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Circus Animal Welfare: analysis through a five-domain approach

Daniel Mota-Rojas[a*] | **Marcelo Daniel Ghezzi**[b] | **Adriana Domínguez-Oliva**[a] | **Leonardo Thielo de la Vega**[c] | **Luciano Boscato-Funes**[a] | **Fabiola Torres-Bernal**[a] | **Patricia Mora-Medina**[d]

[a]Neurophysiology, Behavior and Animal Welfare Assessment, DPAA, Universidad Autónoma Metropolitana (UAM), Mexico City, Mexico
[b]Animal Welfare Area, Faculty of Veterinary Sciences (FCV). Universidad Nacional del Centro de la Provincia de Buenos Aires (UNCPBA), Argentina.
[c]Animal welfare certification "Certificação Produtor do Bem"; F&S Consulting, São Paulo, Brazil.
[d]Animal Welfare Assessment, Department of Livestock Sciences. Universidad Nacional Autónoma de México (UNAM), FESC, Mexico.

Corresponding author: dmota@correo.xoc.uam.mx

Abstract This study aims to review the current available literature regarding circus animals from the perspective of the five domains proposed for evaluating animal welfare to identify the critical points in the use of these animals and understand how circus spectacles affect their mental state and health. Exhibiting animals in circuses continues to be a popular practice today in some countries such as Germany, Spain, or Australia. However, animals' biological needs are not always prioritized due to the inadequate diets, reduced housing spaces, deficient social interaction, and handling that predisposes them to develop stereotypies and alter mental states due to chronic stress. Animal circuses are considered a controversial practice that can decrease the welfare of animals. Understanding the possible negative consequences on animal welfare (mental state and physical health) could contribute to planning strategies to improve the quality of life of wildlife animals exhibited in circuses worldwide.

Keywords: animal ethics, keeper-animal relationships, mental alteration, pathological behaviors, stereotypies

1. Introduction

The origin of the circus traced back to Egypt in the ruins of Memphis and Thebes and later to the beast tamers of ancient Rome and Greece (Seibel 1993). Circuses enjoyed great success in the beginning because, for most spectators, the animals were rare and exotic species (Tait and Farrell 2010). Currently, however, both zoos and circuses face controversy over the welfare of animal species held in captivity. Circuses, especially, are considered places that fail to comply with legislation or maintain minimum standards of animal care and health and it is common to detect physical, mental, and behavioral alterations in the animals (Maple and Perdue 2013; Mota-Rojas et al 2016; Mota-Rojas et al 2018). Hence, circus is associated with animal maltreatment and cruelty (Kawata 2016). Temperament and tameness, considered wild or farm animal characteristics, are important in human-animal interaction (Mota-Rojas et al 2020). Additionally, the stockperson attitudes, and the method and quality of training also influences the interaction. Some international wild or farm animal welfare protocols are also described in this review, together with negative and positive stimuli that affect farm/wild animal welfare (Waiblinger 2017; Mota-Rojas et al 2020). In Europe, the Code of Conduct for Animals created by the European Circus Association includes regulations that authorize the species that can be used in circuses and establish strict quality standards for their conservation and training (ESA 2007). As a result, many countries in Europe and America have implemented regulations and sanctions on the use of fauna in training (Lucassen 2017). However, this is not applied in all regions participating in this activity.

In its efforts to evaluate the welfare of animals in captivity, including those in circuses, the World Association of Zoos and Aquariums (WAZA) has implemented the so-called "Five Domains", which stipulate the need to assess the positive and negative states (Mellor et al 2020). There are four physical/functional domains (nutrition, environment, physical health and behavior); and the fifth addresses mental or affective states (Mellor et al 2015). As Figure 1 describes, the Nutrition domain include restrictions or opportunities regarding water or food intake, the quality of the diet, the variety of the foods, or the nutritional balance of the food given to animals under human care. The environment as the second domain and its characteristics such as thermal conditions, substrates, space for movement, or atmospheric factors, highly influence the third domain of health, when the animal is exposed or is prevented from developing acute or chronic diseases, functional impairment, or poor fitness levels. The last physical domain, the behavior, comprises the constrain of animals to develop species-specific behaviors, or their freedom to show their behavioral repertoire (Mellor 2017). Consequently, the subjective experience as the result of the integration of the domains is assigned to the affective state or five domains, known as the negative or positive mental state of the animal (Kell 2021).

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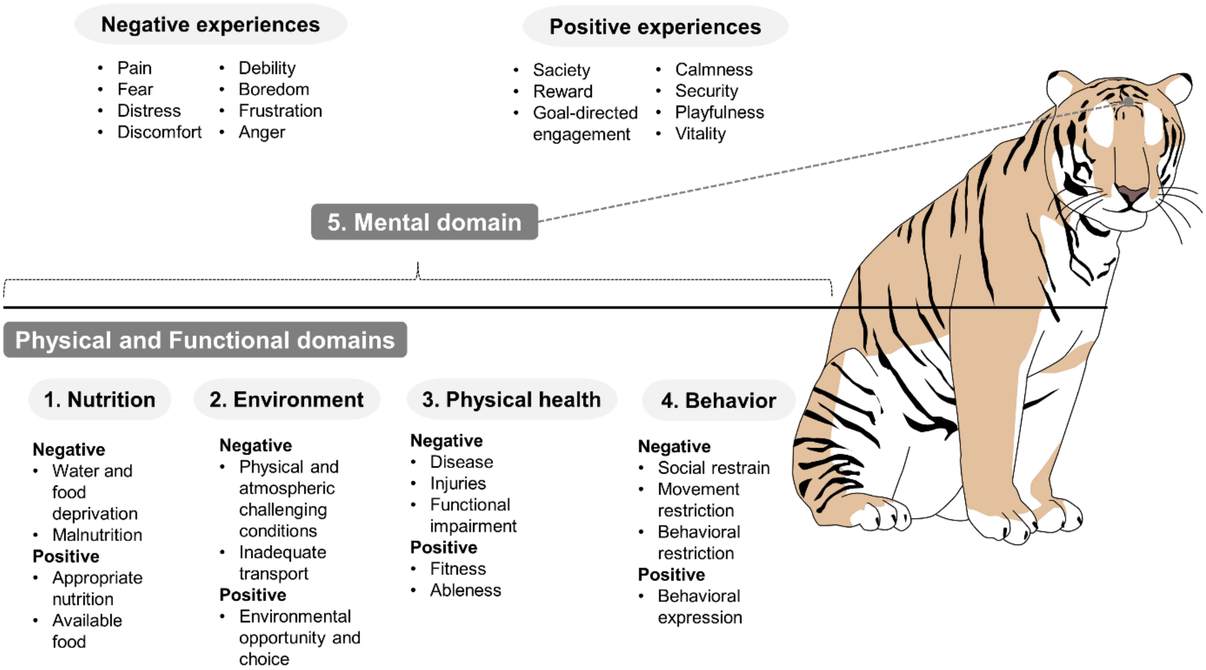

Figure 1 The five domains in circus animals (Mellor et al 2020).

