Cognitive Enrichment Intervention for Captive Orcas

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Cognitive Enrichment Intervention for Captive Killer Whales

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Abstract

The goal of the present proposal was to design a cognitive enrichment program to reduce stereotypy and physiological signs of stress in captive orcas (*Orcinus orca*). This intervention consists of an object discrimination and retrieval task, and was designed to simulate orcas' behavioral need of hunting. Seaworld's three parks were used as locations for each of the group conditions: the Intervention Group, the Increased Training Group, and the Control Group. The hypothesized results demonstrate that the Intervention Group will show the smallest amount of stereotypic behavior at each interval of the experiment and that stereotypic behavior has a strong, positive correlation with blood serum cortisol levels, a physiological measure of stress.

"The orca brain just screams out intelligence and awareness. We took this tremendous brain and we put in a Magnetic Resonance Imaging scanner, what we found is just astounding. […] It's becoming clear that dolphins and whales have a sense of self, a sense of social bonding that they've taken to another level much stronger, much more complex than other mammals, including humans."

Lori Marino, PhD

The people who study and spend time with orcas, more commonly known as killer whales, often argue that they are not quite like any other animal. They describe the awe they feel when a six-foot tall dorsal fin emerges from the waves, the adrenaline rush of witnessing their speed and power as they hunt, and the distinct sense of mutual curiosity when staring into their uncannily human-like eyes. According to these individuals, an orca's gaze is not a blank one. They can see the orca regarding them, not with suspicion or fear, but with an inquisitive interest.

Orcas and humans share a number of distinguishing features, despite the vast physiological and environmental differences between our two species. Like humans, orcas are highly intelligent, live in tight-knit familial groups, engage in play, and pass down group-specific traditions from generation to generation. Orcas use tools and innovative hunting strategies to capture prey, their vocalizations resemble languages with dialects that vary from group to group, and the bond between females and their calves is so strong that mourning mothers are often observed carrying the decomposing body of their young for weeks. In other words, orcas are highly intelligent, social, and emotional animals, and, as I will argue, may be inadequately stimulated in captivity.

The topic of orca captivity has been controversial since the first orca was captured in 1961, leading many to question the ethicality of keeping intelligent and wide-ranging predators in small tanks. Even Seaworld, the popular American marine theme park that is celebrated for having the most well-equipped orca facilities, has recently come under scrutiny in the media. One of the most striking differences between captive orcas and their wild counterparts is their behavior. Just as with many species that are poorly adapted to life in captivity, captive orcas routinely exhibit abnormal and repetitive behavior, referred to as "stereotypic behavior." These behaviors can be deleterious for orcas' health, and may contribute to premature deaths in captivity.

The most effective method for reducing these behaviors is enrichment, the practice of adding sensory stimuli or choices into a captive environment in order to make it more naturalistic. In the present paper, I am proposing a novel enrichment intervention that will simulate one of orcas' most important behavioral needs: hunting.

Orca Intelligence

Taxonomy and evolution.

Contrary to popular belief, orcas are not just whales, but rather the largest members of the dolphin family (*Delphinidae*). Just as with other dolphins, orcas belong to the order *Cetacea*, which includes all dolphins, porpoises, and whales, and are referred to as cetaceans.

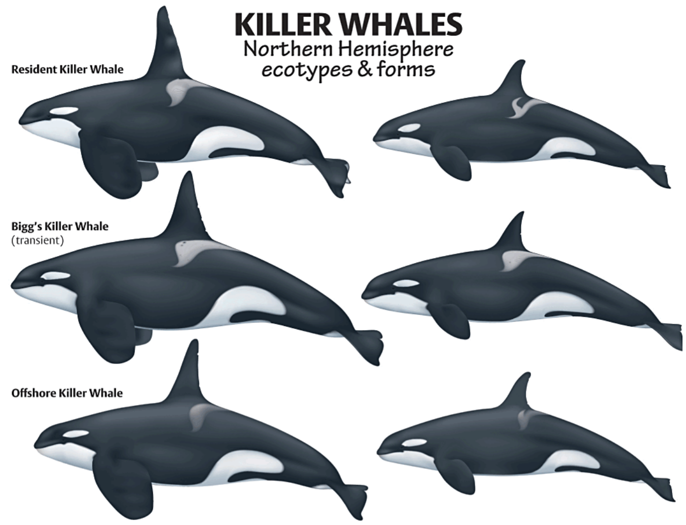

Figure 1.1: Diagram demonstrating the anatomical ecotype and sex differences.

Orcas are found in all oceans, and have a remarkable level of variation between groups. Genetic and behavioral differences between different ecotypes of orca are distinct enough that many propose that they belong to separate species (Pittman & Ensor, 2003). For instance, orcas residing in the coastal waters of British Colombia and Washington state have been divided into three distinct groups (ecotypes): residents, transients, and offshores (see Figure 1.1). Resident orcas live in tight-knit familial groups, feed mainly on fish, and visit the same areas consistently. Transient orcas feed on mammals and travel widely in small groups of two through six individuals. Offshores feed on fish, marine mammals, and sharks, and travel in large groups with up to 200 members. These three subgroups are genetically distinct, have differing anatomical and behavioral features, and rarely interact with one another (Baird, 2000).

Though many populations around the world are thriving, the famous and most well-studied populations of orcas, the Northern and Southern Residents, are considered Threatened and Endangered respectively. Threats to their survival include depletion of their primary food source (Chinook salmon) through overfishing and damming, sound pollution from private commercial and whale watching vessels, and exposure to toxicants such as PCB, PBDE, and DDT, which are stored in orcas' fat (Ayres et al., 2012). For this reason, conservation efforts, further research, and encouraging repopulation are incredibly important to maintaining and bolstering their dwindling numbers.

Neuroanatomy.

Figure 1.2: Photo of orca and human brains.

Cetaceans have the second largest brain to body size ratio after humans (Marino, 1998), though this brain is distinguished by a number of unique features (see Figure 1.2). According to Morgane et al., “the lobular formations in the dolphin brain are organized in a pattern fundamentally different from that seen in the brains of primates and carnivores.” (1980). Cetaceans deviated from their closest ancestor to primates over 95 million years ago (Gingerich & Uhen, 1998, as cited by Marino et al., 2007). Due to this unique evolutionary history, the cetacean brain is characterized by an interesting blend of early mammalian and unique anatomical features. For instance, a Magnetic Resonance Imaging (MRI) examination of an orca brain showed increased convolution and size of the cerebral hemispheres compared to other dolphins, and extremely well developed limbic lobes and insular cortex compared to primates (Marino et al., 2004).

Despite the striking differences between the brains cetaceans and primates, it would appear that cetaceans are capable of performing a similar repertoire of high-level cognitive tasks. Cetaceans and primates share a number of neuroanatomical features, including expanded insular and cingulate cortices associated with high-level cognitive functions (Allman, Watson, Tetreault, & Hakeem, 2005, as cited by Marino et al., 2007), and a large number of large layer V spindle neurons in the anterior insular and anterior cingulate cortex that are generally regarded as being responsible for aspects of social cognition (Hof & Van der Gucht, 2007; Allman et al., 2005, as cited by Marino et al., 2007).

One explanation for these findings is that, despite following different neuroanatomical paths, similar societal demands led to the emergence of similar cognitive abilities in cetaceans and primates. For instance, just as with primates, cetaceans have evolved to live within complex societies. Group living of this sort requires communication and collaboration between individuals, and can result in competition between members. These variables necessitate high-level cognition involved with recognition of others, knowledge of relationships, and ability to adapt to ever-changing social and ecological context shifts (Conner, 2007).

Mirror Self-Recognition.

One example of orcas' complex cognitive capabilities is their self-awareness. The mirror self-recognition test is a commonly used psychological paradigm that examines the subject's ability to recognize its own reflection. It has been suggested that animals capable of recognizing their own reflection may have a conscious understanding of their existence and the ability to monitor their mental states (Anderson 1984; Griffin 1991, as cited by Delfour and Marten 2001). Successful completion of the mirror self-recognition test is rare in non-human animals, and is often considered a marker for advanced intelligence. For instance, only great apes, bottlenose dolphins, and orcas have reliably demonstrated the ability to recognize their mirror image, and humans gain this ability at the age of 18 months (Gallup, 1970; Povinelli, Rulf, Landau, & Bierschwale, 1993; Miles, 1994; Walraven, Van Elsacker, &Verheyen 1995; Patterson & Cohn, 1994; Reiss & Marino, 2000).

In one study, researchers discretely marked four orcas with odorless colored antiseptic cream on their rostrum (the "nose" area of the face) and gave them the opportunity to examine themselves in a window that had been converted into a one-way mirror. After being marked, the orcas were observed moving body parts and simultaneously looking at the mirror to see if the same activity was occurring (contingency checks). One orca, after observing herself in the mirror, went to the side of the tank, rubbed her marked rostrum against the wall, and returned to the mirror to inspect herself. She repeated this behavior three times, each time with less ointment on her rostrum (Delfour & Marten, 2001). These behaviors are consistent with successful completion of the mirror self-recognition test, and demonstrate that orcas may have a sense of self-awareness.

Sociality.

As stated previously, orcas are highly social and live in tight-knit familial groups. Long-term photo identification studies have reported that Southern and Northern Resident orcas live in matrifocal groups called matrilines that remain stable over time. Members of a matriline include a dominant female and her offspring, and both males and females of this population remain with their natal matriline for life (Bigg, Olesiuk, Ellis, Ford, & Balcomb, 1990).

The post-reproductive lifespan of matriarchs may be the longest of all mammals, including humans, and some data has shown support for the attentive mother and helpful grandmother hypotheses. These hypotheses are adaptive explanations for the seemingly maladaptive trait of menopause, and posit that post-reproductive females continue to play an important role for their offspring. While the evidence supporting these hypotheses is limited due to difficulty obtaining comprehensive datasets, some evidence suggests that the infant calves born to mothers directly prior to menopause have higher survival rates than those with younger mothers, and that having a living grandmother increases the likelihood of calf survival between the ages of two and three (Ward, Parsons, Holmes, Balcomb, & Ford 2009).

Additionally, a recent study on the role of post-menopausal orcas suggested that older females act as repositories of knowledge that aid their groups in times of environmental hardship. Evidence such as females generally leading collective movement during salmon hunts, post-reproductive female leadership being "especially prominent" in years when salmon abundance is low, and the fact that females more commonly lead their sons than their daughters, is said to demonstrate that females "boost the fitness of their kin through the transfer of ecological knowledge." (Brent et al., 2015). In other words, females increase the chances of group survival by utilizing their years of knowledge and experience.

While Northern and Southern Resident orcas preferentially associate with close genetic relatives within their matriline, they are also known to associate regularly with members of their pod, a large and often related collection of matrilines (see Figure 1.3). These social units are relatively stable over time, despite the numerous disadvantages of group living, such as increased competition, aggression, parasitism and disease transfer (Parsons, Balcomb, Ford, & Durban, 2009). However, it has been suggested that the risks of living in these stable groups are outweighed by benefits such as group vigilance, cooperative care of offspring, and social foraging, which can play an important role in maintaining large groups of this sort (Hamilton 1964; Maynard Smith, 1964; Giraldeau & Caraco 1993; Ross 2001).

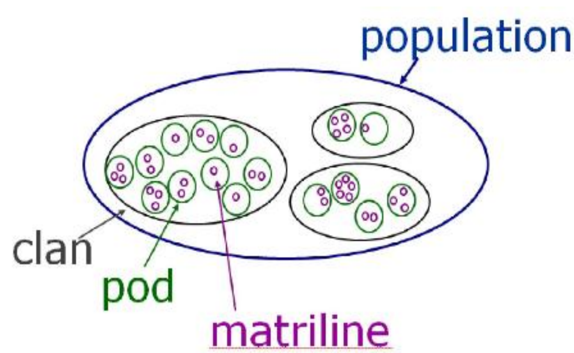

Figure 1.3: Diagram of orca social units.

Cooperative hunting behaviors.

Cooperative hunting is generally observed in social mammalian carnivores that live in groups (MacDonald, 1983). For this reason, it follows that orcas' intensely social nature serves as an important asset when hunting. As stated earlier, orcas are apex predators, which means that they are at the top of their ecosystem's food chain without any natural predators. Their hunting prowess is attributable not only to their size, strength, and speed, but also to their innovative cooperative hunting strategies.

Orcas' dietary habits vary depending on their geographic location and group membership. Different populations of orcas appear to specialize in the particular species for which they have developed complex foraging strategies, and unfamiliar prey are generally ignored (Ford et al., 1998). These strategies are almost ritualistic in nature, and are passed down from generation to generation (Visser, 1999; Lopez & Lopez, 1984). In this way, hunting can be considered an integral part of orca culture, with different populations continually recycling their group's hunting "traditions."

Manta ray tonic immobilization.

One example of cooperative hunting traditions is New Zealand orcas' preference for feeding on stingrays. Orcas worldwide are rarely observed feeding on elasmobranchs (sharks, skates, and rays), but research has suggested that stingrays play an important role in New Zealand orcas' diet despite the dangers posed by the rays' venomous spines. New Zealand orcas use specific cooperative strategies to combat these risks, such as capturing the ray by its tail while a second orca takes the head, or pinning the ray on the ground while another removes the stinger with its teeth (see Figure 1.4).

An observational study examining this behavior reported that 60% of captured rays were shared between whales in a show of cooperative feeding. Consistent with observations of orca hunts in unrelated populations, calves accompanied adults but did not participate (Visser, 1999). This observation lends support to the notion that adults are teaching calves these specialized hunting behaviors, and, furthermore, that these behaviors constitute an important form of culture.

Figure 1.4: New Zealand orca catching a sting ray with its teeth.

Intentional stranding.

Another complex cooperative hunting behavior is intentional stranding. Orcas are seasonally observed hunting in the coastal waters of Punte Norte, Argentina during the birthing months of elephant seals and sea lions. One observational study reported that orcas used the strategy of intentionally stranding themselves in 64.3% of their hunting attempts. This behavior consists of an orca swimming towards the shore and directing itself towards the prey. On some of occasions, other orcas cooperatively swam behind the beaching orca on either side, likely as a method of preventing prey from escaping in each direction. At the opportune moment, the beaching orca would surf a wave onto the shallow shoreline and capture a seal (see Figure 1.5).

None of the whales observed in this study were stranded permanently, demonstrating their ability to perform this behavior expertly despite risks, and 34.4% of their attempts ended with the successful capture of a seal.

Similar to New Zealand calves accompanying adults on hunts, on several occasions both an adult and a juvenile were observed stranding themselves in unison. The adult would fling a seal pup in the direction of the juvenile, who captured it in its mouth. The authors suggest that during these attempts, the adult was teaching the juvenile this hunting strategy (Lopez & Lopez, 1984).

