheetahs. The accepted alpha level was taken to be 0.05. Three separate randomization tests were conducted to compare institutional differences in the highest speeds observed. The accepted alpha level for statistical significance was taken to be 0.01 when comparisons between the institutions were conducted. The reason three separate randomization tests were carried out was due to the sample size of two cheetahs at Fota. In contrast to many other forms of statistical analysis, three randomization tests allowed us to compare each institution separately, allowing us to take the small sample size into consideration when comparing the results from Fota with the two other institutions. All analyses were conducted using R version 3.0.0.

RESULTS

Speeds

The highest speed throughout the entire study was observed at the AvD where one female attained a speed of 100.1 km hr^{-1}. The highest speed observed from males was also observed at the AvD (63.1 km hr^{-1}). On average, for the highest speeds observed, females (71.6 km hr^{-1}) were observed to attain higher speeds compared with males (51.6 km hr^{-1}; Fig. 4). Trained (76.8 km hr^{-1}) cheetahs also attained higher speeds when compared with untrained individuals (54.8 km hr^{-1}; Fig. 4). The average highest speeds were observed at the AvD (76.8 km hr^{-1}) followed by Fota (67.5 km hr^{-1}) and the CCF (51.1 km hr^{-1}; Fig. 4). The most common gait during the highest speeds was galloping, while during medium-paced runs, sprinting was common. Low speed runs consisted predominantly of trotting and walking gaits.

Males and Females

The difference between the mean highest speeds between males and females was equal to or greater than the observed value (20.1 km hr^{-1}) in 20 of the 1,000 permutations (proportion = 0.02). Therefore the observed mean difference in highest speeds between males and females is statistically significant ($P < 0.05$; two-tailed; Fig. 4).

Provision of Training

The difference between the mean highest speeds between trained and untrained cheetahs was equal to or greater than the observed value (21.9 km hr^{-1}) in 10 of the

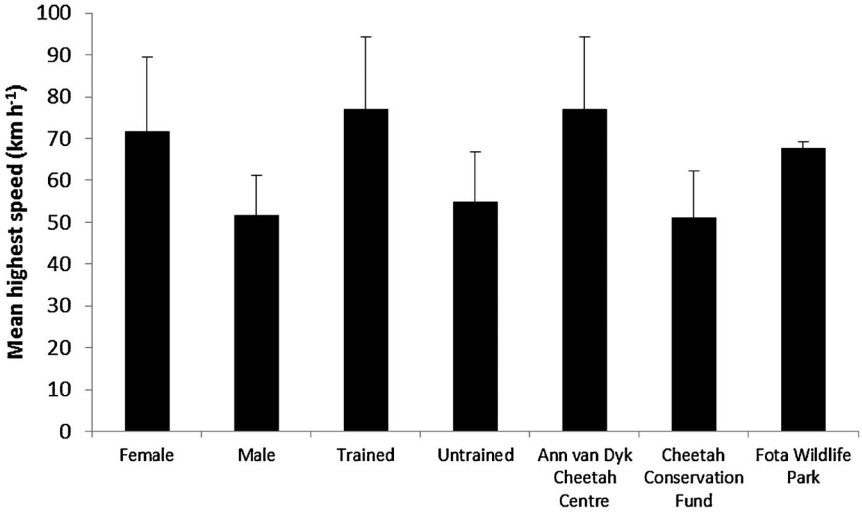

Fig. 4. The mean highest speeds attained (±SD) for female, male, trained and untrained cheetahs, and cheetahs in captivity at the Ann van Dyk Cheetah Centre, the Cheetah Conservation Fund, and the Fota Wildlife Park.

1,000 permutations (proportion = 0.01). Therefore the observed mean difference in highest speeds between trained and untrained individuals is statistically significant ($P < 0.05$; two-tailed; Fig. 4).

Institution

The difference between the mean highest speeds between the cheetahs at Fota Wildlife Park and those at the AvD was equal to or greater than the observed value ($9.3\,km\,hr^{-1}$) in 687 of the 1,000 permutations (proportion = 0.687). Therefore the observed mean difference in highest speeds between the cheetahs in the two institutions was not statistically significant ($P > 0.05$; two-tailed; Fig. 4).

The difference between the mean highest speeds between the cheetahs at Fota Wildlife Park and those at the CCF was equal to or greater than the observed value ($16.5\,km\,hr^{-1}$) in 72 of the 1,000 permutations (proportion = 0.072). Therefore the observed mean difference in highest speeds between the cheetahs in the two institutions was not statistically significant ($P > 0.05$; two-tailed; Fig. 4).