The controversy of whether circuses can provide adequate environments to satisfy the social, environmental, and cognitive needs of the diverse species used in shows (mainly birds, primates, large and small felines, ursids, ungulates, small mammals, reptiles, arachnids, and insects) (Harris et al 2006) arises the need of this issue to be discussed based on scientific knowledge. Therefore, this study aims to review the current available literature regarding circus animals from the perspective of the five domains proposed for evaluating animal welfare to identify the critical points in the use of these animals and understand how circus spectacles affect their mental state and health.

2. Physical and functional domains

2.1. Nutrition

One of the main limitations that circuses face is the difference between animals' diets in the wild and those they can provide to animals in captivity, which may vary greatly in terms of consistency and nutritional balance, failing to provide the nutrients necessary to maintain the health and immunity of animals (Ibáñez et al 2013). The quality and quantity of food, the frequency of meals, the lack of activity, and the confinement in reduced spaces, are all factors that increase the risk of animals developing pathologies like obesity, diabetes, cardiorespiratory diseases, reproductive and urinary disorders, claudication, thermal stress, tumors or even death (Dorning et al 2016).

2.1.1. Type of food

In the wild, Bengal tigers (*Panthera tigris tigris*), a species widely employed in circuses, consume prey like chitals (*Axis axis*), sambars (*Rusa unicolor*) (De et al 2019), and other species of deer *(Axis porcinus, Muntiacus muntjak*) (Karmacharya et al 2019). However, Bengal tigers rarely receive this variety of food in captivity, receiving only beef or chicken. Another example involves the alimentary habits of elephants, which choose among 30-32 varieties of plants (Zahrah 2016) and spend up to 18 hours per day in the quest for food (requirements of 100-200 kg daily) (Kontogeorgopoulos 2009). In captivity, in contrast, animals are fed only with grains and concentrate, are allowed to access hay ad libitum, and receive water a few times a day (Friend and Parker 1999). In 31 elephants at seven circuses in diverse areas of India, Varma et al (2008) found that elephants' diets were restricted to paddy straw, rice, wheat, bread, jaggery, tree leaves, and grass. These poor dietary practices caused obesity, colic, and some vitamin and mineral deficiencies (Clauss and Hatt 2006).

In aquatic circuses that exhibit seals or sea lions, trainers provide food. This severely restricts the animals' natural behavior, involving swimming as many as 15 miles in search of prey (Brando 2016). The easiness of accessing food is a factor that may predispose marine animals to stereotypies, although it does not always result in nutritional deficiencies. For example, Sós et al (2013) states that in-training sea lions (*Zalophus californianus*), the animals receive adequate vitamin and mineral supplementation, contrarily to what is reported in bears. This species recommended digestible diet includes high protein concentrations from fish, eggs, corn flour, beans, fruits, and vegetables, with vitamin and mineral supplements. Nonetheless, bears in captivity are often fed with human food residues, pig swill, and mixtures of rice, corn, and cereals with no calcium (Ca) supplementation. This diet can cause osteoporosis and mandible bone deformities (Maas 2000).

2.1.2. Nutritional deficiencies

Deficient diets have been related to bone pathologies in both captive carnivores and herbivores, such as the porosity of long bones (humerus) caused by a lack of dietary Ca (Kawata 2016). Bone diseases are also common in birds kept as pets or exhibited in shows, linked to high-fat seed diets that may be deficient in numerous nutrients, such as vitamins (A, D, K, B12, riboflavin), aminoacids, minerals (calcium sodium, manganese, zinc, iron, phosphorus), pantothenic acid, choline, and niacin (Koutsos et al 2001). These deficiencies may cause osteodystrophy, hypocalcemic tetany, malformations, and hepatic lipidosis (Peng and Broom 2021). In primate species, vitamin B12, iron, and zinc deficiencies have been associated with anemias, alopecia, and the thickening of areas of the skin (Crissey and Pribyl 2000). In reptiles, canines, and wild felines (e.g., lions, tigers) secondary nutritional hyperthyroidism is a common disorder (Watson et al 2014). Commercial diets deficient in Ca and high in phosphorus (P), like those based on red meats, increase the Ca:P ratio (1:10 to 1:50), generating hypocalcemia, secondary bone resorption, and osteopenia (Turner 2001). Asi et al (2014) reported this in a study of an African lion cub (*Pantera leo*) with osteopenia of the lumbosacral vertebrae, attributed to nutrient deficiencies due to a diet of goat meat, beef and early weaning (at two months).

2.1.3. Alteration of the microbiota

In some circuses, the reduced variety of foods given to Bengal tigers generates imbalances in the bacterial microbiota that negatively affect their immunity and leave them susceptible to inflammatory intestinal disease, Crohn's disease, and ulcerative colitis (Karmacharya et al 2019). These illnesses have also been reported in squirrel monkeys (*Saimiri Sciureus*), lions (*Panthera leo*), and domestic canines and felines, among other species (Schreiner and Liesenfeld 2009). Studies further point out that an animal's microbiota modulate mechanisms associated with the immune system, nutrition, social behaviors, emotional states, memory (Kraimi et al 2019). In the same study, the authors found that the relative population of *Fibrobacter succinogenes* and *Ruminococcus flavefaciens* and total fungi were numerically increased in working elephants as compared to nonworking elephants (Kraimi et al 2019).

Regarding digestibility, Katole et al (2014) compared the digestive efficiency of six Asian semi captive elephants divided in one group performing the scheduled work at a park, i.e., 4-h safari with tourists, and other group of animals who did not performed work. They found that the former had better results, reflected in an apparently better digestive efficiency of crude protein, neutral detergent fiber, acid detergent fiber, hemicellulose, cellulose, and gross energy ($P < 0.01$). However, it is difficult to conclude that results would be similar for circus elephants.