Figure 1.5: Orca intentionally stranding itself in order to capture a seal.

Wave washing.

A third, and perhaps most striking, example of cooperative hunting behavior is wave washing, a strategy for Antarctic orcas hunting seals on ice floes. This behavior begins with a group of five to seven orcas cooperatively chipping away at the sides of the floating ice, reducing the diameter of the seal's refuge and making escape impossible. Additionally, the group often

Figure 1.6: Antarctic orcas wave washing a seal on an ice floe.

moves the ice into open water, away from adjacent ice floes or debris, in order to increase the likelihood of capture.

Once the floe is reduced to a sufficient size, the orcas retreat to a distance of roughly 15 meters then simultaneously swim at full speed towards the ice. At the last moment, the group ducks beneath the ice in order to create a wave to tip the floe (see Figure 1.6). While performing this behavior, groups of orcas are often observed vocalizing at an increased frequency. It has been suggested that these vocalizations may serve to coordinate the group during the attack. If the first attempt is unsuccessful, this behavior is repeated until the seal is washed into the water.

One particularly interesting feature of this strategy is that the orcas do not always immediately kill the seal once it is successfully washed into the water. During several observed wave-washing attacks, a group member captured the seal in its mouth and either released the prey or deposited it onto another ice floe. It is inferred that this unusual behavior may serve as training, social learning, or perhaps as a method of teaching younger group members how to execute this behavior effectively (Visser et al., 2008).

Another possible explanation is that wave washing, and perhaps hunting in general, is an element of play for orcas. In other words, hunting is not only a means for finding sustenance, but also for socializing and entertainment. This suggestion is bolstered by observations of multiple unrelated orca populations playing with their prey at length before killing and eating them (Baird & Dill, 1995, as cited by Visser et al., 2008).

Communication.

One explanation of orcas' ability to perform these cooperative hunting behaviors lies in their method of communication. Orcas vocalize by manipulating air through nasal-sacks located beneath their blowhole, and generate several types of sounds: echolocation, tonal whistles, clicks, and pulsed calls (Schevill & Watkins, 1966, as cited by Deecke, Ford, & Spong, 1999). These sound types are combined to produce complex sequences of vocalizations that show markers of language.

Different populations of orcas use entirely different sets of vocalizations with very little overlap. These sets of vocalizations are referred to as "dialects," and are unique to a single pod. Orca dialects are so distinct that an orca's pod membership can be identified by comparing their individual vocalizations to the pod's known vocal repertoire. This method has been used for reuniting stranded orcas with their group and determining the origin of wild-caught captive orcas. The adaptive function of these calls is unknown, but it has been suggested that they are communicative, and may aid in kin recognition, social cohesion, and avoiding excessive inbreeding (Barret-Lennard, 2000; Yurk et al., 2002).

The suggestion that orca vocalizations reveal an evolved facility with the complexities of a communication system akin to language is further bolstered by studies on bottlenose dolphins' (*Tursiops truncatus*) ability to learn an artificial language. In one study, dolphins were reliably able to understand semantics and syntax in an artificial language that included words representing agents, objects, object modifiers, and actions. These words could be combined into hundreds of sentences with differing meanings, which were used to instruct the dolphins to perform actions on objects with differing degrees of complexity.

The subjects of this experiment showed understanding of lexically novel sentences, structurally novel sentences, semantically reversible sentences that expressed relationships between objects, sentences in which changes in modifier position changed the sentence meaning, and conjoined sentences (Herman, Richards, & Wolz, 1984). In other words, the subjects demonstrated the ability to understand the difference between sentences like "bring ball to bucket" and "bring bucket to ball" by correctly responding to the different requests.

Orcas in captivity.

As stated previously, the topic of orca captivity is controversial due to ethical questions surrounding the confinement of large, highly intelligent, social, and emotional animals. Additional concerns include the historical capture of wild orcas, a violent and traumatic process that involved the separation of mothers and calves, and often the death of pod members who drowned in captors' nets rather than abandoning their young. These early captures contributed to the dwindling numbers of Southern Resident orcas, leading to legislation specifically commanding that marine parks cease this practice (see Figure 1.7). However, though wild capture of orcas is now illegal in most of the world, certain countries are unwilling to place restrictions on this practice, allowing these captures to continue.

Figure 1.7: Orcas being captured in Penn Cove, 1970.

In addition to ethical concerns surrounding wild captures, many anti-captivity advocates question the quality of life of captive orcas. Captive orcas are known to die prematurely, usually of causes attributable to the stressors present in a captive environment. NOAA estimates that, in the wild, female orcas live an average of 50 years, and males an average of 30. However, these averages are frequently surpassed, and a female as old as 103 has been documented. In contrast, only two of Seaworld's male orcas have reached the average lifespan of 30, and the mean lifespan of Seaworld's deceased orcas is 13.48 for females, and 15.67 for males. Furthermore, captive orca behavior is often regarded as abnormal, especially in poorly equipped facilities. In particular, a set of behaviors referred to as "stereotypic behavior," has become a source of controversy, and will be discussed at length below.

Stereotypic Behavior

Captive environments can induce abnormal, repetitive behavior in animals that are poorly suited to life in captivity. This behavior is referred to as stereotypic behavior, and is often used as an index for assessing the welfare of captive animals. Stereotypic behavior manifests itself differently for different species, potentially due to variation in species-specific behaviors. For example, poorly adjusted walruses grind their tusks against concrete pool edges, birds pluck their feathers or skin, and naturally wide-ranging carnivores pace and sway (Mason, 2010). In orcas, stereotypic behavior generally includes logging (remaining still at the surface of the pool for long periods of time), head bobbing (repeatedly lifting the head in and out of the water), tongue-playing, chewing on gates and bars, swimming in circles, and regurgitating food. In addition to being a sign of poor psychological and physiological welfare, these behaviors themselves can lead to health problems of varying severity.

Causes of stress and stereotypic behavior.

The inability to perform important species specific behaviors, often referred to as "behavioral needs," is believed to be a source chronic, long-term stress in captive animals. In captivity, animals are prevented from performing these behaviors and, further, are unable to control or escape from an unsuitable environment. Though much effort has been made to improve conditions in captivity by increasing environmental complexity and naturalism, the human caretakers of captive animals are often unable to anticipate which aspects of captivity may be stressful. For instance, constant sound and proximity to humans, abnormal social groups, the scent or sight of adversary species, the removal of scent marks through cage cleaning, hard surfaces, small enclosures, or exposure to unnatural lighting and temperature conditions may contribute to stress in ways zookeepers cannot predict or improve. These factors are compounded by the animal's inability to escape from these conditions as they would in the wild (Morgan & Tromborg, 2007).

While the cause of stereotypic behavior has not been conclusively established, it is thought to be the result of predictability and boredom in addition to the stressors described above. Indeed, many of orcas' stereotypic behaviors correspond with the nature of their enclosures. For instance, while wild orcas swim for up to 100 miles each day, captive orcas circle endlessly around the perimeter of their tanks. A study on captive primates similarly found that stereotypic pacing levels were positively correlated with natural day journey lengths, such that the species whose wild counterparts traveled widely were more likely to pace (Pomerantz, Meiri, & Terkel, 2013). Though the links between orca stereotypy and particular aspects of their confinement have not yet been proven empirically, the physiological correlates of chronic stress bolster the suggestion that the stress of a captive environment plays a role in stereotypic behavior.

Stereotypy and mortality.

Due to the tendency of in-house morticians to inconsistently report either proximal or ultimate causes of death in autopsy reports, it is difficult to provide an accurate estimate of how many deaths of captive orcas were caused by stereotypic behaviors. However, several of these behaviors have been linked to risk factors for a wide variety of health deficiencies. For instance, logging is especially common in male orcas (see Figure 1.8), who are estimated to spend >50% of their daily behavioral repertoire floating motionlessly at the surface (Jett & Ventre, 2012). This behavior increases exposure to ultra violet rays (UVR), which can lead to sunburn, and, more seriously, suppressed immune system function (Kripke, 1994, as cited by Jett & Ventre, 2012).

Figure 1.8: Male orca (Ulises) logging at Seaworld San Diego.

Extended periods of time at the surface additionally allows mosquitos access the dorsal side of the orcas' bodies, which can lead to the transmission of a variety of diseases. Former Seaworld trainers have reported high occurrences of mosquito bites on stationary orcas, as mosquitos are drawn to large bodies of water, and preferentially land on warm, dark surfaces. Mosquito-transmitted diseases, such as the West Nile Virus and St. Louis Encephalitis Virus, have been implicated in at least two captive orca deaths (Jett & Ventre, 2012). However, it is likely that there are additional unreported cases of mosquito-transmitted diseases leading to mortalities.

Another stereotypic behavior that contributes to orca health deficiencies is gate chewing, captive orcas' tendency to chew on concrete and metal structure of their tanks (see Figure 1.9). Gate chewing is believed to be the result of pent up frustration, for instance, when aggressive orcas are separated and subsequently gnaw on the gates preventing them from attacking one another. This behavior grinds down the teeth of the orca, exposing the nerve and necessitating medical intervention. Orcas with severely ground teeth undergo a modified pulpotomy procedure, which consists of drilling the tooth and removing the nerve (see Figure 1.10). These bore holes are left open following the procedure, and can serve as a conduit for debris and pathogens to enter an orca's bloodstream (Jett & Ventre, 2012).

Figure 1.9: Orca (Morgan) chewing on her tank at Loro Parque.

Figure 1.10: Wild orca's teeth (above), captive orca's teeth post-pulpotomy (below).

The issue of suppressed immune system function is further compounded by the administration of prophylactic antibiotics. Because orcas are so susceptible to disease, these antibiotics are used to combat the risk of systemic proliferation of bacteria. However, long-term use of antibiotics is known to lead to health problems such as “antibiotic-resistant bacteria (van de Sande-Bruinsma et al., 2008), increased susceptibility to certain cancers (Kilkkinen et al., 2008), and disruption of intestinal flora (Schley and Field, 2002), leading to phytochemical malnourishment (Kilkkinen et al., 2002)” (Jeff and Ventre, 2012). Additionally, these antibiotics can lead to immunosuppressive effects themselves, further impeding captive orcas’ ability to fight off infections (Lemus & Blanco, 2009, as cited by Jeff and Ventre, 2012).

Taken together, one can surmise that stereotypic behaviors have the potential to seriously damage orcas’ health, and may even contribute to a number of deaths in captivity. The most commonly cited causes for death in captivity are pneumonia and septicemia (see Appendix A). It is possible that a number of these cases can be linked to the poor dentition, exposure to mosquitos, and suppressed immune system caused by stereotypic behavior.

Assessing stress in captive animals.

A myriad of long and short-term behavioral and physiological responses are used to operationally define and assess stress in captive animals. Short-term stressors are associated with behavior such as alarm and increased vigilance, and can lead to “tachycardia, increased respiration rate, increased glucose metabolism, and an increase in various isomers of glucocorticoids (GCCs), which can shift metabolism toward energy mobilization and away from energy conservation.” (Morgan & Tromborg, 2007).

Chronic long-term stress can lead to serious health problems, particularly because GCCs can damage the brain regions that terminate stress responses (Sapolsky & Plotsky, 1990, as cited by Morgan & Tromborg, 2007). Behaviors associated with long-term stress include a decrease in reproductive behavior, exploratory behavior, and behavioral complexity, as well as an increase in abnormal behavior, hiding, aggression, and tendency to startle. Additional physiological symptoms of chronic stress are suppressed reproductive cycling, reduced growth hormone levels and growth rate (Chrousos, 1997, as cited by Morgan & Tromborg, 2007), suppressed immune responses, and reduced body weight.

Various physiological measures are used to assess stress levels in captive animals. At Seaworld, samples of blood, urine, blow, blubber and feces are regularly collected and examined with cytology. Commonly used evaluations of these samples include CBC (complete blood count), serum chemistry, protein electrophoresis, and urinalysis, which can be used to measure the physiological correlates of stress described above.

In captivity, one of the most commonly used physiological measures of stress is blood serum cortisol levels. Cortisol is used in endocrinology due to its known link with stress response, and is one of the first adrenal hormones to increase during acute and chronic stress. Further, it is considered to be the most prominent glucocorticoid in cetaceans (St. Aubin & Dierauf, 2001). In a stable captive environment orca serum cortisol levels are estimated to be around 0.4 µg/dl (Suzuki et al., 1998).

Captive orcas are taught to participate in routine husbandry procedures, blood collection being one of them. While wild populations would undoubtedly exhibit a stress response during blood sample collection, captive orcas are comparatively desensitized to procedures of this sort.

For this reason it is generally accepted that these measurements represent baseline cortisol levels in captive orcas, and can be used to make inferences about an orca's stress and wellbeing.

Enrichment

Enrichment, the practice of adding sensory stimuli or choices in an environment, is one of the most successful tools for reducing stereotypy in captive animals. Young (2003, as cited by Maple & Perdue, 2013) described the goals of enrichment as "(1) Increase behavioral diversity; (2) Reduce the frequencies of abnormal behavior; (3) Increase the range of normal (i.e., wild) behavior patterns; (4) Increase positive utilization of the environment; (5) Increase the ability to cope with challenges in a more normal way" (p. 2).

When an enrichment intervention is successful, it can produce profound improvements in the psychological and physiological wellbeing of its recipients. Swaisgood and Shepherdson reviewed a number of publications examining enrichment programs, and found that 53% percent of the studies reported a reduction in stereotypic behavior. Another meta-analysis reported that 90% of the 54 studies reviewed showed a reduction in stereotypic behavior compared to baseline conditions, though none eliminated stereotypic behavior completely (Shyne, 2006).

Behavioral needs.

In order for enrichment to provide the benefits described above, the enrichment program must be effective. One challenge of implementing an effective enrichment program is determining the behavioral needs of the animals in question. Behavioral needs are defined as "behaviors that are primarily motivated by internal stimuli and, if the animal is prevented from performing them for prolonged periods, the individual's welfare may be compromised." (Friend, 1989, as cited by Goldblatt, 1993). Goldblatt (1993) states that the specific behavioral needs of an animal vary from species to species, and argues that these behavioral needs must be taken into account when designing a protocol for enrichment (see Figure 1.11).

Figure 1.11: Wild orca playing with kelp (left), captive orca playing with a plastic kelp toy (right).