The difference between the mean highest speeds between the cheetahs at the AvD and those at the CCF was equal to or greater than the observed value ($25.7\,km\,hr^{-1}$) in 9 of the 1,000 permutations (proportion = 0.009). Therefore the observed mean difference in highest speeds between the cheetahs in the two institutions was statistically significant ($P < 0.01$; two-tailed; Fig. 4).

DISCUSSION

The activity budget of felids in general has previously been described as being one of sustained inactivity interspersed with short bursts of hunting behaviors [Wright and Walter, 1990]. A variety of enrichment experiments related to fulfilling the behavioral needs of felids have included the use of intact carcasses [McPhee, 2002], presentation of live fish [Shepherdson et al., 1993], multiple feedings of hidden food [Shepherdson et al., 1993], electronically controlled feeding boxes [Jenny and Schmid, 2002; Kistler et al., 2009], and more complicated acoustic systems which stimulated hunting behaviors in a leopard [Markowitz et al., 1995]. Specifically for cheetahs, Bond and Lindburg [1990] reported improved appetites, longer feeding bouts, and a greater possessiveness of food in cheetahs that were carcass-fed. Quirke and O'Riordan [2011a,b] highlighted how the use of temporal feeding variation, spatial feeding variation and olfactory enrichment reduced levels of stereotypical behavior in cheetahs. Williams et al. [1996] recorded an increase in hunting and observation behavior in cheetahs provisioned with a moving bait system at feeding time. Lure systems are now employed at a large number of institutions to enrich cheetahs [Ziegler-Meeks, 2009]. This system provides cheetahs in captivity with mental stimulation and the opportunity to perform locomotory activity associated with the chase portion of a hunt in the wild.

Females were observed to attain higher speeds in the current study. Caro [1994] reported that 25%, 11%, and 29% of failed hunts in solitary, paired and trios of male cheetahs on the Serengeti respectively, were as a result of them "not being serious" about the hunt. Cooper et al. [2007] emphasized that the decision to hunt is not based upon hunger in cheetahs. This suggests that motivation to hunt plays an important role. Cooper et al. [2007] also noted that males tended to select for larger prey than females. It is possible that, on occasion, males in the current study were less inclined to initiate high speed "hunts" as a result of decreased motivation to pursue the relatively small "prey" item. Conversely, females appeared visibly excited prior to commencement of the majority of runs. This visible excitement in females was consistent across the three institutions. Incorporating

personality into future studies relating to this enrichment practice will highlight whether any particular personality types derive more benefit from this form of enrichment. In the wild, females are responsible for providing food for their young and will increase their intake of food during lactation [Laurenson, 1992; Caro, 1994]. Although none of the females in the current study were either pregnant or caring for young, Wielebnowski and Brown [1998] reported that, during estrus, female cheetahs exhibit behavioral changes such as an increase in object sniffing, rolling, and rubbing. No evidence suggests that estrus may have influenced the speeds observed in this study but, future studies employing fecal hormone analyses, may reveal any possible influence of reproductive status on the motivation and speeds of females during cheetah run enrichment. This may also provide important insights into wild female behavior.

It has been suggested that the cognitive skills of animals in captivity should be tested through a requirement to use navigational, tool-making, or cooperative social skills in order to stimulate their minds in a captive environment, where the need to employ various cognitive skills are diminished. Such stimulation may also directly lead to improved welfare through the minimization of stereotypical behaviors [Meehan and Mench, 2007]. A recent study by Szolkalski et al. [2012] revealed that 77.9% of surveyed big cat zookeepers practice training of the animals under their care. More specifically, 50% of cheetah keepers practiced training. This husbandry practice was perceived to be more beneficial than hands off and protected contact approaches [Szolkalski et al., 2012]. Training in captivity has been used effectively to train chimpanzees (*Pan troglodytes*) to move voluntarily to indoor sections of their enclosures [Bloomsmith et al., 1998], to collect semen noninvasively in western lowland gorillas (*Gorilla gorilla gorilla*) [Brown and Loskutoff, 1998] and to monitor pregnancy in an unanesthetized snow leopard (*Uncia uncia*) [Broder et al., 2008]. By incentivizing the process through training, the AvD cheetahs were cognitively challenged to pursue the lure for a reward and therefore, fully engage in the pursuit, resulting in higher speeds. Although food in the form of whole rabbits or chickens constituted the lure at Fota Wildlife Park, food was always provided after the run, whether or not the cheetahs actively pursued the lure. The phenomenon of contra-freeloading, whereby animals will work for "earned" food even though "free" food is available, was therefore clearly demonstrated at Fota Wildlife Park [Inglis et al., 1997]. The constant reward of food at Fota may have contributed to the lower speeds by effectively minimizing the cheetah's eagerness to fully engage in high speed pursuits on certain days. On any given day at Fota Wildlife Park, the response of the cheetahs to the lure was variable, ranging from energetic, high speed chases, to lethargic, low speed attempts to capture their "prey." The lack of both a food reward or training at the CCF resulted in the lowest speeds observed in the study. Although on any given day, a trained or untrained cheetah can react independently and variably to a lure, the provision of training appears to result in cheetahs that are more highly motivated to pursue the lure.