2.1.4. Modification of consumption habits

There is a substantial difference between animals' consumption habits in the wild and the ones they adopt in captivity. Large felines consume great amounts of meat and viscera but also go for long periods without consuming food (Sunquist and Sunquist 2002). Tanzanian lions feed only every two and a half days (Kawata 2016). In circuses, in stark contrast, animals receive food six days a week with only one day of fasting (Kawata 2016), a practice that substantially modifies their food digestion pattern. Reduced housing space also alters the expression of alimentary behaviors in Bengal tigers (Veasey 2020), as observed in elephants. Studies of Asian elephants (*Elaphus maximus*) have determined that feeding, social, and cognitive behaviors are restricted in captivity (Veasey 2019). For example, the time that chained pachyderms spent seeking food, feeding, or drinking water was only 25% compared to 49% when their extremities were free (Gruber et al 2000). The maltreatment and dietary abuse are also seen as a training method where food deprivation (hunger) is used to tranquilize animals, so they obey orders, incentivized by anticipating rewards in the form of food (Wilson 2017).

2.2. Environment

2.2.1. Transport

During trips from city-to-city, a basic reality of traveling circuses (Nevill and Friend 2006), animals are usually kept in containers (Iossa et al 2009). This is deemed a stressor because of movement, vibration, and noise in the vehicle (Mota-Rojas et al 2016; Padalino and Riley 2020), food and water intake restrictions, and weather changes (Roadknight et al 2021). Padalino and Riley (2020) demonstrated this in horses transported by plane, as the probability of suffering fever when offloaded increased threefold. Toscano et al (2001) found that habituation to frequent travel can help reduce negative impacts on animal welfare, but if the animals do not become accustomed and suffer persistent chronic stress, then organic alterations can ensue (Marcondes Ávila et al 2020). Extreme meteorological conditions can severely impact elephants' health, so the recommendation is to maintain thermoneutral conditions during trips in line with the age and physiological state of the animal(s) (Toscano et al 2001). Pohlin et al (2021) reported that when key factors (temperature, duration, speed, loading density) are not controlled, travel can activate catabolic pathways, cause dehydration, fatigue, immunosuppression, sleep disorders (REM sleep phase), and alter patterns of circadian activity (Berger 2011).

One method for evaluating the effect that movement exerts on animals is to measure physiological parameters (heart rate, HR) and stress biomarkers, especially glucocorticoid levels. Studies of elephants have found high levels of these indicators during relocations, in reaction to loud noises, or while they participate in public activities (Bansiddhi et al 2020). Transporting elephants in dark cages with inadequate supplies of food or water, and housing them in tents unprotected from the sun, under unhygienic conditions, on concrete floors, and keeping them chained for many hours, are other conditions that increase the risk of injuries –and even death– (Bradshaw 2007).

Dembiec et al (2004) determined that the HR of five tigers (hybrid Bengal/Siberian and Bengal/Siberian/Corbetti) increased from 56.1 to 94.6 beats per minute (bpm) during transport and that cortisol concentration soared by up to 482%, and that pacing back-and-forth was prevalent. Another example in felines is the presence of stereotypies in two circus tigers (*Panthera tigris*) during transport of approximately 4.2-4.5 hours. In that study by Nevill and Friend (2003), keeping the animals in shelters where they were able to exercise and allowing them to participate in shows before trips reduced the incidence of pathological behaviors and increase resting behaviors. Some authors recommend applying tranquilizers and programming rest stops during trips (Teixeira et al 2007), but the use of drugs is only indicated under adequate medical supervision, and circuses may not always be able to schedule rest stops during long trips. Mammal species are not the only ones affected in this domain, a study with 23 turtles (*Testudo hermanni*) found that transport generated a stress response measured by elevated cortisol levels (+286%; $P < 0.001$) that did not return to baseline values until four weeks had passed (Fazio et al 2014).

2.2.2. Housing

Housing plays a fundamental role in the welfare of wild animals in captivity. The animals' capacity to exhibit their natural behaviors, as well as their physical and mental health, depends mainly on the dimensions of the enclosure (Bryan et al 2017). Some wild animal trainers argue that animals habituated to humans prefer their cages, based on the observation that they enter them voluntarily once used to confinement. They further sustain that species like lions and bears, which spend much of the day sleeping, do not suffer while living in cages if they are accustomed to them early (Wilson 2017). Others, however, insist that space is extremely important, especially for carnivores like large felines, and that handlers must provide enriched, high-quality environments if they wish to prevent behavioral and reproductive alterations (Bryan et al 2017; Veasey 2020).

Cages and similar types of confined housing for felines and nonhuman primates tend to measure around 26.3 ± 8.2% less than the average area recommended for zoos that provide open-air housing, while beast wagons provide, on average, 27.5 ± 4.2% less than the recommended space (Iossa et al 2009). Wild tigers inhabit broad territories that range from 7-1000 km^2 in extension, with a mean roaming area of over 160 km^2 (Tait and Farrell 2010). Even though large felines only spend an average of a quarter of an hour per day in activity (Nevill and Friend 2006), for carnivores, in general, reduced spaces are associated with stress and the development of stereotypies (like pacing). Breton and Barrot (2014) reported this on 38 tigers in captivity, where pacing correlated negatively with the size of the shelter. In contrast, Hitchens et al (2017) sustain those non-compliances regarding space (41.7%) and exercise requirements (38.5%) in captive animals are common, but these two factors alone cannot determine animals' directly positive or negative state. Shelters for circus elephants have usually roofed tents that measure around 126m^2, where they rest, bathe, and sleep, so they lack spaces designed specifically for each activity (Varma et al 2008). Sea lions are generally kept in indoor pools that measure around 12m^3 (for shelter in winter) or outdoor pools (summer) that measure 21m^3 (Sós et al 2013). These pools are considerably smaller than the requirements established for zoos.

Other elements that impact on the homeostasis in circus animals include thermal stress that affects their metabolism and immune system (Dorning et al 2016) and acoustic contamination that generates chronic stress with subsequent immunosuppression (Birnie-Gauvin et al 2017). Indirectly, restrictive housing conditions are also cause of problems in other centers, such as zoos, which often adopt animals from circuses, most of which arrive with pre-existing health problems and stereotypes due to captive conditions (Maple and Perdue 2013).