Mason (2010) builds on this point by suggesting that it is important to determine the behaviors that captive animals are unable to perform in their environment, and design enrichment that somehow simulates this behavior. For instance, Mason summarizes a study performed by her own laboratory that investigated whether carnivores were affected by their inability to hunt and range. This study concluded that being a naturally wide-ranging animal predicted for stereotypic behavior and increased infant mortality, and suggests that enclosures with more space, multiple den sites, or greater day-to-day environmental variability may improve their welfare (Clubb & Mason, 2007).

Because orcas spend the largest percentage of their activity budgets in the wild hunting and foraging, hunting is arguably an important behavioral need that is inadequately met in captive environments. This idea is strengthened by elements of play observed during hunts, and the suggestion that hunting may constitute an important element of orca culture. Therefore, an enrichment intervention that somehow simulates the act hunting may provide profound benefits for captive orcas, and could result in a significant decrease in harmful stereotypic behavior.

Habituation and anticipation.

One obstacle to providing effective enrichment is habituation. Habituation refers to "the loss of interest due to repeated or prolonged exposure to [an] object" (Kuczaj et al., 2002). In one study, the authors reported that animals were more likely to interact with enrichment devices that were presented in short variable intervals than when they were given continuous access (Kuczaj et al., 2002). They found that when novel objects are first introduced into an environment, the animals generally interact with it. However, prolonged exposure can result in loss of interest, and ultimately fails to yield long-term benefits.

Similar to habituation, anticipation can lead to undesirable behavior in captive animals. The term anticipation refers to captive animals expecting that some event in their predictable environment will occur at a certain time or in a certain circumstance. If these expectations are not fulfilled, it can lead to behavioral problems (Kuczaj, Lacinak, & Turner, 1998). The failure to fulfill an orca's expectation of food, for example, could lead to aggression towards its tank mates or trainers. Indeed, after examining footage of a captive orca's fatal attack on Seaworld trainer Dawn Brancheau, former trainers posit that the orca's aggression was the result of not receiving reinforcement after completing a requested behavior (Cowperthwaite, 2013).

Forms of enrichment.

Many different forms of enrichment exist, some of which are more easily implemented than others. Hoy et al. (2010, as cited by Maple & Perdue, 2013) described eight types of enrichment: feeding, tactile, structural, auditory, olfactory, visual, social, and human-animal. Additionally, Maple and Perdue (2013) include cognitive enrichment on this list. Each of these types of enrichment is beneficial to captive animals, particularly when combined.

Feeding enrichment.

One of the most commonly used forms of enrichment is feeding enrichment, which consists of manipulation of the manner in which food is delivered to the animals (see Figure 1.12). In other words, instead of feeding the animals directly at specific times of the day, zookeepers could spread food across an enclosure to require that animals search for all the items (scatter feeding), use devices that must be manipulated by the animal in order to obtain the food, or require that an animal perform a specific behavior or set of behaviors before being fed (Maple & Purdue, 2013).

Figure 1.12: By hanging the giraffe's food from the ceiling, the giraffe is able to graze in a way that imitates wild giraffes' eating habits.

At Seaworld, the animals are fed on a variable-ratio schedule. This means that orcas' daily amount of food is delivered at different times and in different pools to avoid habituation and expectation. Additionally, this varied feeding schedule mimics wild orcas in that their feeding is not a predictable event (Kuczaj, et al., 1998).

Cognitive enrichment.

Another form of enrichment is cognitive enrichment, or allowing the animal to challenge and stimulate its memory, decision-making, judgment, perception, attention, problem solving (see Figure 1.13), executive functioning, learning, and species-specific abilities (Maple & Perdue, 2013).

Figure 1.13: Chimpanzee participating in a cognitive enrichment experiment.

One interesting aspect of cognitive enrichment is the subject's willingness to participate regardless of external rewards. In one study, bottlenose dolphins were taught to whistle at a particular frequency in order to receive a food from a dispenser. The subjects continued to whistle after the dispenser no longer produced food, demonstrating that the subjects were motivated to participate in cognitive tasks even in the absence of a reward (Mackay, 1981).

One explanation for this finding is that cognitive enrichment gives captive animals the rare opportunity to challenge their physical-cognitive skills. For marine mammals in particular, cognitive enrichment may provide an improved alternative to conventional enrichment, which generally consists of simple floating objects and toys. While these toys usually rouse immediate interest and playful behavior (Kuczaj et al., 2002), these effects are short lived, and have little impact on the frequency of stereotypic behavior in the absence of the object. Cognitive enrichment, on the other hand, has been shown to reduce stereotypy in general, and promotes normal behaviors observed in the wild. For instance, one study on captive chimpanzees showed that the subjects who participated in a cognitive enrichment program behaved more similarly to wild chimpanzees than those that did not participate (Yamanashi & Hayashi, 2011).

It has been suggested that orcas are inadequately stimulated in a predictable captive environment because, in the wild, orcas' environment is ever changing and highly stimulating (Spinka & Wemelsfelder, 2011, as cited by Clark, 2012). Due to the advanced cognitive capabilities wild orcas utilize when they hunt, play, and socialize, it follows that they could benefit greatly from this form of enrichment, especially if it simulates these behavioral needs.

Assessing enrichment.

An enrichment intervention cannot be considered a success unless it has been systematically evaluated and shown to improve the psychological or physiological wellbeing of the recipient of the intervention. Kuczaj et al. (2002) propose that enrichment assessments should be based on principles of comparative psychology, as much of the logic behind enrichment is based on psychological findings.

In some studies, enrichment objects (toys) are evaluated by the likelihood of the target animal interacting with them. Variables such as duration of interest behavior, duration of interaction/manipulation behavior, occurrence of interest behavior, and occurrence of interaction are used to calculate the effectiveness of the enrichment object (Delfour & Beyer, 2012). While these methods successfully pinpoint the toys favored by the subjects, they fail to measure the long-term benefits that enrichment can provide. A more telling strategy for evaluating enrichment is an observed reduction in stereotypic behavior, especially when physiological measures are collected and analyzed in tandem (Shyne, 2006).

Marine Mammal Training

In order to participate in the cognitive enrichment intervention proposed in the present paper, the orcas would first have to be trained to complete the exercise itself. At Seaworld, teaching orcas novel behaviors relies on B. F. Skinner's principles of operant conditioning, and their central philosophies include reinforcement, communication, and target recognition.

Operant conditioning.

The most commonly used strategy for training captive orcas is operant conditioning, based on the principles of B. F. Skinner. The central principle of operant conditioning is that the likelihood of a subject performing a behavior can be increased or decreased depending on the consequences that follow. In other words, a subject can be taught to repeat a behavior if it is followed by a reward (positive reinforcement), or decrease a behavior if it is followed by the lack of a desired reward (negative punishment) (Seaworld Parks & Entertainment, 2015).

History of operant conditioning in marine mammal training.

Operant conditioning in marine mammal training can be traced back to Marine Studios, a Floridian oceanarium and tourist attraction. Though a number of marine animals were housed at this facility, the bottlenose dolphin (*Tursiops truncatus*) quickly became a crowd favorite. One particularly popular attraction, "Top Deck Show," involved an employee leaning over the water holding a fish, prompting the dolphins to leap out from their tanks to retrieve it. This performance, unbeknownst to the employees, was actually a crude form of operant conditioning, in that the dolphins were being asked to execute exceedingly higher jumps in order to retrieve the fish (Gillaspy, Brinegar, & Bailey, 2014).

More official forms of operant conditioning were soon employed thanks to the contributions of the Brelands, who created the first operant training manual for dolphins. This manual included basic learning and behavioral principles, providing the reader with instructions for shaping, extinction, differentiation, schedules of reinforcement, props, and using the bridge stimulus. Manuals such as this allowed for standardized language and protocol for trainers, removing the shroud of secrecy previously surrounding animal training techniques, and allowing the animals to be taught by different trainers interchangeably.

Seaworld's main contribution to the field of training marine mammals was using operant conditioning to train orcas. The original Shamu, whose name has since become the stage name for all of Seaworld's performing orcas, was captured and sent to Seaworld for training in 1965. The theme of the original Shamu show was "doctor's visit," and consisted of a trainer (dressed as a physician) asking Shamu to show her fluke reflexes, have her heart checked, and open her mouth to display her teeth and have them brushed. The show ended with Shamu kissing the trainer on the cheek and completing a 15-foot high jump (Burgess, 1968). Orcas have since become Seaworld's mascot and main attraction.

Basic principles with regard to marine mammal training.

The central principles of operant conditioning used in marine mammal training include reinforcement, schedules or reinforcement, communication, target recognition, shaping, and the ability to avoid habituation and anticipation (Seaworld Parks & Entertainment, 2015).

Reinforcement.

Reinforcement and punishment can be positive or negative, each of which have different effects on the performance of a behavior. Positive reinforcement is delivered immediately following the desired behavior in the form of a pleasurable sensory experience. The most commonly used reinforcer is food, largely because it is a primary reinforcer (see Figure 1.14). This means that the reinforcer (food) is automatically rewarding, without having to teach the orcas to form positive associations with it. Other forms of positive reinforcement, called conditioned reinforcers, are not inherently pleasurable to the subject, and must be learned. For example, by pairing a conditioned reinforcer with a primary reinforcer, such as saying "good job" in addition to receiving a primary reinforcer, the animal will begin to find the phrase "good job" rewarding. Additional reinforcers include back scratches, rub downs, toys, favorite activities, being sprayed with a hose, and ice cubes. Different whales respond favorably to different reinforcers, and types of reinforcement must be varied in order to avoid habituation.

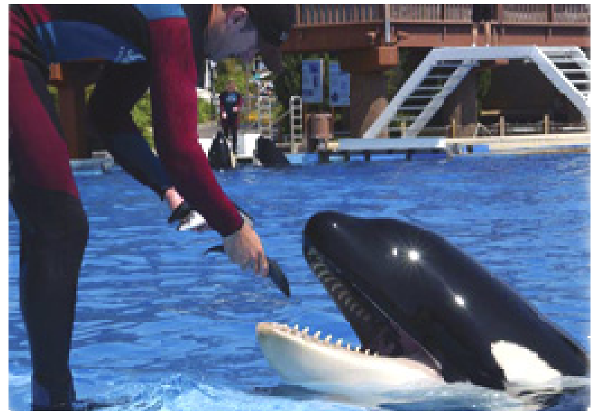

Figure 1.14: Seaworld orca being reinforced with food.

Another form of reinforcement is negative punishment. Contrary to popular belief, negative punishment is not the introduction of an undesirable consequence, but rather the removal of a favorable object. In marine mammal training, negative punishment is replaced by a "least reinforcing scenario" (LRS), in which the trainer does not reinforce a subject following the incorrect performance of the desired behavior. Negative punishment can also be used in extinction, the elimination of undesirable behavior. The principle behind this process is that, if a subject does not receive a favorable response to a behavior, over time the animal will discontinue the behavior entirely (Seaworld Parks & Entertainment, 2015).

Schedules of reinforcement.

As stated previously, habituation and anticipation can lead to undesirable behavior in orcas, such as boredom, lack of motivation, frustration, or aggression. Therefore, reinforcement is most effective when it is delivered on a variable ratio reinforcement schedule. On this schedule the delivery of reinforcement varies unpredictably, which leads the animal to perform the behavior without knowing whether it will be reinforced. While this schedule slows the process of new behaviors, once learned, the subject will perform the behavior more frequently, and the behavior is less likely to be extinguished (Seaworld Parks & Entertainment, 2015).

Communication.

The second of Seaworld's central philosophies is communication, such that the subject understands what the trainer wants from them. For instance, as stated earlier, positive reinforcement must directly follow the performance of a desired behavior. If there is a delay of even a few minutes, the trainer could accidentally reinforce the wrong behavior. Because it is not always possible or convenient to immediately reinforce a behavior, a bridging signal is used. A bridging signal, such as a whistle or light touch, indicates to the animal that they have performed the behavior correctly (see Figure 1.15). Trainers teach orcas to recognize a bridging signal by using it prior to giving the subject a reward until the subject eventually associates the signal with completion of the correct requested behavior. This signal can additionally be seen as a conditioned reinforcer of sorts (Seaworld Parks & Entertainment, 2015).

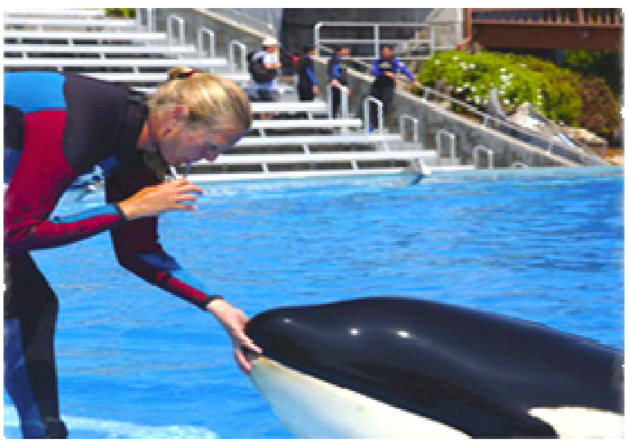

Figure 1.15: Seaworld trainer using the bridging signal.

Target recognition.

Figure 1.16: Seaworld trainer using targeting.

The third of Seaworld's central philosophies is target recognition. Trainers often use their hand as a focal point, and animals are taught to approach the hand and await the next signal (see Figure 1.16). If the animal is further away, another object, such as a tap on the glass, ice cube, or long pole with a foam float or ball at the end, is used as a target. This practice is called "targeting," and the target is used to direct the subject to a position or direction. After the animal is able to perform the desired sequence of positions or behaviors the target is replaced with a hand signal, which indicates to the animal that the trainer is requesting the behavior sequence in its entirety (Seaworld Parks & Entertainment, 2015).

Shaping and habituation.

Seaworld orcas are taught new behaviors according to the principle of shaping, which is based on the idea of successive approximation. Shaping consists of gradually reinforcing small components of the desired behavior. For instance, if a trainer wanted to teach an orca to present its pectoral fin, they may start by reinforcing

Figure 1.17: Seaworld trainer uses shaping to teach the orca to present its pectoral fin.

the orca for floating sideways alongside the trainer. Next, they could reinforce the orca for turning on its side, a behavior slightly closer to the objective (see Figure 1.17). This process would continue in small increments until the new behavior has been learned.

Another important component of learning sessions is desensitization, which incorporates the principle of habituation in order to slowly familiarize the animals with novel situations. An example of this would be training an orca to ignore the presence of a trainer in the water. This process would be similar to the shaping procedure described above in that orcas would be slowly desen-sitized to small components of the situation, such as placing a hand or foot in the water. The trainer would teach the orca to ignore the hand or foot by asking it to perform another behavior, such as presenting their pectoral fin, in order to distract them. The trainer would put more and more of their body in the water while the whale is being distracted, until desensitization to the situation is complete (Kuczaj et al., 2002).