In addition to the provision of training and food rewards during this enrichment practice, the schedule of the practice and way in which cheetahs were run at each individual institution must be taken into account. Cheetahs in the wild hunt on average, every 2–5 days [Estes, 1992]. Cheetahs were run twice a week at the AvD while at Fota and the CCF, cheetahs were run five times and one time per week on average, respectively. It is possible that the combination of training and the relative low frequency at which the cheetahs at the AvD were run, contributed to the higher speeds observed. The predictable daily regime and increased frequency of runs at Fota may have contributed to the lower speeds observed because the cheetahs lacked the motivation or energy to pursue the lure with vigor on a daily basis. However, care must be taken with the interpretation of the comparisons between Fota and the other institutions due to the sample size of two cheetahs observed at Fota. The only significant institutional difference was observed between AvD and CCF. However, trained individuals ran significantly faster than untrained individuals and females ran significantly faster than males. Only untrained females were observed at Fota while trained and untrained males and females were observed at AvD and CCF, respectively. From this information, one could expect to see that Fota would be in the middle range of speeds, possibly approaching a level closer to that of CCF if males were observed at Fota.

The differences in the areas in which the cheetahs were run at each institution also influenced the observations in this study. Each run enclosure provided similar areas of cover in the form of shrubs, bushes, and trees. Cooper et al. [2007] reported that cover availability had no influence on decisions to hunt in cheetahs. In contrast, the size of the run enclosure was an important factor. At the CCF, in the largest run enclosure, cheetahs would frequently observe the lure when it was on the other side of the track, walk in its general direction, and only occasionally engage in short, medium to high speed bursts as the lure passed them. Rarely, extended chases encompassing two or three full lengths of each side of the square run were completed by an individual. In contrast, the smaller, dedicated run enclosures at AvD and Fota ensured that the cheetahs were in close proximity to the lure at all times. Many predatory animals will only fully commit to a hunt if the energetic rewards either equal or exceed the energy expended. It is possible that the smaller enclosure size and run tracks at AvD and Fota effectively made more "hunts" worth the effort, therefore increasing the frequency and intensity of chases. Ziegler-Meeks [2009] recommended that cheetahs should not be run on hot/humid afternoons or in wet or muddy conditions. Cheetahs were not run in wet conditions at any of the three institutions. At the AvD and CCF, where videos were collected in June–September (Winter), cheetahs were run early in the morning (before 8.30 AM). In contrast, at Fota where videos were collected in April/May (Spring/Summer), cheetahs were run in the afternoon (4 PM). The seasonal

difference and times at which the cheetahs were run, effectively minimized the temperature differential between the institutions as well as any influence this may have had on the observed speeds. In addition to these physical differences, only the AvD ran cheetahs individually, whereas at Fota and CCF, cheetahs were run in groups. Cheetahs which were run in groups were often observed to divert their attention away from the lure and begin to chase conspecifics playfully. Four of the six males in this study were run as a group at the CCF. Hence, the aforementioned institutional differences may have also influenced the observed differences in speeds between the sexes.

CONCLUSIONS

Developing an understanding of how various enrichment practices influence captive animals is of fundamental importance in promoting natural behavior and in improving their welfare in captivity. The current study represents the first detailed study of any aspect of the cheetah run across multiple institutions. It also represents the first quantification of the speed of cheetahs in captivity in relation to enrichment practices. If attaining high speeds and showing a strong interest in the lure is a valid measure of the enjoyment and value cheetahs receive from this enrichment practice, the methods (including training) employed at the AvD provide the most enriching experience for the animals amongst the three institutions studied. However, all forms of this enrichment practice represent an opportunity for cheetahs to express different stages of natural hunting behavior in captivity. It also provides zoological institutions with the chance to condition their animals and provide public spectacles that can be used for the purpose of education. The current study involved small sample sizes of cheetahs and limited varieties of "cheetah run" enrichment strategies. However, this research can be used as a baseline for future research to further enhance our understanding of how to fully enrich captive cheetahs in relation to their complex array of feeding behaviors.

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