2.2.3. Physical health

Animals held in captivity can suffer health problems caused by physical and mental deterioration that rarely occur in the wild (Müller et al 2011; Mota-Rojas et al 2018). These may be due to the use of accessories, costumes during performances, or dangerous postures and movements that can generate irreversible damage to the musculoskeletal system. For example, it has been reported in young camels spinal column injuries (Khalaf 1999), or hernias and asphyxia in elephants forced to adopt a posture of sternal reclination that places excessive pressure on the diaphragm (West 2002; Dorning et al 2016).

Providing animals with adequate medical attention is another element often neglected in circuses. Hitchens et al (2017) evaluated conditions at 38 circuses in Sweden, detecting deficiencies in the care of animals' hooves, claws, and coats (9.1%), in their overall body condition (10.0%), and cleanliness (0%). Prolonged nulliparity is a common pathology that affects animals in captivity. In female elephants, this has been associated with stress, reproductive tumors, and cystic hyperplasia that can lead to reproductive aging and a gradual loss of fertility (Agnew et al 2004; Hermes et al 2004). Female African elephants are naturally polyestrous (oestrus cycle duration of 14-15 weeks); however, Allen (2006) reported that in captivity, elephants manifest an absence of the estrus cycle due to chronic stress, immunosuppression, and the development of stereotypies and leiomyomas.

Regarding infectious diseases, the offspring of captive Asian elephants (*Elephas maximus*) are susceptible to infections of acute hemorrhagic disease, which has a high mortality rate (65-80%). In this species (especially in 3-year-olds), herpesvirus causes intense pain in the trunk and can be an acute and fatal infection (Ossent et al 1990). Arthritis and laminitis caused by *Mycoplasma sp* (Clark et al 1980) are common afflictions in species with large body mass (e.g., bears, bovines, elephants, and gorillas) (Dawson et al 1923). Concerning parasites, Lukešová et al (2000) reported that a study of animals at 7 circuses in the Czech Republic found high incidences of *Giardia* (57.2%), *Trichuris* (85.7%), *Eimeria* (30.0%), *Toxocara canis* (42.9%), *Toxascaris leonina* (87.5%), and strongyles (33.3-66.7%) in species like macaques, doves, dogs, lions, and solipeds. *Trichuris ovis* has also been isolated in samples from goats, llamas, sheep, and musk oxen at circuses in Moscow (Pasechnik 2015). Dermatomycosis caused by *Microsporum gypseum* was reported in two California sea lions in conditions of low water quality, frequent travel, and constant temperature changes (Sós et al 2013). The close human-animal contact is also a risk factor for developing zoonosis, such as tuberculosis in Asian elephants (Michalak 1998; Mikota and Maslow 2011).

In elephants, foot diseases like cracked nails and foot rot are often diagnosed due to inappropriate substrates and the practice of chaining animals for long periods (20.8 hours/day) (Varma et al 2008). De Vries (2014) reported that African elephants (*Loxodonta africana*) used in tourism activities had a high prevalence of cutaneous and spinal lesions as a result of being chained up and inadequate handling (24% and 10%, respectively).

2.3. Behavior

In nature, the coexistence of prey and predators contributes to the development of a broad repertory of behaviors that help maintain the biological diversity of species (Dias et al 2019). In contrast to operant conditioning applied in zoos –a technique that reinforces human-animal relationship and promotes natural behaviors–, circus training focused on performance directly affects animals' behavior and emotional states (English et al 2014; Keulartz 2016).

2.3.1. Social behavior

In circuses social interaction tends to be limited in all species (Mota-Rojas et al 2016; Mota-Rojas et al 2018; Mota-Rojas et al 2020). Orangutans, gibbons, and macaques are separated from their congeners in early infancy to initiate training (Agoramoorthy and Hsu 2005). This social isolation affects their ability to relate to congeners and perform activities with important functions for their health and hygiene, such as grooming (Crailsheim et al 2020). A similar situation occurs with lions, as pups are separated from their mothers just 3-4 days after birth and raised as if they were pet puppies. The training to perform behaviors that do not form part of their natural repertory can cause anxiety and frustration that can be manifested in aggression towards handlers (Wilson 2017; Mota-Rojas et al 2018). The training method used with young elephants in Thailand also begins with separation from their mothers after 3-4 days. Being isolated from the herd inside a room with food deprivation and physical abuse inculcate obedience (Kontogeorgopoulos 2009). Raising the offspring of some species may generate habituation, but in others it increases animals' fear of humans and can trigger aberrant behaviors (Carlstead 2009). In the case of chimpanzees, they exhibit agonistic behaviors more often when housed under conditions of high social density (Kranendonk and Schippers 2014).

2.3.2. Reassignment of the behavioral budget

Since 80% of the lifetimes of circus animals transpire in confinement and only 1-9% is spent performing (Iossa et al 2009), the behavioral budget and telos of these animals are modified, the latter quite directly. Aristotle's term telos refers to the quality of life as a function of species-specific characteristics: an animal's innate nature (Harfeld 2012). In animals under human care, this imposes an obligation to ensure ethical handling and planning following the telos of each species (Spencer et al 2006). The goal should be to mold the environment to the animal, not *vice versa* (Rollin 2014). Harfeld (2012) mentions that boredom (animals that are not offered options among which to choose) and loneliness (in individuals of social species isolated in shelters) are two examples of conditions that can interfere with a species' telos. Emotions like frustration and boredom have been related to conditions like insufficient space to perform natural physical activities with such consequences as poor body condition, excessive growth of hooves, loss of muscle mass, and obesity (Browning and Veit 2021; Mota-Rojas et al 2021). This has been documented in Sumatran elephants (*Elephas maximus sumatranus*) in the northern regions of that country and in the provinces of Aceh and Lampung in Indonesia. In all those places, elephants show stereotypies (weaving) that reflect stress and boredom due to the absence of social interaction (Stremme et al 2007). In contrast, Hart and Sundar (2015) observed that involving the elephants in activities with humans and arranging a fixed, daily routine helped improve their physical and mental welfare.