Summary

Wild orcas spend a large percentage of their time hunting and foraging using specialized complex cooperative strategies that are passed down from generation to generation. For this reason, it can be said that being unable to hunt in captivity may contribute to stress and boredom, leading to the performance of stereotypic behaviors. Stereotypic behavior is a widespread problem for captive orcas, and can have serious deleterious effects on their health. Therefore, it is of great importance to implement effective enrichment in order to decrease these behaviors.

Previous research suggests that captive animals will benefit from cognitive enrichment that simulates an important behavioral need. Furthermore, wide-ranging captive carnivores have been shown to benefit from feeding enrichment, which consists of presenting food to an animal in a way that mimics their feeding habits in the wild (Club & Mason, 2003; 2007). For orcas, highly intelligent apex predators, hunting is arguably the most important wild behavior that they are unable to perform in captivity.

For these reasons, I am proposing a novel cognitive enrichment intervention that combines the variables described above. Seaworld San Diego's orcas will be taught to associate certain environmental enrichment objects (toys) with different symbols, presented them on cards. After learning these associations, the toys will all be emptied into the pool, and the orcas will be required to retrieve only the toys associated with the symbol they had been shown. Successful retrieval of the correct object will result in food reward. The proposed intervention would be considered a success if a reduction in stereotypic behavior and physiological markers for stress is observed.

In order to perform the proposed task, orcas' abilities to see the symbol, understand its meaning, and, most importantly, be trained to participate must be established. In one study, the visual acuity of orcas was tested using a two-choice visual discrimination apparatus. The subjects demonstrated the ability to distinguish between the stimuli, leading the authors to conclude that orca vision is "sufficiently well-developed for it to be of considerable use in the guidance of behavior." (White, Cameron, Spong, & Bradford, 1971). For this reason, it can be assumed that orcas' vision is sufficient to see the shapes on the cards.

The second consideration is that orcas must be able to understand the meanings of card symbols. While the ability of orcas to do so has not, to my knowledge, been empirically examined, the research on bottlenose dolphins (*Tursiops truncatus*) discussed previously has demonstrated the ability of dolphins to learn and understand an artificial language, arguably a more complex task than what is being proposed here (Herman, 1984).

Research has additionally shown that bottlenose dolphins are able to form concepts, (Clark, 2012). Concept formation refers to the ability of an animal to apply general rules to novel situations they encounter in life. A commonly used method of measuring concept formation in marine mammals is called "matching-to-sample" (MTS). In this experimental method, a subject is shown a sample stimulus. In order to receive food reinforcement, the subject must correctly identify the stimulus from a number of comparison stimuli. Different concepts, such as the relational concept of larger versus smaller, have been demonstrated in dolphins. In one MTS study dolphins were shown two sets of dots, one of which had less than the other, and were trained to identify the set with the smaller number of dots. The dolphins were consistently able to select the set with fewer dots, even when presented with novel sets of dots that they had not seen before (Jaakkola et al., 2005).

In addition to concept formation, dolphins have demonstrated abilities such as imitation and understanding of symbols. In a series of studies summarized by Herman (2002), dolphins were consistently able to understand televised commands, imitate televised dolphins, and respond accurately to sample stimuli presented on a screen. Due to the necessity of recognizing the self and others during imitation, imitative behaviors are considered to be a marker of self-awareness and high-level cognitive ability (Clark, 2012). The findings of these studies further bolster the suggestion that orcas' understanding of symbols and concepts is adequate to understand the rules of the game.

Thirdly, in order to participate in the proposed intervention, the subjects must be capable of learning how to participate. As discussed previously, operant conditioning is the primary method for training marine mammals. Subjects in the present study will be taught associations between shapes and cards by following the same procedures used in routine training sessions, such as shaping and positive reinforcement on a variable ratio schedule.

Dolphins are known for having excellent short-term memory for sights and sounds. Delayed MTS tests are used to identify the maximum length of time that a subject can retain memory of a sample stimulus (Clark, 2012). In one study, dolphins demonstrated the ability to correctly respond to a sound stimulus by swimming to the specific sound's corresponding pool location. The dolphins were able to do so after a time delay of up to 70 seconds (Thompson & Herman, 1981). In another study, one dolphin was able to remember and correctly respond to up to four distinct sounds, an impressive feat in comparison to the maximum of seven in humans. For these reasons, it can be expected that orcas are capable of learning to participate in the intervention.

This intervention can be beneficial to orcas for several reasons. Firstly, the difficulty threshold of the task can easily be increased over time, for example, by combining symbols or asking the orcas to retrieve different objects in synchrony. Once the associations between symbols and toys have been learned, any number of combinations or novel tasks and games can be built around them. Therefore, I suspect that habituation to this intervention can be avoided.

Secondly, this intervention contains an element of feeding enrichment, in that animals are fed after they've successfully completed a cognitive task. Feeding enrichment has similarly been shown to reduce stereotypic behavior in that it mimics the uncertain nature of feeding in the wild, and additionally can serve to reduce undesirable or aggressive behaviors caused by anticipation.

Lastly, it simulates hunting in that they will be asked to identify and retrieve particular objects in order to receive a food reward, just as wild orcas discriminate between unfamiliar prey and prey for which they have developed hunting strategies. This element of the intervention constitutes cognitive enrichment and fulfillment of a behavioral need, both of which have been shown to reduce stereotypic behavior.

In sum, previous research supports the notion that orcas, highly intelligent apex predators, will benefit from a form of cognitive enrichment that simulates the behavioral need of hunting. Further, orcas and their close relatives have demonstrated the ability to participate in cognitive enrichment interventions of this sort, strengthening the notion that the proposed intervention can be learned. If a reduction stereotypy is observed compared to the control group, the intervention will be considered a success.

Method

Subjects

The subjects will consist of 12 orcas (6 male, 6 female) from Seaworld's three facilities: Seaworld San Diego, Seaworld Orlando, and Seaworld San Antonio. The subjects were selected such that the gender and average age of each participant at each park was roughly matched, and calves (aged 0 to 9) were excluded. Orcas are highly social, and are known to transmit knowledge such as vocalizations and trained behaviors to members of their group. For this reason, groups were assigned by location in order to avoid comingling and possible contamination of learned knowledge between different groups.

Intervention group.

The Intervention Group consists of subjects housed at Seaworld San Diego. The subjects include Ulises (35, M), Orkid (27, F), Keet (22, M), and Shouka (22, F) (M=26.5). Their living environment consists of 5 pools: the show pool, two adjacent pools, the underwater viewing pool, and the medical pool (see Figure 2.1). The show pool is 36 feet deep, 180 feet long, and 90 feet wide. The two adjacent pools are each 15 feet deep, 150 feet long, and 80 feet wide. The underwater viewing pool is 30 feet deep, and the medical pool is 8 feet deep.

Figure 2.1: Birdseye of Seaworld San Diego.

Increased training group.

Figure 2.2: Birdseye view of Seaworld Orlando.

The Increased Training Group consists of subjects housed at Seaworld Orlando. The subjects include Katina (37, F), Tilikum (32, M), Kayla (27, F), and Trua (10, M)(M=26.5). Their living environment consists of 6 pools: the show pool, two adjacent pools, the shading tank, the medical pool, and the underwater viewing pool (see Figure 2.2). The show pool is 36 feet deep, 190 feet long, and 90 feet wide. The two adjacent pools are each 25 feet deep and 70 feet long. The shading tank is 20 feet deep and 100 feet long. The medical pool is 20 feet long. The underwater viewing pool is 36 feet deep, 220 feet long, and 70 feet wide.

Control group.

Figure 2.3: Birdseye view of Seaworld San Antonio.

The Control Group consists of subjects housed at Seaworld San Antonio. The subjects include Takara (24, F), Kyuquot (24, M), Unna (19, F), and Tuar (22, M)(M=29.6). Their living environment consists of 4 pools: the show pool, two adjacent pools, and the medical pool (see Figure 2.3). The show pool is 40 feet deep, 220 feet long, and 150 feet wide. The two adjacent pools are each 25 feet deep, 115 feet long, and 69 feet wide. The medical pool is 10 feet deep, 26 feet long, and 42 feet wide.

Materials

Stereotypic behavior coding sheet.

These coding sheets will record observed instances of stereotypic behavior, type of stereotypic behavior, and duration of stereotypic behavior (see Appendix B). The stereotypic behaviors included on this sheet are gate chewing and logging, and the total number of minutes spent performing these behaviors will be used as a behavioral measure of stress. These sheets will be collected at the end of the final observation session each day, filed into the appropriate subject's folder, and ultimately used for data analysis.

Blood samples.

Blood samples will be collected at the beginning of each of the four intervals of the experiment: baseline (one day prior to the training period), interval 2 (one day prior to the intervention period), interval 3 (one day prior to the post-intervention period), and interval 4 (the last day of the post intervention period). The length of these intervals will be determined by the Intervention Group, such that each of the groups spend the same amount of time in each phase.

These blood samples will be tested for cortisol levels, which will serve as a physiological measure of stress. As discussed previously, cortisol has known links with stress responses, and is one of the first adrenal hormones to increase during acute and chronic stress. Captive orcas are desensitized to husbandry procedures such as this, and it is generally accepted that these measurements represent baseline cortisol levels in captive orcas.

Enrichment toys.

The toys to be used in the intervention are regularly used as enrichment for the subjects, and thus will be familiar to each of them (see Figure 2.4). The enrichment toys include a foam mattress (200 x 100 x 8 cm), a foam stick (94.4 x 12 x 11 cm), a plastic ball (*d*=32 cm), a fireman hose (*L*=150 cm), a frisbee (*d*=23 cm), and a circular buoy (*d*=32 cm).

Figure 2.4: Seaworld's orca enrichment toys.

Shape cards.

The shape cards will be used to request that the subject retrieve a particular enrichment toy. The shapes cards were randomly assigned to each toy (see Appendix C), and the paired associations will remain constant throughout the trial. The shapes include a red square, a yellow triangle, a green diamond, a blue circle, an orange "hourglass", and a purple star. The cards are 12 x 26 inches, and the shape is a minimum of 8 inch wide and 8 inches long, sizes consistent with previous studies on orcas' ability to see and respond to symbols (White, Cameron, Spong, & Bradford, 1971).

Food reward.

After correctly retrieving the requested enrichment object, the subjects will be rewarded with food. The food rewards will include salmon, capelin, herring, mackerel, and smelt. As per Seaworld protocol, these rewards will be given on a variable ratio schedule. In other words, these rewards will be given randomly to each subject in order to avoid habituation and anticipation for receiving a particular reward.

At Seaworld, each of the orcas has an individually prescribed quantity of food for each day. During the intervention, any received rewards will be subtracted from the subject's overall daily food intake in order to avoid over-feeding.

Training log.

The training log will be used by assistant trainers to monitor training sessions for the intervention (see Appendix D). This training log will include information such as which associations were taught, the subject's number of correctly retrieved objects, the duration of the session, received rewards, and a detailed description of all events of the training session.

Procedure

Intervention group.

Baseline data collection.

The experimenters will begin by collecting baseline medical and behavioral data on the subjects. All baseline data will be collected from all subjects in the same 24-hour period prior to introducing the intervention. Each of the subjects will have blood samples collected and tested. These samples will be used as a physiological measure of stress prior to the intervention.

Additionally, four raters will record instances of stereotypic behavior as a behavioral measure of stress before, during, and after the intervention is introduced. Each of the raters will be randomly assigned a single subject each morning, which they will observe for 10-minute periods every two hours between 6:00 A.M. and 8:00 P.M. (for a total of eight observation periods each day). During these observation sessions, the raters will use the Stereotypic Behavior coding sheets to record instances and duration of stereotypic behaviors. These raters will be kept blind to the subjects' condition and the study's hypothesis in order to avoid influencing their interpretation of behavior.

Training period.

The day after the baseline data are collected, the training period of the experiment will begin. The intervention is a game called "Cognitive Fetch." During this game the subject will first be shown a Shape Card, a rectangular card with a colored shape in the center. Each Shape Card has an associated enrichment toy, which the subject must retrieve and return to the trainer in order to receive a food reward. The game itself continues for roughly 30-minutes in order to avoid boredom, and ends when the subject correctly retrieves the final toy and is rewarded.

The subjects in the Intervention Group will be taught to play Cognitive Fetch via shaping, the principle of operant conditioning that is commonly used for marine mammal training. This training will begin by introducing two toys into the water, displaying a Shape Card, and positively reinforcing subjects if they return the correct toy to the trainer. As the subjects form more associations between Shape Cards and toys, the number of toys in the pool during training sessions will be increased, until all the associations have been learned and the subject is able to play the game with all of the toys in the pool.

Each of the subjects will be taught separately by the same trainer, and an assistant trainer will observe and record these sessions in the Training Log in order to ensure qualitatively equivalent learning sessions for each subject. Due to individual variation, the number of trials for each subject will likely vary. The Training Period will end when all of the subjects demonstrate the ability to identify and retrieve the requested object with a 90% success rate in three consecutive blocks of 24 trials, consistent with previous studies on orcas' abilities to see and interpret symbols (White et al., 1971). During this phase, the raters will continue to record their assigned subject's behavior throughout the day. Additionally, blood samples will be collected on the last day of this phase.

Intervention Period.

When the subjects have an adequate understanding of Cognitive Fetch as demonstrated by the success criterion, the intervention trial period will begin. During this period, each of the subjects will individually play the Cognitive Fetch for 30-minute sessions with the same trainer that taught them. Each of the subjects will play Cognitive Fetch a total of ten times during the intervention trial period, five in the morning (between the hours of 8:00 A.M. and 12:00 P.M.) and five in the afternoon (between the hours 1:00 P.M. and 5:00 P.M). In order to avoid habituation and anticipation, the subjects will never play Cognitive Fetch at the same time of day or in the same area of a tank more than once. During this phase, the raters will continue to record their assigned subject's behavior throughout the day. Additionally, blood samples will be collected on the last day of this phase.

Post-intervention period.

Following the intervention period, participation in Cognitive Fetch will be discontinued and the subjects' schedules will return to normal. This phase will continue for one week, after which this group will have finished their participation in the experiment. During this phase, the raters will continue to record their assigned subject's behavior throughout the day. Additionally, blood samples will be collected on the final day.

Increased training group.

Baseline data collection.

Following the completion of the Post-Intervention Period for the Intervention Group, the Increased Training Group will begin the experiment. Just as with the Intervention Group, the experimenters will begin by collecting baseline medical and behavioral data on the subjects. All baseline data will be collected from all subjects in the same 24-hour period prior to the Increased Training Period. Each of the subjects will have blood samples collected and tested. These samples will be used as a physiological measure of stress prior to the Increased Training period.

