THE EFFECT OF AUDITORY ENRICHMENT ON ABNORMAL, AFFILIATIVE, AND AGGRESSIVE BEHAVIOR IN LABORATORY-HOUSED RHESUS MACAQUES (*Macaca mulatta*)

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THE EFFECT OF AUDITORY ENRICHMENT ON ABNORMAL, AFFILIATIVE,

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RHESUS MACAQUES (*Macaca mulatta)*

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ABSTRACT

THE EFFECT OF AUDITORY ENRICHMENT ON ABNORMAL, AFFILIATIVE, AND AGGRESSIVE BEHAVIOR IN LABORATORY-HOUSED RHESUS MACAQUES (*Macaca mulatta*)

by

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Research has shown that environmental enrichment can reduce abnormal behaviors in captive primates. However, auditory enrichment has generated mixed results. The purpose of this study was to determine if two types of auditory enrichment, white noise and designer music, were effective at reducing aggression and abnormal behavior, while also increasing affiliative behaviors in laboratory-housed rhesus macaques (*Macaca mulatta).* Forty laboratory-housed rhesus macaques at the Oregon National Primate Research Center were observed for 19 days over a 4 week period. During the first week, subjects were observed with no music to acquire a baseline level of behaviors (Phase 1). During week 2 subjects were exposed to white noise for three hours a day for five days (WN Phase). During week 3, designer music was played for three hours a day for five days (DS Phase). Observations continued into week four to determine if changes in behavior were residual (Phase 4). Results show that white noise was able to significantly increase affiliative behaviors, such as rates of social play and grooming. However, the white noise had minimal effect at reducing aggression or reducing the expression of abnormal behaviors. Designer music was found to decrease aggression but this was not correlated with the TEST period when the music was played. The designer music was found to significantly reduce abnormal behaviors and also significantly increase rates of social play and time spent in active exploration. Importantly, these behavioral changes were significant during the TEST period when the designer music was being played to the animals. The designer music was also effective at significantly reducing abnormal behaviors in those animals with adverse early rearing conditions (e.g., nursery-rearing). This study finds that auditory enrichment, specifically designer music, is an effective enrichment strategy to reduce abnormal behaviors and increase affiliative behaviors in laboratory-housed rhesus macaques.

CHAPTER I

INTRODUCTION

Macaca mulatta

The genus *Macaca* is the most widely distributed species of nonhuman primate. They inhabit a wide range of habitats from sea level to 2500 meters and can be found in India, China, Japan, Afghanistan, and Nepal (Fa 1989). Rhesus macaques (*Macaca mulatta*) are Chinese- or Indian-derived, quadrupedal, sexually dimorphic primates. They are robust and relatively large bodied (5.35kg to 7.71kg as adults) (Fa 1989). Rhesus macaques live in multi-male / multi-female groups and are characterized by female philopatry and male dispersal. Females form dominance hierarchies with young inheriting rank from their mothers (Nowak 1999). Rhesus macaques are characterized as highly aggressive, and reconciliations between former opponents shortly after an aggressive encounter, are rare (Augustsson and Hau 1999; deWaal and Johanowicz 1993; Thierry et al. 2000).

Macaques (*Macaca* spp.) are the most commonly-held species of nonhuman primate in laboratories throughout the world (Baker et al. 2009; Isa et al. 2009). They are phylogenetically close to humans, being catarrhines, and have a similar body structure and physiological make up which allows them to be a useful model in biomedical research (Isa et al. 2009). In 2000 there were 57,000 studies that utilized nonhuman primates or nonhuman primate biological material (Goodman and Check 2002). Of 2,937 articles published involving research with nonhuman primates in 2001, rhesus macaques (*Macaca mulatta*) were used in 18.4% of studies. Rhesus macaques are the overwhelming species of choice for neurological, AIDS, and pharmacological research (Carlsson et al. 2004). Due to the fact that rhesus macaques menstruate, they are also predominately used for reproduction studies, propagation of embryonic stem cells, and endometriosis research (Goodman and Check 2002).

The Laboratory Environment

Animals housed in biological medical laboratories face a wide range of stressors. A stressor is defined as anything that challenges homeostasis: the ability of the animal to maintain stable psychological and physiological states (Morgan and Tromborg 2007). Sources of stress in captivity range from environmental factors, such as artificial lighting, uncomfortable substrates, or elevated sound levels to behavioral stressors, such as maintenance in abnormal social groups, prevention of the animals' engagement in species typical behaviors, or the absence of a retreat space (Morgan and Tromborg 2007). For nonhuman primates in bio-medical laboratories these stressors are compounded with invasive medical procedures that may result in further deleterious effects on the animal.