The circus environment also alters behaviors in tigers, a species that in the wild sleeps for around 18 h a day with only short bursts of activity around dawn (Nevill and Friend 2006). The lack of mental stimulation that characterizes their life in captivity makes them prone to develop stereotypies like pacing, associated with frustration due to a lack of locomotor activity that participation in shows or short periods of exercise cannot compensate (Mota-Rojas et al 2016; Mota-Rojas et al 2018). In this regard, Nevill and Friend (2006) determined that giving tigers an exercise corral with a diameter of 9.14 m allows them to walk between 124.6 ± 21.6 m and 219.5 ± 79.7 m, depending on the time of activity (0, 20, and 40 minutes). Although that increase in the level of physical activity favored the tigers' health, the authors did not find a significant reduction in the presentation of pacing, which was observed during 83% of the periods measured.

In primates, the regular presence of unknown people (human visitors) and the conditions of reduced spaces are stressors that often alter affiliative behaviors like grooming or predispose the animals to manifest aggression to their congeners or humans (Hosey 2004). A study by Browning and Veit (2021) found that some animals prefer a predictable environment with routine activities in unchanged surroundings. This suggests that some species of wild fauna can adapt to a provided environment.

2.3.3. Modification of predatory behavior

Predatory behavior allows animals to obtain nutrients and sources of energy (Coria-Avil et al., 2022). In the wild, the environment influences this behavior, as an individual animal's success depends on its ability and prey availability. Leopards (*Panthera pardus*) are examples of a species that modified its predatory activity from nocturnal to diurnal (Dias et al 2019). Urbanization and anthropogenic activities impact ecosystems, affecting the alimentary and hunting behaviors of wild animals held in captivity that do not inhabit enriched environments where they could express these natural behaviors (Fleming and Bateman 2018). Under these conditions, their organisms may respond to biological deficiencies through cerebral GABAergic pathways that modify their behavior (Cai et al 2020).

2.3.4. Learned behaviors and training

Training animals for shows is controversial because they are forced to perform unnatural behaviors and adopt unnatural postures. Schmitt (2020), however, argues that training for circus acts only entails modifying certain natural behaviors and then reinforcing them through repetition, as in the case of elephants that in the wild sit, play, and roll tree trunks to reach food. He further sustains that those trained behaviors actually improve elephants' health and prevent boredom (Moore and Doyle 1986). The association of the different methods of training to the physical and mental health of animals comes from the participation of neurotransmitters and neural changes during the training sessions, particularly dopamine (Wise 2008). When animals are trained using positive reinforcement, this activates several brain centers and the dopamine reward system to learn the association between a desired behavior and a reward (Figure 2).

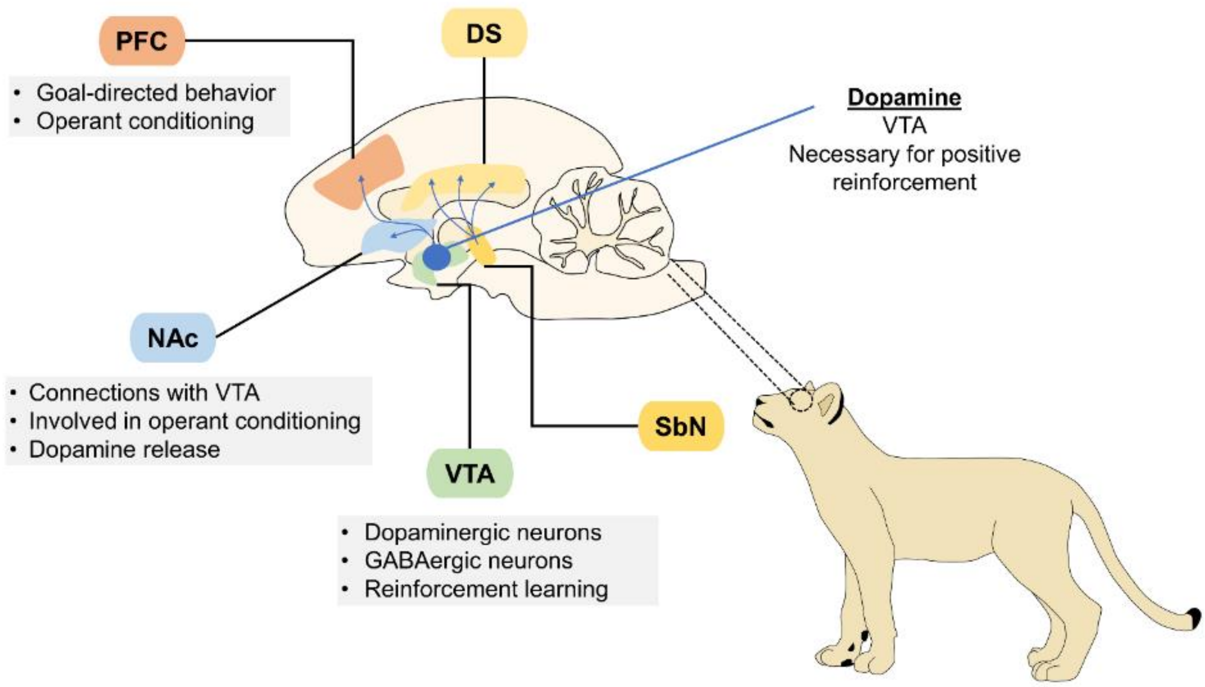

Figure 2 The main brain structures involved in different training methods, and dopamine's role in positive reinforcement. The dopaminergic reward system is a main pathway through which animals can be trained by means of positive reinforcement, operant conditioning, and goal-directed behaviors. Dopamine neurons in the VTA and SbN have connections to several regions in the limbic system (represented above as NAc, PFC, and DS). When an unexpected reward or a reward-predicted stimulus is presented to the animal, the learning association between the compensation and the desired behavior is reinforced and helps train it to perform specific behaviors through positive reinforcement. DS: dorsal striatum; VTA: ventral tegmental area; NAc: nucleus accumbens; PFC: prefrontal cortex; SbN: substantia nigra (Taber et al 2012; Mota-Rojas et al 2016).

Preferably, the reinforced behaviors must be those that are part of the natural behavioral repertoire of animals. In nonhuman primates (gibbons, pig-tailed macaques), innate behaviors like brachiation (swinging from tree to tree using only their arms), swimming, underwater diving, and picking coconuts from palm trees are all part of training routines for shows. Nonetheless, performing magic tricks, dancing, roller-skating, boxing, playing golf, or riding a bicycle do not pertain to their telos but, rather, produce a re-directioning of the species' typical social behaviors (Agoramoorthy and Hsu 2005).