Additionally, four raters will record instances of stereotypic behavior as a behavioral measure of stress throughout the experiment. Each of the raters will be randomly assigned a single subject each morning, which they will observe for 10-minute periods every two hours between 6:00 A.M. and 8:00 P.M. (for a total of eight observation periods each day). During these observation sessions, the raters will use the Stereotypic Behavior coding sheets to record instances and duration of stereotypic behaviors. These raters will be kept blind to the subjects' condition in order to avoid influencing their interpretation of behavior.

Increased training period.

The day after the baseline data are collected, the Increased Training Group will begin attending extra training sessions. During these sessions, the subjects will participate in veterinary and husbandry training, performance behavior training, and interaction with enrichment objects. These sessions will consist of the same material covered in Seaworld's standard training sessions, the only difference being an increase in frequency.

This phase will continue for the same amount of time as the Training Period and Intervention Period for the Intervention Group. The frequency of the sessions will be increased in accordance with the Intervention Group's training sessions, such that the subjects in the Increased Training Group will train during the same times and for the same number of hours as the Intervention Group. During this phase, the raters will continue to record their assigned subject's behavior throughout the day. Additionally, blood samples will be collected at the same time intervals as the Intervention group.

Post-intervention period.

Following the Increased Training period, the extra training will be discontinued and the subjects' schedules will return to normal. This phase will continue for one week, after which this group will have finished their participation in the experiment. During this phase, the raters will continue to record their assigned subject's behavior throughout the day. Additionally, blood samples will be collected on the final day.

Standard training and interaction group.

Baseline data collection.

Following the completion of the Post-Intervention Period of the Increased Training Group, the Control Group will begin the experiment. Just as with the two previous groups, the experimenters will begin by collecting baseline medical and behavioral data on the subjects. All baseline data will be collected from all subjects in the same 24-hour period prior to introducing the intervention. Each of the subjects will have blood samples collected and tested. These samples will be used as a physiological measure of stress prior to the experiment.

Additionally, four raters will record instances of stereotypic behavior as a behavioral measure of stress throughout the experiment. Each of the raters will be randomly assigned a single subject each morning, which they will observe for 10-minute periods every two hours between 6:00 A.M. and 8:00 P.M. (for a total of eight observation periods each day). During these observation sessions, the raters will use the Stereotypic Behavior coding sheets to record instances and duration of stereotypic behaviors. These raters will be kept blind to the subjects' condition in order to avoid influencing their interpretation of behavior.

Observation period.

The Control Group will continue on their regular schedule after the baseline data collection day, with the exception of the daily observations of stereotypic behavior recorded by the raters. This phase will continue for the same duration as the Intervention and Increased Training groups. Additionally, blood samples will be collected at the same time intervals as the Intervention and Increased Training groups.

Results

Data Preparation

Blood samples will be collected a total of four times over the course of the experiment: before beginning, after training, after the intervention, and one week after the removal of the intervention. The periods between each of these intervals will be matched across groups, such that each of the groups spend the same amount of time in each phase. Blood serum cortisol levels will be combined into a single value for each of the groups during each interval of the experiment. Additionally, the duration of stereotypic behaviors will be collapsed into a single score for each subject during each phase. Each subject will have a mean logging time, a mean gate chewing time, and a mean blood serum cortisol level for each of the four intervals of the experiment, which will then be compared across groups.

In addition to comparing these means across groups, change scores will be calculated between phases in order to determine the subjects' progress over the course of the experiment. These scores will be calculated by subtracting the mean values of selected intervals from the mean values of an earlier interval. Therefore, large, positive values reflect significant improvements. One set of change scores of interest is the relationship between the baseline and interval 3, which demonstrates the mean stereotypic behaviors and blood serum cortisol levels at the beginning and end of the intervention. This score will establish the subjects' improvement over the course of the experiment. Likewise, the relationship between intervals 3 and 4 reflects the subjects' behavior post removal of the intervention, and demonstrates their retention of the intervention's effects.

Baseline Blood Serum Cortisol Between Groups

An ANOVA will be used to compare the mean baseline blood serum cortisol levels between the three groups. If the expected results are found, there will be no significant difference in mean blood serum cortisol levels between the three groups (see Figure 3.1).

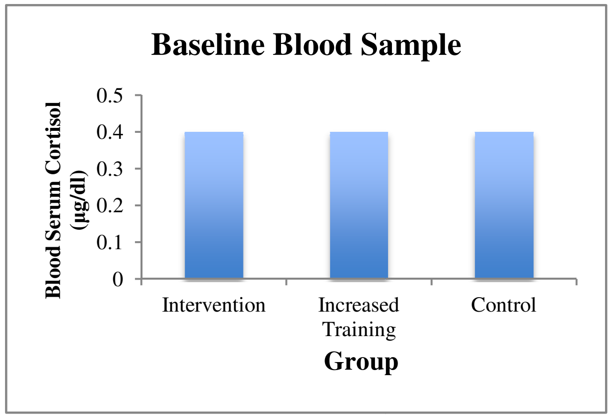

Figure 3.1: Graph showing the baseline mean blood serum cortisol levels for the three groups.

Baseline Stereotypic Between Groups

Logging.

An ANOVA will be used to compare the mean baseline logging time between the three groups. If the expected results are found, there will be no significant difference in mean logging time between the three groups (see Figure 3.2).

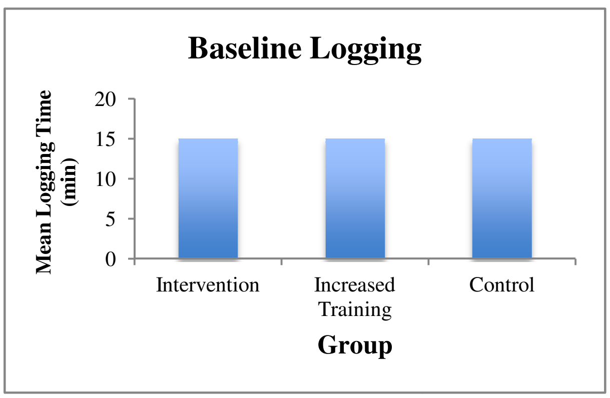

Figure 3.2: Graph showing the baseline mean logging time for the three groups.

Gate Chewing.

An ANOVA will be used to compare the baseline mean gate-chewing behavior between the three groups. If the expected results are found, there will be no significant difference in mean

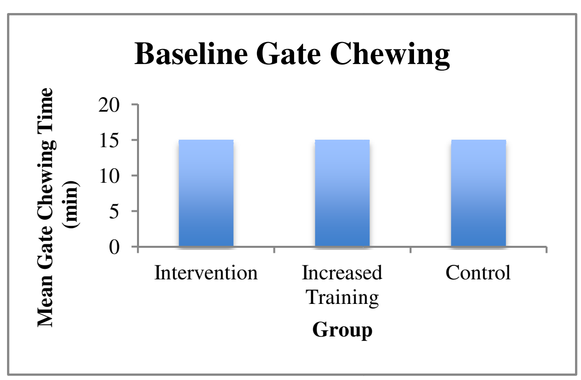

Figure 3.3: Graph showing the baseline mean gate chewing time for the three groups

gate chewing time between the three groups (see Figure 3.3).

Interval 2: Blood Serum Cortisol Between Groups

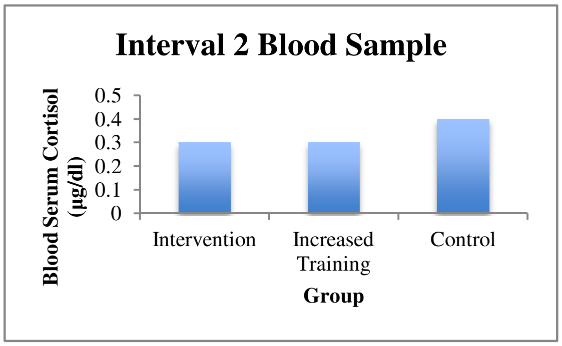

Figure 3.4: Graph showing the mean blood cortisol levels for the three groups at interval 2.

An ANOVA will be used to compare mean blood serum cortisol levels at the second interval between the three groups. If the expected results are found, the three groups will be significantly different, and pairwise t-tests will be conducted to determine the direction of the results. These tests will show that both the Intervention Group and the Increased Training Group will have smaller mean blood serum cortisol levels compared to the Control Group (see Figure 3.4).

Interval 2: Stereotypic Between Groups

Logging.

An ANOVA will be used to compare mean logging time at the second interval between the three groups. If the expected results are found, the three groups will be significantly different, and pairwise t-tests will be conducted to determine the direction of the results. These tests will show that the Intervention Group and

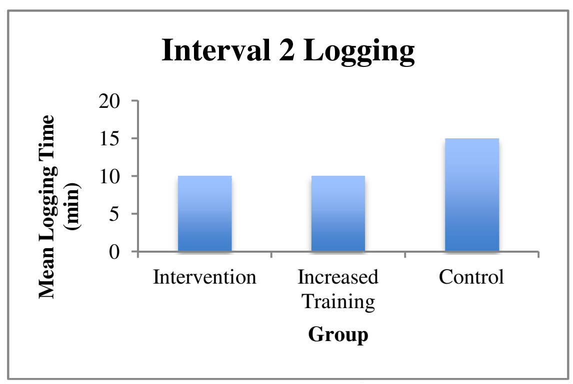

Figure 3.5: Graph showing the mean logging time for the three groups at interval 2.

Increased Training Group will have the smallest mean logging time, while the Control Group will have the largest mean logging time. In other words, the Control Group will spend more time logging than the other two groups (see Figure 3.5).

Gate Chewing.

An ANOVA will be used to compare mean gate chewing time at the second interval between the three groups. If the expected results are found, the three groups will be significantly different, and pairwise t-tests will be conducted to determine the direction of the results. These tests will show that the Intervention Group and Increased Training Group will have the smallest mean gate chewing time, while the Control Group will have the largest mean gate chewing time. In other words, the Control Group will spend more time gate chewing than the other two groups (see Figure 3.6).

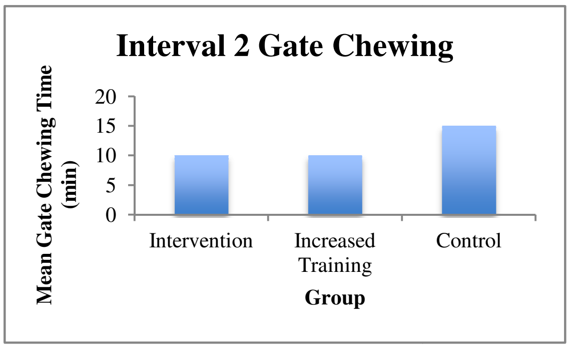

Figure 3.6: Graph showing the mean gate chewing time for the three groups at interval 2.

Interval 3: Blood Serum Cortisol Between Groups

An ANOVA will be used to compare mean blood serum cortisol levels at the third interval between the three groups. If the expected results are found, the three groups will be significantly different, and pairwise t-tests will be conducted to determine the direction of the results. These tests will show that

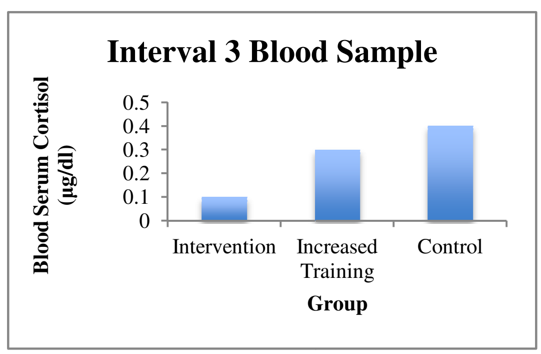

Figure 3.7: Graph showing the mean blood serum cortisol levels for the three groups at interval 3.

the Intervention Group will have the smallest mean blood serum cortisol level. The Increased Training Group will have a slightly smaller mean blood serum cortisol level compared to the Control Group, which will have the largest mean blood serum cortisol level (see Figure 3.7).

In addition, change scores will be calculated for each of the groups, subtracting mean blood serum cortisol levels at interval 3 from mean blood serum cortisol levels at the baseline interval. If the expected results are found, the Intervention Group will show the largest change score, and thus the largest reduction in mean blood serum cortisol levels compared to the baseline (see Figure 3.8). The Increased Training Group will show a small but significant change score, demonstrating a small reduction in mean blood serum cortisol levels compared to the baseline. The Control Group will show no change.

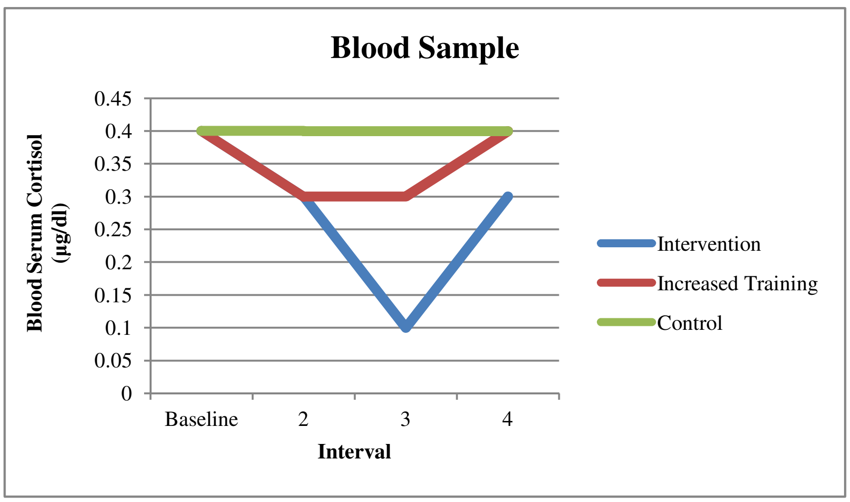

Figure 3.8: Graph showing the mean blood serum cortisol scores for the three groups at each interval of the experiment.

Interval 3: Stereotypic Between Groups

Logging.

An ANOVA will be used to compare mean logging time at the third interval between the three groups. If the expected results are found, the three groups will be significantly different, and pairwise t-tests will be conducted to determine the direction of the results. These tests will show that the Intervention Group will have a significantly smaller mean logging time than the other two groups. The Increased Training Group will have a slightly smaller mean logging time than the Control Group, who will show the largest mean logging time (see Figure 3.9).