Training animals for circuses also raises whether this is accomplished through pure teaching or by conditioning them to fear (Mota-Rojas et al 2016). Tiplady (2013) affirms that charming snake spectacles where cobras "dance" to the rhythm of music is a fear and defense response developed during training based on abuse. A similar issue in India involves dancing bears. In that case, cubs are separated from their mothers at four weeks of age. The cub's canine teeth are extracted, and their snouts pierced without anesthesia as part of their training. These procedures run contrary to the bases of operant conditioning or motivation-based responses, which are a systematic and biological process that require the activation of several neural circuits to produce a reinforced learning or goal-directed response where the animal, without aversive stimuli, learns to repeat certain behaviors (Kim 2013). Contrarily, as in the case of the aforementioned bear cub, when a behavior is learned through fear conditioning, this causes physiological and endocrine alterations that may be harmful in the long term (Sørensen et al 2020) (Figure 3).

Some authors have discussed the subjectivity of judgments of circus spectacles as negative practices because animals are forced to perform unnatural behaviors, citing the fact that assistance animals (for people with visual or motor impediments, for example) are also subjected to rigorous training (Kiley-Worthington 2016). Literature on this topic shows that restricting species' biological needs has repercussions for their behavior and mental state.

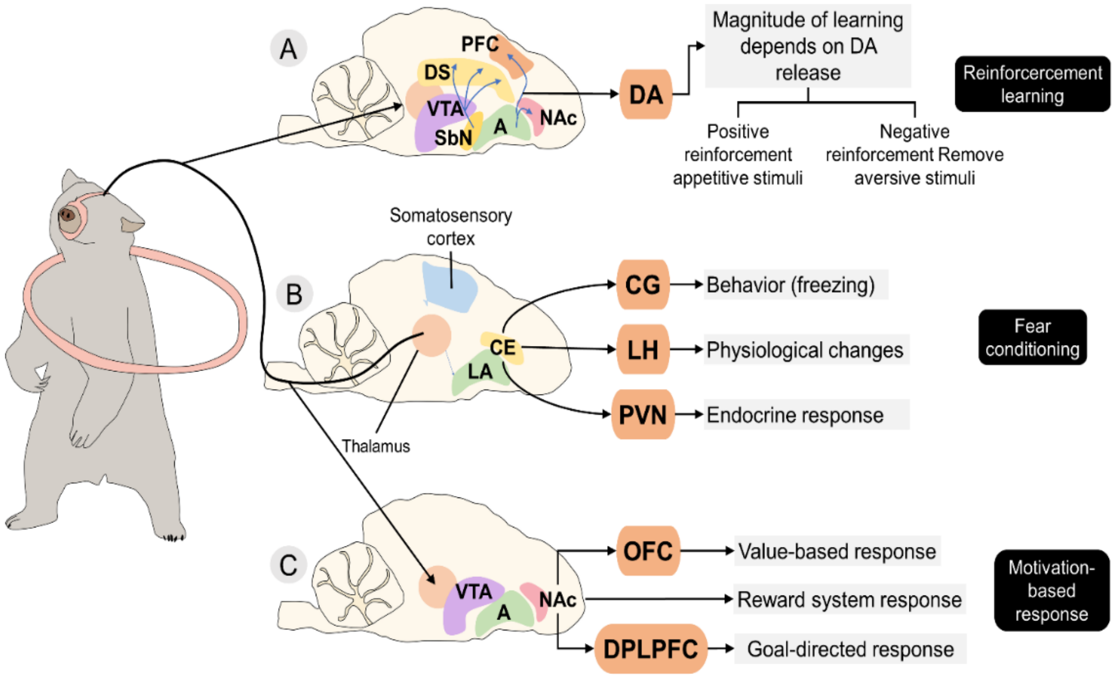

Figure 3 Neural circuits activated during motivation, reward, and fear conditioning. A. DA is associated with learning through reinforcement and the reward system. This neurotransmitter sends signals to distinct regions of the limbic system. VTA and A neurons have further connections to the NAc and PFC. Stimuli reach the DG through dopaminergic neurons in the SbN. The interaction between a certain stimulus and this neuroendocrine response leads to associative learning between the stimulus and the desired behavior. B. During fear conditioning, stimuli activate neurons in the LA upon being signaled by the thalamus and somatosensory cortex. This information is transmitted to the CE and other structures –CG, LH, PVN– that mediate fear-conditioned behavior and animals' physiological and neuroendocrine responses. C. DA plays an important role in motivation-based behaviors. These combine responses such as value-based, goal-directed, and reward-based effects, depending on the site of action of the dopaminergic neurons (OFC, NAcc, and DPLPFC, respectively). A: amygdala; CE: central nucleus of the amygdala; CG: central gray; DA: dopamine; DPLPFC: dorsolateral prefrontal cortex; DS: dorsal striatum; LA: lateral amygdala; LH: lateral hypothalamus; NAc: nucleus accumbens; OFC: orbitofrontal cortex; PFC: prefrontal cortex; PVN: paraventricular nucleus; SbN: substantia nigra; VTA: ventral tegmental area (Medina et al 2002; Kim 2013, Mota-Rojas et al 2016).

2.4. Mental or affective state domain

2.4.1. Altered mental alteration

Mental alterations in animals in captivity are associated with social isolation and austere housing conditions (Lyons et al 1997; Krawczel et al 2005, Mota-Rojas et al 2016; Mota-Rojas et al 2020). The practice of picketing elephants (*i.e.*, chaining one forelimb and one hindlimb diagonally with cables or parallel chains) restricts their movement and while allowing them to interact with nearby congeners, is associated with a high prevalence of stereotypies (Friend and Parker 1999), such as swinging the body or head (Gruber et al 2000). In contrast, a study demonstrated that when 9 female Asian elephants (*Elephas maximus*) were exhibited in open-air circus corrals (52m^2 per animal), the incidence of stereotypies like swinging the body or head and shaking the trunk decreased (P = 0.019), especially the latter form (P < 0.001) (Friend and Parker 1999).

In contrast to the negative effect just described, Hopster and De Jong (2014) reported that South American (*Otaria flavescens*) and Californian (*Zalophus californianus*) sea lions show anticipatory behaviors before performances. Experts sustain that those behaviors translate into feelings of happiness since anticipation is an element of the pleasure cycle and reflects positive emotional states (Berridge and Kringelbach 2015). However, during a rehabilitation program, 15 in-training chimpanzees (*Pan troglodytes*) studied by Llorente et al (2015) manifested pathological behaviors like hyper-aggression, social phobia, and locomotion stereotypies, coprophagia, over-grooming, vocalizations, and an absence of social abilities. Keeping the animals in adequate housing (naturalized, 5640m^2 in size that allowed them to develop species-specific behaviors) reduced stereotypies and promoted positive behaviors.

2.4.2. Reactivity

The high frequency of aggressive behaviors in circus animals is related to social hierarchies, increased glucocorticoid levels (Ibáñez et al 2013), and reduced spaces that, in elephants, induce hyper-aggression, depression, self-mutilation, and stereotypies (Varma et al 2008). The Psittacidae are other species prone to developing hyper-aggressiveness and exaggerated fear responses under conditions of inadequate environmental enrichment due to their natural neophobia of unknown objects, surroundings, and people (Meehan and Mench 2006).

2.4.3. Anxiety

The time spent performing (Krawczel et al 2005), psychological maltreatment, and the manifestation of unnatural behaviors (Carmeli 2002) can all trigger a stress response that affects the mental state of circus animals. Examples of this areIn large felines forced to leap through rings of fire, elephants that perform acrobatics, or nonhuman primates that dance or ride bicycles (Agoramoorthy and Hsu 2005). Krawczel et al (2005) found that 54.33% of the tigers they studied paced for 1 or 2 hours before acting (Kawata 2016), while 15 hours after performances, they spent more time resting (84.9 ± 3.9 %; 85.2 ± 3.7%) than pacing (10.2 ±2.4%; 11.3±1.3%). The lighting and sounds of the audience con lead to the development of gastroenteritis in tigers and trigger escape or flight behaviors in bears and wild ungulates (Iossa et al 2009). A study of 39 rhesus macaques (*Macaca mulatta*) in captivity at Oregon's National Primate Research Center (Gottlieb et al 2013) showed that establishing fixed times for specific procedures helped reduce stress and motor stereotypies related to displacement. However, on the topic of circus elephants, some authors sustain that exposure to diverse novel stimuli (the stage) constitutes environmental enrichment, prevents boredom, and facilitates medical attention due to habituation to handlers (Schmitt 2020). Environmental enrichment has indeed been shown to reduce incidences of anxiety, even in snakes (*Pantheorophis guttatus*) (Hoehfurtner et al 2021).

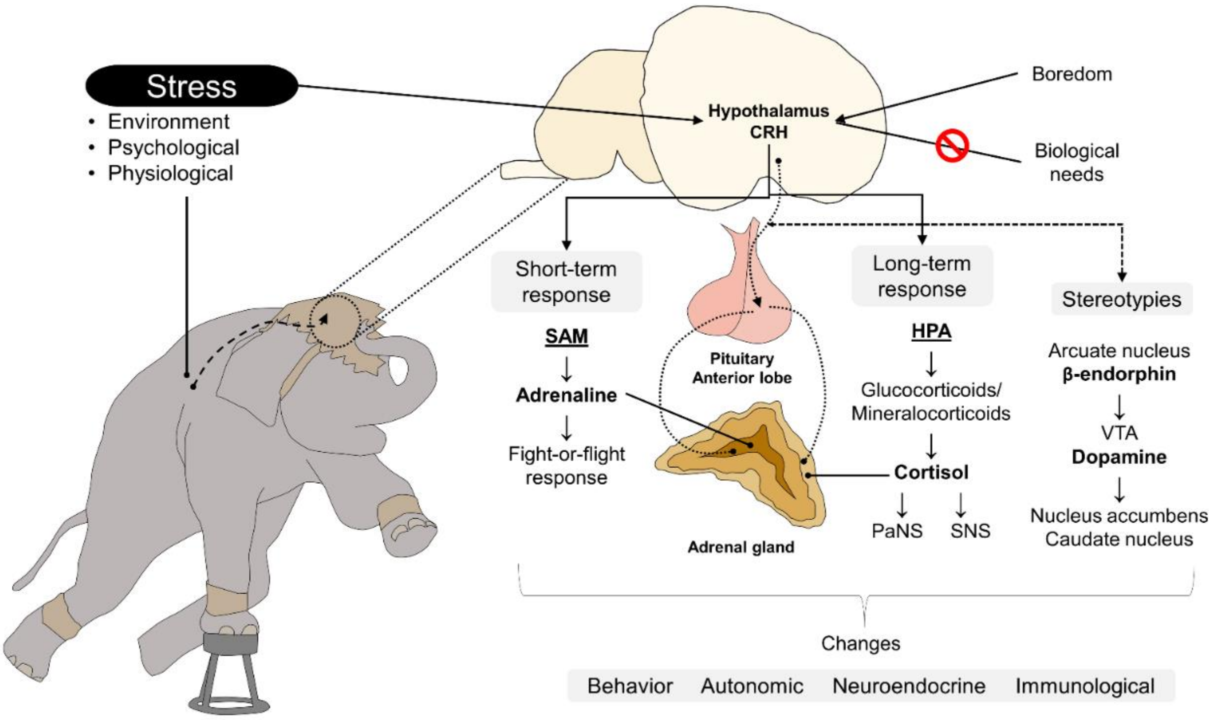

Figure 4 Neurobiology of stress and stereotypies in circus animals. Environmental, psychological, and physiological stressors are factors recognized by brain structures that activate the SAM and HPA, responsible for behavioral, neuroendocrinal, and immunological changes. Short-term responses are mediated by the SAM, which releases adrenaline to trigger the fight-flight response. Long-term responses are initiated by the HPA, beginning with the secretion of CRH and its subsequent action on the pituitary and adrenal glands for the secretion of glucocorticoids (cortisol) and mineralocorticoids. The development of stereotypies is also associated with the action of HPA, cortisol, a predominant sympathetic tone, and the presence of endogenous opioids (β-endorphin), since they modulate responses through the arcuate nucleus-VTA-nucleus accumbens pathway. This system can be activated either by the action of CRH or independently. CRH: corticotropin-releasing hormone; HPA: hypothalamic-pituitary-adrenal axis; SAM: sympathetic-adrenal-medullary axis; VTA: ventral tegmental area. SAM: sympathetic adrenal medullary axis; SNS: the sympathetic nervous system; HPA: hypothalamic-pituitary-adrenal axis; PaNS: parasympathetic nervous system (Manteuffel 2002; Williams and Randle 2017).