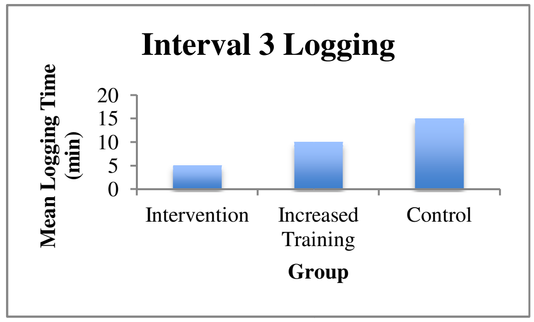

Figure 3.9: Graph showing the mean logging time for the three groups at interval 3.

In addition, change scores will be calculated for each of the groups, subtracting mean logging time at interval 3 from mean logging time at the baseline interval. If the expected results are found, the Intervention Group will show the largest change score value, the Increased Training Group will show the median change score value, while the Control Group will show the smallest change score value (see Figure 3.10). In other words, the Intervention Group will show the largest reduction in mean logging time compared to the baseline, the Increased Training Group will show a small reduction in mean logging time compared to the baseline, and the Control Group will show no change.

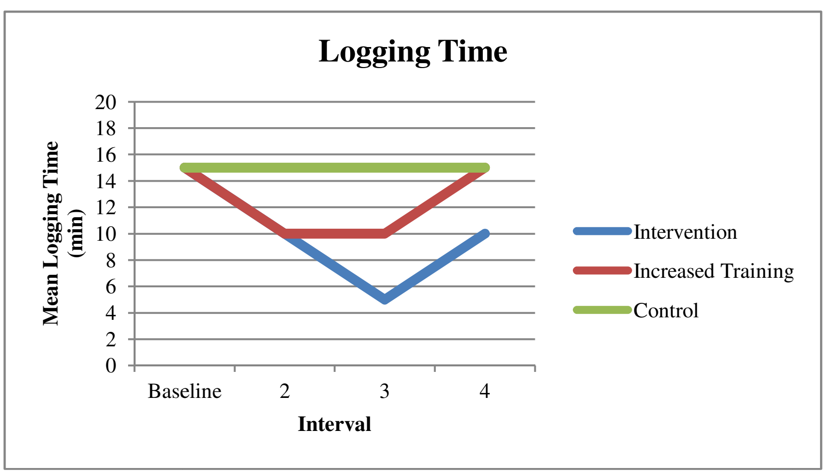

Figure 3.10: Graph showing the mean logging time for the three groups at each interval of the experiment.

Gate Chewing.

An ANOVA will be used to compare mean gate chewing time at the third interval between the three groups. If the expected results are found, the three groups will be significantly different, and pairwise t-tests will be conducted to determine the direction of the results. These tests will show that the Intervention Group will have a significantly smaller mean gate chewing time than the other groups. The Increased Training Group will have a slightly smaller mean gate chewing time than the Control Group, who will show the largest mean gate chewing time (see Figure 3.11).

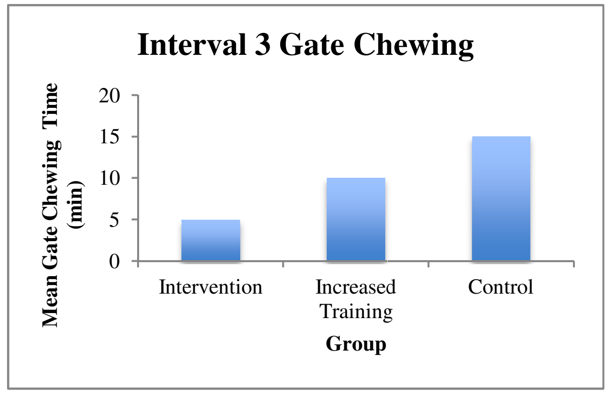

Figure 3.11: Graph showing the mean gate chewing time for the three groups at interval 3.

In addition, change scores will be calculated for each of the groups, subtracting mean gate chewing time at interval 3 from mean gate chewing time at the baseline interval. If the expected results are found, the Intervention Group will show the largest change score value, the Increased Training Group will show the median change score value, while the Control Group will show the smallest change score value (see Figure 3.12). In other words, the Intervention Group will show the largest reduction in mean gate chewing time compared to the baseline, the Increased Training Group will show a small reduction in mean gate chewing time compared to the baseline, and the Control Group will show no change.

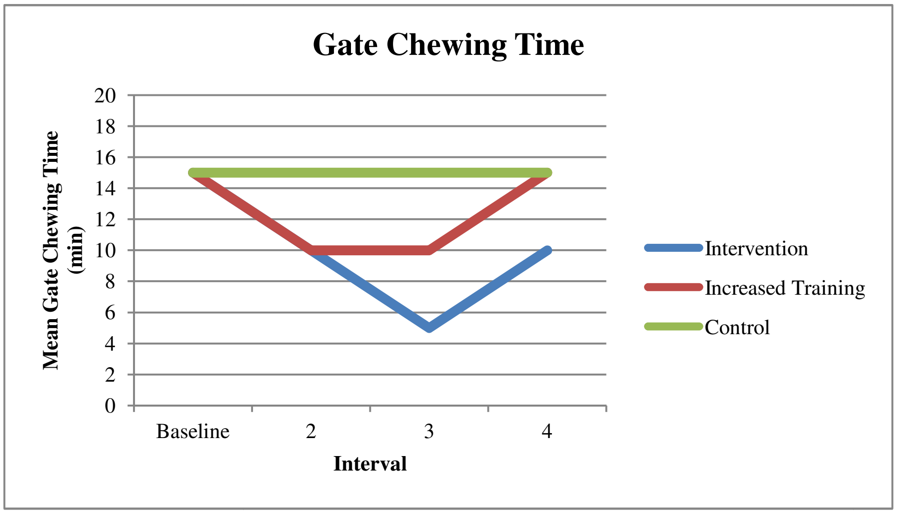

Figure 3.12: Graph showing the mean gate chewing times for the three groups at each interval of the experiment.

Interval 4: Blood Serum Cortisol Between Groups

An ANOVA will be used to compare mean blood serum cortisol levels at the fourth interval between the three groups. If the expected results are found, the three groups will be significantly different, and pairwise t-tests will be conducted to determine the direction of the results. These tests will show that the Intervention Group will continue to have the smallest mean blood serum cortisol level. The Increased Training Group and the Control Group will have the largest mean blood serum cortisol levels (see Figure 3.13).

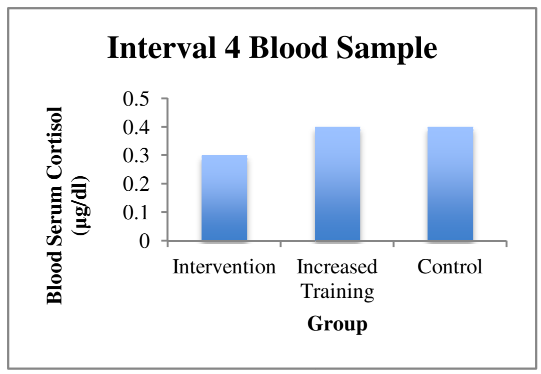

Figure 3.13: Graph showing the mean blood serum cortisol levels for the three groups at interval 4.

In addition, change scores will be calculated for each of the groups, subtracting mean blood serum cortisol levels at interval 4 from mean blood serum cortisol levels at interval 3. If the expected results are found, the Intervention Group will show the smallest change score, or smallest increase in mean blood serum cortisol levels compared to interval 3 (see Figure 3.8).

The Increased Training Group and the Control Group will each show a larger change scores, indicating a larger increase in mean blood serum cortisol levels compared to interval 3.

Interval 4: Stereotypic Between Groups

Logging.

An ANOVA will be used to compare mean logging time at the fourth interval between the three groups. If the expected results are found, the three groups will be significantly different, and pairwise t-tests will be conducted to determine the direction of the results. These tests will show that the Intervention Group will continue to have the smallest mean logging time. The Increased Training Group and the Control Group will likewise have equally large mean logging times (see Figure 3.14).

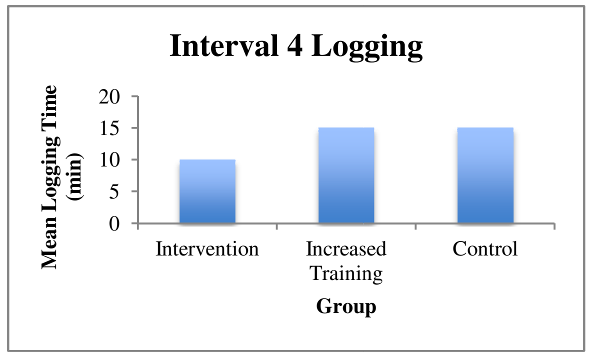

Figure 3.14: Graph showing the mean logging times for the three groups at interval 4.

In addition, change scores will be calculated for each of the groups, subtracting mean logging time at interval 4 from mean logging time at interval 3. If the expected results are found, the Intervention Group will show the smallest change score, or smallest increase in mean logging time compared to interval 3. The Increased Training Group and the Control Group will each show a larger change scores, indicating a larger increase in mean logging time compared to interval 3.

Gate Chewing.

An ANOVA will be used to compare mean gate chewing time at the fourth interval between the three groups. If the expected results are found, the three groups will be significantly different, and pairwise t-tests will be conducted to determine the direction of the results. These tests will show that the Intervention Group will continue to have the smallest mean gate chewing time. The Increased Training Group and the Control Group will likewise have equally large mean gate chewing times (see Figure 3.15).

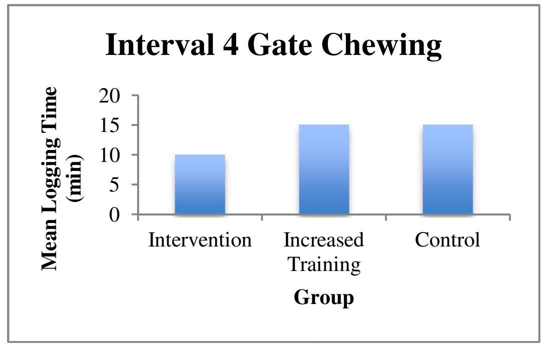

Figure 3.15: Graph showing the mean gate chewing times for the three groups at interval 4.

In addition, change scores will be calculated for each of the groups, subtracting mean logging time at interval 4 from mean gate chewing time at interval 3. If the expected results are found, the Intervention Group will show the smallest change score, or smallest increase in mean gate chewing time compared to interval 3. The Increased Training Group and the Control Group will each show a larger change scores, indicating a larger increase in mean gate chewing time compared to interval 3 (see Figure 3.12).

Correlations Between Stereotypy and Blood Serum

Six correlations will be performed to determine the relationship between stereotypic behavior and physiological markers of stress at the baseline and interval 3 for the three groups (see figures 3.16-3.19). If the expected results are found, blood serum cortisol levels will show strong, positive correlations with both logging time and gate-chewing time for each of the groups at each of the intervals.

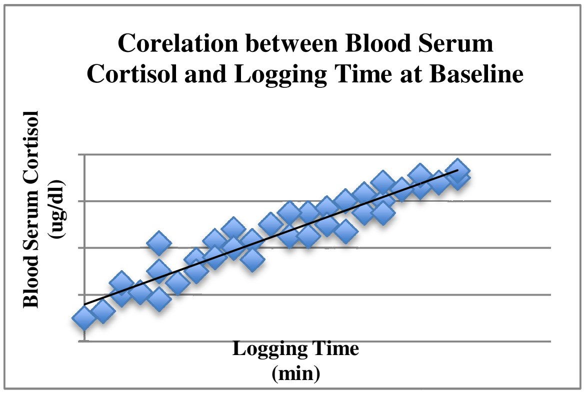

Figure 3.16: Graph showing the positive relationship between logging time and blood serum cortisol for all of the subjects at the baseline.

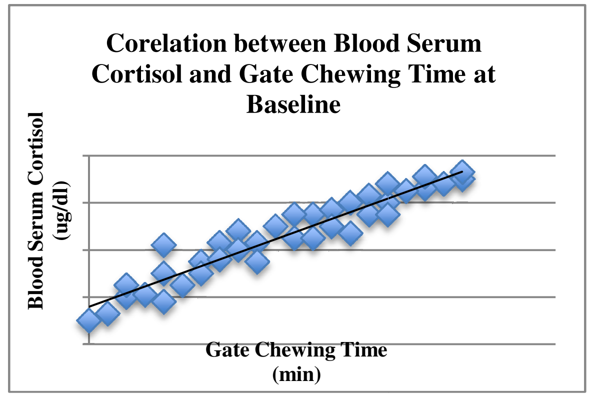

Figure 3.17: Graph showing the positive relationship between gate chewing and blood serum cortisol for all of the subjects at the baseline.

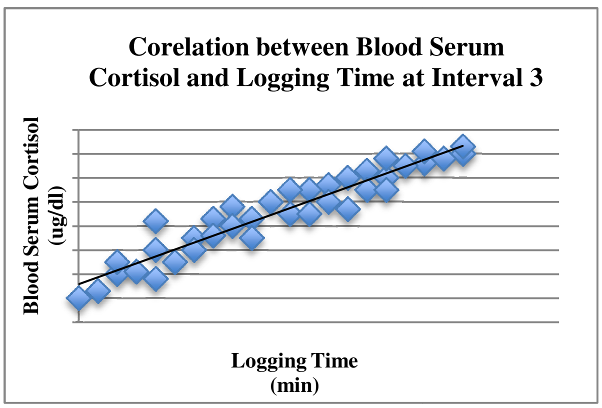

Figure 3.18: Graph showing the positive relationship between logging and blood serum cortisol for all of the subjects at Interval 3.

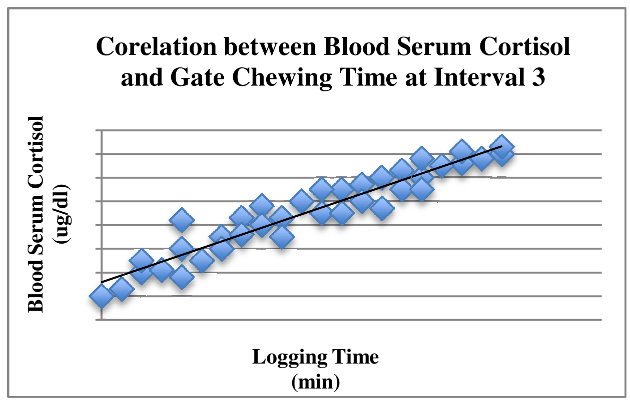

Figure 3.19: Graph showing the positive relationship between gate chewing and blood serum cortisol for all of the subjects at Interval 3.

Discussion

The goal of the present proposal was to develop a cognitive enrichment intervention to reduce stereotypic behavior in captive orcas. Stereotypic behavior is often associated with poor wellbeing, and may be the cause for a number of health deficiencies, and perhaps low life expectancy, in captive orcas (Jett & Ventre, 2012). Orcas are highly intelligent, emotional, and long-lived animals that are poorly adapted to the repetition, boredom, and stress of captivity. For these reasons, it is important to find a method of stimulating captive orcas mentally.

The predicted results demonstrate that orcas in the Intervention Group would show the smallest mean logging time, mean gate chewing time, and mean blood serum cortisol levels compared to the other groups at each interval of the experiment (excluding the baseline). The Increased Training Group would show a small but significant decrease in stereotypic behavior and blood cortisol levels compared to their baseline, while the Control Group would show no changes. The expected results would further demonstrate that, after the removal of the intervention, the Intervention Group would continue to show the least stereotypic behavior and smallest blood serum cortisol levels compared to the other groups. Finally, the expected results demonstrated strong, positive correlations between logging, gate chewing, and blood serum cortisol levels for each of the groups at each of the intervals. In other words, these expected results would show that the proposed intervention is the most effective method of reducing stereotypic behavior in the three groups, that it decreases the duration of stereotypic behavior even in the removal of the intervention, and that stereotypic behavior is strongly correlated with physiological symptoms of stress.

These findings suggest a possible theoretical model for the effects of stereotypic behavior: that poor mental welfare, caused by lack of stimulation, leads to the performance of stereotypic behavior, which subsequently leads to poor physiological welfare. Likewise, a cognitive enrichment intervention introduces stimulation, improves mental welfare, lessens the occurrence of stereotypic behavior, and decreases physiological symptoms of poor welfare.

Implications

The first implication of the expected results is that stereotypic behavior can be alleviated by mentally stimulating tasks. While the specific avenue through which cognitive enrichment affects stereotypic behavior was not the focus of the present study, the expected results would suggest that providing the subjects with the opportunity to engage in mentally challenging tasks decreases their tendency to perform abnormal repetitive behaviors. Therefore, it could be inferred that boredom, or lack of mental stimulation, could be a cause of stereotypic behavior.

The second implication is the link between stereotypic behavior and physiological signs of stress. The expected results demonstrate that stereotypic behaviors such as logging and gate chewing have a strong, positive correlation with blood serum cortisol levels, a known physiological measure of stress. Chronic, long term stress is known to lead to a variety of lasting health problems, and seriously depletes the immune system's ability to fight off infections. These expected findings demonstrate that animals that frequently perform stereotypic behaviors are also likely to show high physiological symptoms of stress, and suggest that stereotypy may be a symptom or cause of poor physiological welfare.

Thirdly, if the expected results were found, another implication would be that enrichment is most successful when it simulates a behavioral need. Behavioral needs are defined as "behaviors that are primarily motivated by internal stimuli and, if the animal is prevented from performing them for prolonged periods, the individual's welfare may be compromised." (Friend, 1989, as cited by Goldblatt, 1993). In the wild, orcas spend a large portion of their activity budgets hunting. Different populations of orcas utilize group-specific strategies to hunt particular prey, ignoring other potential targets for which they have not developed these tactics (Ford et al., 1998). The essential components of hunting are correct identification of prey, capture of prey, and having the opportunity to feed if they are successful. Similarly, subjects who participate in Cognitive Fetch are asked to identify a particular object, retrieve it, and receive food as a reward. Because the proposed intervention simulates orcas' behavioral need of hunting, the expected results would show that hunting constitutes a significant behavioral need of orcas and, furthermore, that allowing orcas to engage in behavioral needs can reduce stereotypic behavior.

Lastly, the fourth implication of the expected results would be additional evidence that cognitive enrichment improves the wellbeing of captive animals. The expected results would demonstrate that the cognitive enrichment intervention reduced stereotypic behavior, and with it, the detrimental effects these behaviors can have on orcas' physical health. Because stereotypic behavior is considered to be a sign of poor welfare in captivity, its reduction is a sign of improved wellbeing. Therefore, the expected results would demonstrate that cognitive enrichment is an effective method of improving the welfare of captive animals.

Strengths

The most evident strength of this proposal, if the expected results were found, would be the ability to lengthen the lifespans of captive orcas. As discussed previously, stereotypic behaviors such as tank chewing and logging are linked to immune system suppression (Jett & Ventre, 2012). It is likely that the immune system deficiencies caused by stereotypic behavior are the source of viruses such as pneumonia and septicemia, the two most common causes of death for orcas in captivity. If the proposed intervention were able to reduce the frequency of these behaviors, it is possible that the incidence of these viruses would decrease and, consequently, may lengthen the lifespans of captive orcas.

A second strength of this proposal would be simulating orcas' behavioral need of hunting. Despite the suggestion that behavioral needs should be taken into account when designing enrichment, marine mammal enrichment is largely based around enrichment toys. While these toys have been shown to reduce stereotypic behavior in the short term, they are inevitably unsuccessful in producing long-term results due to habituation. Further, they fail to simulate wild behavior or orcas' sophisticated cognitive abilities (Clark, 2012). It is thought that behavioral needs may be linked to stereotypic behavior in that, when an animal is prevented from performing important species-specific behaviors, they instead engage in repetitive stereotypic behavior with no function. By allowing captive animals to perform behaviors similar to those of their wild counterparts, the stress and boredom of their unnatural environment can be alleviated. For this reason, the proposed intervention is arguably more beneficial to captive orcas than enrichment in the form of toys, which do not mimic important wild behaviors.

A third strength of the proposed intervention is its combination of feeding and cognitive enrichment. Feeding enrichment, or administering food to a captive animal in a way that mimics their wild feeding behavior, has been found to reduce stereotypic behavior by increasing the naturalism of their captive environment. While feeding enrichment in the form of scatter-feeding and introducing live prey into an enclosure is common in terrestrial animals, it is difficult to implement this practice with marine mammals due to the necessity of keeping their tanks sterile (Goldblatt, 1993). Cognitive Fetch addresses this issue by requiring the animal to perform an identification and retrieval task similar to hunting, which results in a food reward. Because Cognitive Fetch simulates the behavioral components of hunting, it allows for feeding enrichment without the need for scatter feeding or live prey.

A fourth strength is that, in addition to enriching the subjects' feeding schedule, the proposed intervention would also constitute cognitive enrichment in that it allows the animal to challenge and stimulate its memory, decision-making, judgment, attention, problem solving, executive functioning, learning, and species-specific abilities (Maple & Perdue, 2013). When playing Cognitive Fetch, the animals are required to pay attention when learning the associations between toys and Shape Cards, utilize their memory to recall which toy is associated with which Shape Card, and use decision-making and judgment when selecting the correct object. For these reasons, it follows that this intervention constitutes cognitive enrichment and, further, that the subjects will experience the reduction in stereotypic behavior that cognitive enrichment is known to provide.

In addition to the benefits the proposal would offer the subjects themselves, this intervention would also avoid the problem of habituation, a common barrier to the success of enrichment. The term habituation refers to prolonged exposure leading to loss of interest in the intervention (Kuczaj et al., 2002). For Cognitive Fetch, habituation could be avoided in a number of ways, one of which is increasing the threshold of difficulty. Cognitive Fetch was designed to teach the subjects the concept of associating Shape Cards with objects, and once this concept is learned, it would be simple to expand it. For example, the rules of Cognitive Fetch could be broadened by asking the subject to retrieve multiple toys at once, teaching new Shape Card associations, adding rules to the game, or having the subjects play as a group. Because

Cognitive Fetch was designed to lend itself to expansion, the ways trainers could build upon the game are limited only by imagination.

Another strength of this proposed intervention is that it would be inexpensive to implement. Seaworld owns an expansive collection of enrichment objects and fish rewards, so the only expenses this intervention would generate would be the Shape Cards, which would be cheap and easily produced. Compared to structural additions and expansions of enclosures, which can be expensive and eventually lead to habituation, Cognitive Fetch is cheap, requires no noisy or time consuming construction, and its rules can easily be built upon to maintain the subjects' level of interest.

Weaknesses

As the proposed intervention has not been performed, it is difficult to predict which aspects of the design may weaken the interpretability of the expected results. However, one possible confounding variable may be the speed with which the subjects learn the associations. Because the design of the experiment stipulates that each orca must fulfill the success criterion of the Training Period before continuing to the Intervention Period, it is possible that variation in learning speed between subjects may result in differing levels of enrichment. Individual orcas are often known for being particularly quick at learning new behaviors for show routines, so it follows that certain subjects may learn the six associations more quickly than others in their group. These advanced subjects will continue practicing the game, which is essentially equivalent to playing Cognitive Fetch itself. Therefore, it is possible that the subjects in a single group will be receiving unequal amounts of enrichment.

Despite variation between subjects, it is also possible that the learning process may serve as enrichment in and of itself, leveling the field between those who learn the game at different speeds. Previous studies have noted that training to participate in a cognitive enrichment intervention often yields similar effects to the intervention itself. Further, some have reported that subjects perform behaviors which suggest they are highly motivated to participate in the training, such as voluntarily lining up outside the experiment room and producing recognizably excited vocalizations (Yamamashi & Hayashi, 2011). Therefore, it follows that the subjects who learn more slowly are being enriched by the training, just as those who quickly learned the associations are being enriched by repeatedly practicing the full game.

Future Directions

As discussed previously, Cognitive Fetch lends itself to expansion in that the concept of card and symbol associations can be applied in multiple ways. Future studies, for example on learning, vision, language, or memory, would benefit from this concept in that the subjects would already understand the idea behind identification, retrieval, and reward, and may pick up on new associations more quickly. Additionally, the model proposed in the present paper may prove useful in studies on enrichment itself. For instance, future studies could attempt to pinpoint how long the effects of enrichment last in the absence of the intervention itself.

A second interesting direction for future studies could be attempting to identify the specific causes for each stereotypic behavior, as well as determining whether individual stereotypic behaviors may be reduced by particular types of enrichment. Because the present proposal is meant to simulate hunting, it is my belief that certain boredom, aggression, and frustration related behaviors may be reduced, such as tank-chewing and logging. In contrast, other behaviors less related to the behavioral need of hunting could remain the same. Future studies should thus attempt to isolate the specific causes behind individual stereotypic behaviors.

Another future application of this intervention would be attempts to make captive orca enclosures even more naturalistic by simulating more wild behaviors. One example of this could be placing the enrichment objects inside of identical containers and asking the subjects to identify the requested object by using their echolocation. In the wild, echolocation is vital to a number of important behaviors, hunting being one of them (Barrett-Lennard, 1992). In captivity, however, orcas rarely have the opportunity to use this sense. Though it is currently unknown whether the inability to use echolocation impacts captive orca wellbeing, designers of captive environments should make every effort to ensure maximal naturalism, and thus an intervention of this sort may provide unforeseen benefits to its subjects.

A second example of increasing naturalism with this intervention could be showing the subjects the symbols underwater, or using objects that sink rather than float. In captivity, orcas spend an unnatural amount of time at the surface, which leads to dorsal fin collapse, sunburn, and UVR exposure that could suppress their immune system (Jett & Ventre, 2012). By playing the game underwater, the negative health effects of excessive time at the surface may be reduced.

A third method of increasing naturalism with this intervention would be playing a cooperative version of the game. Examples of this could include asking orcas to retrieve objects in tandem, using objects that require two orcas to move efficiently (such as a weighted barrel with two straps), or requiring that the subjects relay the objects from one orca to the next during retrieval. As discussed previously, orcas are highly social, and many of their hunting strategies rely on communication and cooperation between group members (Lopez & Lopez, 1985; Visser, 1999; Visser et al., 2008). Because Cognitive Fetch is meant to simulate hunting behavior, it follows that adding a social feature to gameplay may provide additional benefits to the subjects in that it more accurately mimics wild orcas' hunting experience.

Rehabilitation and release of captive orcas is a controversial subject, and many argue that orcas acclimated to captive environments would fare poorly in the wild. However, due to the declining populations of wild orcas and ethical concerns surrounding captivity, release could potentially become a viable option in the future. The present intervention could be utilized in rehabilitation in that it could be used to teach captive orcas the basic concept of hunting. The subjects could begin by playing the intervention described in the present proposal, then additional aspects of hunting could be incrementally included in gameplay. In addition to the future applications of Cognitive Fetch described above, the subjects could be taught to play the game using plastic replicas of wild prey appropriate for their ecotype instead of enrichment objects. For instance, captive orcas descended from fish-eating residents may use a plastic model of a school of fish, while orcas descended from mammal-eating transients may use a life-size seal toy. In previous attempts at rehabilitation, the subjects were moved into a sea pen, or a roped off area of a cove, prior to full release. If this protocol was in place, subjects could be taught to play the game by retrieving live prey placed into their enclosure.

General Discussion

In sum, the proposed intervention is expected to provide profound benefits for captive orcas due to its fulfillment of a behavioral need, ability to avoid habituation, and combination of feeding and cognitive enrichment. In the wild, orcas can live for up to 100 years, and are known for their intelligence, highly social natures, and impressive hunting abilities. In contrast, captive orcas perform abnormal, repetitive behaviors, are riddled with health issues, and experience significantly shorter lifespans. A likely symptom of captive orcas' poor mental and physiological wellbeing is stereotypic behavior, which is known to cause adverse health effects, and may even lead to death. Enrichment, or providing diversity and naturalism to a captive animal's environment, is a promising avenue for improving the conditions of captivity. For these reasons, interventions such as the one proposed here are of the utmost importance to improving the conditions for these highly intelligent creatures.

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Appendix A

The following is a table indicating the name, cause of death, sex, and place of death for all deceased captive orcas. This data was compiled by the Orca Project in 2013, and reorganized here using only information relevant to the proposal.