2.4.4. Stereotypies

Stereotypies are associated with restrictions on space, changes in alimentation, and the loss of social structures, all of which can trigger excitation, conflict, and frustration as animals seek to cope with stress (Krawczel et al 2005; Nevill and Friend 2006; Mota-Rojas et al 2016; Mota-Rojas et al 2018). Stereotypies in elephants are associated with being chained up, inadequate housing, and social isolation because in the wild, they traverse large distances accompanied by members of their herd (Bansiddhi et al 2020). Reports on this species revealed that 23 of 31 observed animals (74.2%) presented some stereotypy (repeated trunk swings) (Varma et al 2008). Bansiddhi et al (2020) mention that stereotypies may function as a way to release stress, secrete neuropeptides, and improve blood flow from the extremities to the heart. It is known that when environmental, psychological, or physiological factors cause a stress response in animals, the central nervous system activates different pathways to cope with the stressor (Manteuffel 2002). Apart from the short- and long-term response, mediated by catecholamines or glucocorticoids, respectively, is suggested that stereotypies secrete endorphins and dopamine to aid in the control of the physiological changes caused by stress (Figure 4).

Table 1 summarizes some studies relevant to the critical points for the welfare of circus animals, using the five domains proposed by the WAZA.

Table 1 Critical points within the five domains to assess welfare in circus animals.

Domain	Factor	Effect	Affected species	References
Physical Functional	Nutrition	Foods with different sensory characteristics	All species	Ibañez et al (2013)
		Nutrient deficiencies	Lion	Kawata (2016)
		Lack of variety of food in the diet	Bengal tiger Elephant	Karmacharya et al (2019) De et al (2019) Friend and Parker (1999)
		Alteration of the intestinal microbiota	Tiger, lion	Karmacharya et al (2019)
		Modification in consumption habits	Lion	Kawata (2016)
	Environment Transport	Limited travel container space	All species	Iossa et al (2009)
		Stressors: driving, environmental and vehicle conditions	All species	Iossa et al (2009)
		Transport-derived diseases	Horse	Padalino and Riley (2020)
	Environment Enclosure	Reduced spaces	Big cats Nonhuman primates	Bryan et al (2017) Iossa et al (2009)
		Pens with insufficient spaces to exercise	Tiger	Nevill and Friend (2006)
	Health	Deficient care of hooves/claws, coat, and body condition	All species	Hitchens et al (2017)
		Lack of cleanliness	All species	Friend and Parker (1999)
		Infectious diseases	All species	Clark et al (1980) Dawson (1923) Michalak (1998) Mikota and Maslow (2011) Ossent et al (1990)
		Reproductive problems	Elephant	Agnew et al (2004) Hermes et al (2004)
	Behavior	Decreased interaction with conspecifics	Nonhuman primates	Agoramoorthy and Hsu (2005)
		Behavioral budget reallocation	All species	Iossa et al (2009) Nevill and Friend (2006)
		Alteration of predatory behavior	Leopard	Dias et al (2019)
Mental / Affective state	Movement restriction	Mental alteration	Tiger Elephant	Nevill and Friend (2006) Lyons et al (1997) Krawczel et al (2005) Friend and Parker (1999) Gruber et al (2000)
	Rearrangement of social structure	Behavioral reactivity	All species	Ibañez et al (2013)
		Anxiety	Big cats, elephant, Nonhuman primates	Krawczel et al (2005) Carmeli (2002) Agoramoorthy and Hsu (2005) Kawata (2016) Iossa et al (2009)
		Stereotypes	Big cats and elephants	Nevill and Friend (2006) Krawczel et al (2005)

In light of the panorama described above, it is important to consider the position sustained by Dr. Marthe Kiley-Worthington (1995), who seeks to explain the irrationality of postures that oppose circuses, zoos, stables, horse races, and dog-breeding operations based on arguments that emphasize animal suffering. In several world areas, this perspective has resulted in prohibitions on the use of fauna in training because it generates problems of animal welfare and significant logistical issues due to the need to coordinate the care of affected animals in rehabilitation centers or zoos (Gupta and Chakraborty 2005). On the one hand, Carmelli (1997) affirms that circuses –in contrast to the "beast houses" of earlier times– do not exhibit animals to watch them fight. Unlike zoos, circuses isolate and decontextualize animals by forcing them to perform behaviors that are not part of their natural repertory (Mota-Rojas et al 2016; Mota-Rojas et al 2018). Kiley-Worthington (1995) finds no significant differences between the cruelty and physical maltreatment to which circus animals are exposed and the conditions of animals employed in production systems. In both contexts, animals manifest behavioral disorders and suffer stress and health problems derived from occupational boredom.

3. Final considerations

The welfare of circus animals is associated with allowing freedom of movement, offering diverse foods that satisfy their nutritional and energy requirements, allowing them to perform natural behaviors, and providing adequate housing following species-specific characteristics. However, observations of circuses often identify alterations in some of the five domains proposed for evaluating the welfare of wild fauna. Nutritional deficiencies, incidences of lesions and pathologies, and the presentation of stereotypies are all results of the stress to which circus animals are routinely exposed.

Scientific evidence has identified problems related to these centers and generated proposals for improving animal welfare. In countries where circus animals are not banned is essential to raise awareness in the society and among the stakeholders that having wildlife in captivity requires to comply with certain biological needs regarding enclosure, nutrition, health, and mental state. This can be achieved with the advice of veterinarians, ethologists, biologists, and animal welfare experts that can provide minimal recommendations for each species. However, because the amount of scientific information on the specific case of circus animals is still scarce, the legal prohibitions implemented in various countries do not necessarily have solid scientific foundations. Therefore, additional studies and comparisons are required to reach an objective understanding of the mental states of animal species destined to perform in circus acts.

Conflict of Interest

The authors declare that there is no conflict of interest with this work.

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