Name	Cause of Death	Sex	Place of Death
Ahab	Unknown	M	US Navy Hawaii
Ai (Al)	Candidiasis	F	Nanki Adventure World
Algonoquin	Twisted Intestine	M	Marineland of Canada
April	Malnutrition	F	Marineland of Canada
Asuka	Unknown	F	Sea Paradise
Athena	Unknown	F	Marineland of Canada
Baby Shamu II	Heart Defect	F	Seaworld of California
Belen (Bethlehem)	Unknown	F	Acuario Mundo Marino
Benkei	Acute Pneumonia	M	Nanki Adventure World
Benkei II (Ushikawa)	Malignant Lymphoma	M	Nanki Adventure World
Benkei III	Unknown	M	Private Residence, Japan

Betty	Pneumonia	F	Marineland Antibes
Bjossa	Chronic Bronchopneumonia	F	Seaworld of California
Bjossa's calf (no name)	Malnutrition	F	Vancouver Aquarium
Bjossa's calf (no name)	Ruptured Umbilical Cord. Died minutes after birth.	F	Vancouver Aquarium
Bonnie	Heart Failure	F	Marineworld Africa USA
Calypso	Unknown	F	Marineland Antibes
Canuck	Candidiasis	M	Seaworld of Florida
Canuck II	Chronic Kidney Disease	M	Seaworld of California
Caren (Calen)	Agranulocytosis	F	Kamogawa Seaworld
Chappy	Peritosis of Lumbar Bone	M	Kamogawa Seaworld
Chi	Unknown	F	Taiji Whale Museum
Chimo	Pneumonia, Streptococcal Septicemia, Chediak-Higashi Syndrome	F	Sealand of the Pacific
Clovis	Myotosis	M	Marineland Antibes
Corky	Mediastinal Abscess	M	Marineland of the Pacific
Corky II's Calf (No Name)	Asphyxiation	F	Marineland of the Pacific

Corky II's Calf (No Name)	Brain Damage	M	Marineland of the Pacific
Dzul-Ha (Shamu)	Unknown	M	Aquarama on Parade
Finna	Pneumonia	M	Vancouver Aquarium
Frankie	Influenza	M	Seaworld of California
Freyja (Patty)	Acute Enteritis	F	Kamogawa Seaworld
Goro	Acute Pneumonia	M	Nanki Adventure World
Gudrun	Septicemia, Bacteremia associated w/ Endomyometritis	F	Seaworld of Florida
Haida	Lung Infection	M	Sealand of the Pacific
Haida II	Necrosis of Cerebum/Fungal Infection	F	Seaworld of Texas
Haida II's calf (no name)	Pneumonia Multifocal Pyogranulomatous W/Gram+Filamentous	*	Seaworld of Texas
Halyn	Acute Necrotizing Encephalitis	F	Seaworld of Texas
Hoi Wai (Peanuts)(Suzie Wong)	Severe Intestinal Blood Loss	F	Ocean Park, Hong Kong
Hudson	Meningitis	M	Marineland of Canada
Hugo	Aneurysm Cerebral Artery	M	Miami Seaquarium

Hyak II (Tung-Jen)	Pneumonia	M	Vancouver Aquarium
Jumbo	Liver Dysfunction	M	Kamogawa Seaworld
Junio	Brain Damage	F	Marineland of Canada
Kahana	Severe Trauma, Intestinal Ganglioneuroma	F	Seaworld of Texas
Kalina	Acute Bacterial Septicemia	F	Seaworld of Florida
Kandu	Pneumonia, Liver Necrosis	F	Seaworld of California
Kandu II	Pneumonia	M	Marineland of Canada
Kandu III	Uraemia-Nephritis	F	Seaworld of California
Kandu V	Hemorrhage; Maxillary Bilateral Fracture	F	Seaworld of California
Kandu VII	Cancer	M	Marineland of Canada
Kanduke (Kandu IV)	Viral Leptomeningitis	M	Seaworld of Florida
Kandy	Acute Pneumonia	F	Marineland of Canada
Kanuck	Traumatic Shock	M	Marineland of Canada
Katerina	Severe Suppurative Hemorrhage. Bacterial Pneumonia.	F	Nanki Adventure World
Katy	Unknown	F	Seattle Marine

			Aquarium
Kenau	Hemorrhagic Bacterial Pneumonia	F	Seaworld of Florida
Kenny	Pneumonia	M	Marineland of the Pacific
Kianu (Clyde)	Gastrointestinal Disease	F	Nanki Adventure World
Kilroy	Gangrenous Pneumonia	M	Seaworld of California
Kim (Oum)	Lung Abscess	M	Marineland Antibes
Kim II	Pneumonia	M	Marineland Antibes
King	Acute Pneumonia	M	Kamogawa Seaworld
Kiska's calf (no name)	Drowning	M	Marineland of Canada
Kiva	Respiratory Failure	F	Marineland of the Pacific
Kona	Septicemia, also reported as Pulmonary Abscession	F	Seaworld of California
Kona II	Pulmonary Abscession	F	Seaworld of Florida
Kotar	Acute Hemorrhagic Pneumonia	M	Seaworld of Texas
Ku	Heart Failure	F	Port of Nagoya Aquarium
Kyosha	Brain Infection	F	Vancouver Aquarium

Kyu	Bacterial Pneumonia	M	Nanki Adventure World
Lil Nooka	Asphyxiation	M	Sea-Arama Inc
Lupa	Pneumonia	F	New York Aquarium
Maggie (Maggy)(Miss Piggy)	Birth Complications	F	Kamogawa Seaworld
Maggie's calf (no name)	Unknown	M	Kamogawa Seaworld
Magnus	Agranulocytic Anaemia	M	Harderwijk Dolphinarium
Malik (E-Day)	Immune System Deficiency	F	Marineland of Canada
Mamuk	Acute Streptococcal Septicemia	M	Sea-Arama Inc
Milagro	Unknown	M	Acuario Mundo Marino
Miracle	Drowning	F	Sealand of the Pacific
Moby Doll	Drowning, Skin Disease	M	Vancouver Aquarium
Nami	Ulcerative Colitis (Necropsy pending)	F	Port of Nagoya Aquarium
Namu	Drowning. Infection- Clostridium Perfrigens	M	Seattle Marine Aquarium
Nandu	Adrenal Gland Tumor	M	Aquarama Sao Paulo
Natsidalia	Heart Failure	M	Pender Harbour
Nemo	Thrombocytosis	M	Windsor Safari

			Park
Neocia (Baby October)	Internal Infection	F	Marineland of Canada
Nepo	Acute Bronchopneumonia	M	Marineworld Africa USA
Neptune	Appendicitis	M	Clackton Pier
No Name	Pneumonia	F	Saedyrasafnid Aquarium
No Name	Pneumonia	M	Clackton Pier
No Name	Unknown	F	Saedyrasafnid Aquarium
No Name	Unknown	*	Seattle Marine Aquarium
No Name	Unknown	*	Seattle Marine Aquarium
No Name	Unknown	*	Seattle Marine Aquarium
No Name	Unknown	F	Seattle Marine Aquarium
No Name	Unknown	F	Marineland of Canada
No Name	Nutritional Disorder	F	Nanki Adventure World
No Name	Heart Attack	M	Saedyrasafnid Aquarium
No Name	Acute Enterotoxaemia	F	Nanki Adventure World
No Name	Birth Complications, Delivered a stillborn	F	Saedyrasafnid

	calf		Aquarium
No Name	Haemophilia	M	Taiji Whale Museum
No Name	Neck Injury	M	Sealand of the Pacific
No Name	Traumatic shock. Ruptured kidney	M	Marineland of Canada
No name	Bacterial Pneumonia (Bronchopneumonia)	F	Nanki Adventure World
No name	Unknown	F	Japanese Fishermen Group
No name	Unknown	F	Utrish Dolphinarium
No name	Unknown	M	Kamogawa Seaworld
No name	Systematic Viral Infection (Herpes Grp)	M	Nanki Adventure World
No name (aka Father Kshamenk)	Unknown	M	Acuario Mundo Marino
Nootka (Knootka)	Pyogranulomatous; Pneumonia	F	Seaworld of California
Nootka II	Ruptured Aorta	M	Sealand of the Pacific
Nootka III	Perforated Post-Pyloric Ulcer. Abscess in Gastrointestinal Tract	M	Sealand of the Pacific
Nootka IV	Pneumonia, Septicemia	F	Seaworld of Florida

Nootka IV's calf (no name)	Infection. Extremely High White Blood Cell Count	M	Sealand of the Pacific
Nootka V	Unknown	F	Marineland of Canada
Nootka V's calf (no name)	Unknown	F	Marineland of Canada
Nova	Pneumonia. Starvation.	M	Marineland of Canada
Nyar	Suppurative Encephalitis; Osteoarthritis	F	Seaworld of Florida
Orky	Pneumonia, Influenza	F	Marineland of the Pacific
Orky II	Acute Bronchopneumonia Salmonellosis	M	Seaworld of California
Pascuala	Immune System Failure. Malnutrition. Infection.	F	Vallarta Dolphin Adventures
Patches	Mediastinal Abscess Salmonellosis	M	Marineland of the Pacific
Prince (Bubba)	Pseudomonas	M	Ocean Park
Ramu	Old Age	M	Seaworld of Florida
Ramu II	Unknown	M	Marineland Australia
Ramu IV	Unknown	M	Marineland Australia
Ran (Lan)	Unknown. Gave birth to premature calf on 8-26-04	F	Nanki Adventure World
Ran's calf (no name)	Broken skull	F	Nanki Adventure

			World
Ruka (Orca)	Traumatic shock	F	Nanki Adventure World
Sacchi	Pneumonia	F	Enoshima Aquarium
Sacchie's calf (no name)	Brain abscess	M	Enoshima Aquarium
Samoa	Mycotic Meningoencephalitis	F	Seaworld of Texas
Sandy	Cerebral Haemorrhage	F	Seaworld of Florida
Sarah	Unknown	F	Kamogawa Seaworld
Scarred Jaw Cow	Malnutrition	F	Pedder Bay
Shachi	Pneumonia	F	Sea Paradise
Shamu	Septicemia	F	Seaworld of California
Sharkan	Bacillus Pyocyanique	F	Marineland Antibes
Shawn	Pneumonia	F	Seaworld of California
Skana (Walter)	General Mycotic Infection	F	Vancouver Aquarium
Splash	Acute Perforating Gastric Ulceration w/ Associated Peritonitis	M	Seaworld of California
Spooky	Pneumonia, Colitis	M	Marineland of the Pacific
Sumar	Acute Intestinal/Mesentric Vol	M	Seaworld of California

Surfer Girl	Pneumonia. Kidney failure. Perforated Gastric Ulcer	F	Marineworld Africa USA
Tai	Unknown	M	Taiji Whale Museum
Taiji	Harpoon Wound	M	Taiji Whale Museum
Taima	Peracute Uterine Prolapse	F	Seaworld of Florida
Taku	Severe Multifocal Intestinal Pneumonia	M	Seaworld of Texas
Tanouk (Yamato)	Unknown	M	Sea Paradise
Tula	External Fungus	M	Harderwijk Dolphinarium
Vigga	Heart Failure, Brain/Lung Abscess, Pneumonia	F	Six Flags Marine World
Wanda (Newport)	Pneumonia, Gastroenteritis	F	Marineland of the Pacific
Whale (Wally)	Heart Failure	F	Munchen Aquarium
Winnie (Frya)	GI Tract Obstruction	F	Seaworld of Texas
Winston (Ramu)	Chronic Cardiovasular Failure	M	Seaworld of California
Yaka	Pleuritis/Pneumonia From Upper Respiratory Infection	F	Marineworld Africa USA
Zero	Unknown	*	Kamogawa Seaworld

Appendix B

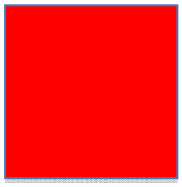
SUBJECT:___________________________

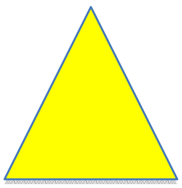
DATE:_______________________________

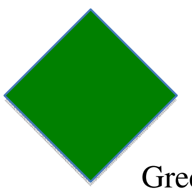
FACILITY:___________________________

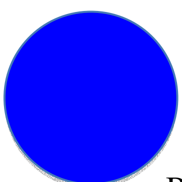
	Logging	Tank Chewing
6:00 A.M.		
8:00 A.M.		
10:00 A.M.		
12:00 P.M.		
2:00 P.M.		
4:00 P.M.		
6:00 P.M.		
8:00 P.M.		

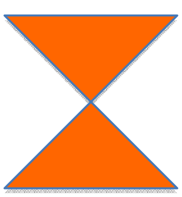
Appendix C

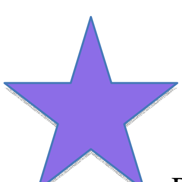

Red square. Associated with foam mattress toy.


Yellow triangle. Associated with foam stick.


Green Diamond. Associated with plastic ball.


Blue circle. Associated with fireman hose.


Orange hourglass. Associated with Frisbee.


Purple star. Associated with buoy.

Appendix D

<u>Training Log</u>

Subject:____

Date:____

Start Time:______________________________________

End Time:_______________________________________

Indicate which associations have been taught by checking the following boxes. Circle newly taught associations. Indicate the number of correctly and incorrectly retrieved trials for each object:

☐ Foam mattress and red square

[Correctly Retrieved: ___][Incorrectly Retrieved ____]

☐ Foam stick and yellow triangle

[Correctly Retrieved: ___][Incorrectly Retrieved ____]

☐ Plastic ball and green diamond

[Correctly Retrieved: ___][Incorrectly Retrieved ____]

☐ Fireman hose and blue circle

[Correctly Retrieved: ___][Incorrectly Retrieved ____]

☐ Frisbee and orange hourglass

[Correctly Retrieved: ___][Incorrectly Retrieved ____]

☐ Buoy and purple star

[Correctly Retrieved: ___][Incorrectly Retrieved ____]

Indicate the quantity and type of rewards received during the session:

☐ Salmon: ____

☐ Capelin: ____

☐ Herring: ____

☐ Mackerel: ____

☐ Smelt: ____

Provide a detailed, play-by-play account of the training session. Include information such as practiced associations, taught associations, rewards, and all observed behaviors of the subject:

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<u>Training Log</u>

Subject: __Shouka________

Date:___1/23/15__________

Start Time: ___1:30 P.M.___

End Time:___2:30 P. M.____

Indicate which associations have been taught by checking the following boxes. Circle newly taught associations. Indicate the number of correctly and incorrectly retrieved trials for each object:

☑ Foam mattress and red square

[Correctly Retrieved: _9][Incorrectly Retrieved: _2]

☐ Foam stick and yellow triangle

[Correctly Retrieved: ___][Incorrectly Retrieved: ____]

☑ Plastic ball and green diamond

[Correctly Retrieved: _6][Incorrectly Retrieved: _8]

☐ Fireman hose and blue circle

[Correctly Retrieved: ___][Incorrectly Retrieved: ____]

☑ Frisbee and orange hourglass

[Correctly Retrieved: 10][Incorrectly Retrieved: _4]

☐ Buoy and purple star

[Correctly Retrieved: ___][Incorrectly Retrieved: ____]

Indicate the quantity and type of rewards received during the session:

☑ Salmon: ____

☐ Capelin: ____

☑ Herring: ____

☐ Mackerel: ____

☐ Smelt: ____

Provide a detailed, play-by-play account of the training session. Include information such as practiced associations, taught associations, rewards, and all observed behaviors of the subject:

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