Elevated stress levels in nonhuman primates can result in many negative psychological, physiological, and behavioral effects. Chronic activation of the stress response in mammals can lead to impaired reproduction, increased cortisol levels, and reduced immunosuppression (Abbott et al. 2003; Morgan and Tromborg 2007). Stress can also lead to increased abnormal behaviors and increased self-injurious behavior (Baker et al. 2009; Blanchard et al. 2001; Morgan and Tromborg 2007; Wells 2009). Humans with cognitive disorders, such as mental retardation and schizophrenia, have been shown to develop self-injurious behaviors (Lutz et al. 2003). Furthermore, humans that engage in self-biting behavior have been suggested to use pain as a means to outcompete unmanageable environmental stressors such as noise (Rommeck et al. 2009a). Similarly to humans, the development of these abnormal and self-injurious behaviors in laboratory-housed primates may develop as a coping mechanism and suggests a state of decreased welfare (Baker et al. 2009; Bloomsmith and Else 2005; Lutz et al. 2003).

Abnormal behaviors observed in laboratory-housed rhesus macaques include a wide range of abnormal, stereotypic, and self injurious behaviors that include pacing, rocking, back flipping, swaying, eye-poking, digit or self-sucking, self-clasping, and hair pulling, along with idiosyncratic ritualized movements (Baker et al. 2009; Lutz et al. 2003; Morgan and Tromborg 2007; Olsson and Westlund 2006). A survey of 362 laboratory-housed rhesus macaques in one National Primate Research Center found that 321 exhibited at least one abnormal behavior. The most common behavior observed was pacing (Lutz et al. 2003).

There are multiple risk factors for the development of abnormal behaviors discussed in the literature (Blanchard et al. 2001; Lutz et al. 2003; Morgan and Tromborg 2007; Olsson and Westlund 2006; Rommeck et al. 2009a). Nonhuman primates subjected to an impoverished rearing experience in early life (e.g., nursery-rearing) are at the greatest risk for developing abnormal behaviors (Bloomsmith and Else 2005; Coleman and Maier 2010; Lutz et al. 2003; Morgan and Tromborg 2007; Olsson and Westlund 2006). Rhesus macaques reared without their mothers developed a suite of abnormal and stereotypic behaviors including rocking, self-huddling, self-clasp, and self-sucking behaviors (Baker et al. 2009; Lutz et al. 2003; Rommeck et al. 2009a). Animals housed in environments that lack complexity or that prevent expression of species-typical behaviors, also risk developing abnormal behaviors (Baker et al. 2009). Though early life experience is strongly correlated with the development of abnormal behaviors, these behaviors can manifest in adult monkeys. Indeed, individuals housed singly as adults have been shown to spend more time engaging in stereotypic behavior (Lutz et al. 2003). In addition, exposure to stressful events, such as an increase in sound level or involvement in medical procedures, can lead to the expression of abnormal behaviors. In fact, an increase in sound level lead to increased rocking in chimpanzees (*Pan troglodytes*) (Lutz et al. 2003).

The aggressive nature characteristic of rhesus macaques in the wild can be even more pronounced in the laboratory setting. Aggression is frequently used to establish and reinforce social position (Augustsson and Hau 1999). When social groups become unstable in captivity, aggression becomes prolonged, intensified, and has the potential to escalate out of control possibly leading to physical trauma and decreased psychological well-being (McCowan et al. 2008). Furthermore, reconciliations and other post-conflict affiliative behaviors are infrequent in captive-housed rhesus macaques (deWaal and Johanowicz 1993; McCowan et al. 2008).

Reducing stress, thereby reducing or eliminating the expression of abnormal behaviors and reducing aggression, for captive primates is not only imperative for their welfare, but also necessary to improve research at biomedical laboratories around the world. Prolonged activation of the stress response in nonhuman primates can lead to increased cortisol levels as well as decreased immunosuppression (Morgan and Tromborg 2007) which could affect the results of biomedical tests. In order to determine the effectiveness of treatments and the validity of research conducted in these facilities, veterinarians and others who are involved with the care of laboratory animals must ensure that the animals utilized in biomedical studies are psychologically, physiologically, and neurologically healthy.

Environmental Enrichment

In 1985 an amendment to the Animal Welfare Act mandated the provision of physical environments to promote the psychological well-being of nonhuman primates (Bloomsmith and Else 2005). Environmental enrichment was first introduced as a research tool to understand how the brain reacts to experience and has since evolved to become the essential component for reducing stress and improving the psychological well-being of captive primates in zoological parks, sanctuaries, and laboratories (Benefiel et al. 2005). Environmental enrichment can be defined as "an animal husbandry principle that seeks to enhance the quality of captive animal care by identifying and providing the environmental stimuli necessary for optimal psychological and physiological well-being" (Shepherdson 1998). Environmental enrichment has two main goals: to promote species-typical behavior and to prevent, reduce, or eliminate abnormal behaviors (Bloomsmith and Else 2005). Baker et al. (2006) surveyed twenty-two laboratories housing nonhuman primates and found that 77.0% have a formal enrichment plan in place.

There are many types of enrichment strategies used for nonhuman primates and they can be divided into two general categories: providing the animals with inanimate forms of enrichment, and providing the animals with social contact. Inanimate enrichment can then be divided into passive and active forms of enrichment. Active forms of enrichment require some physical activity on part of the animal and may include toys, foraging devices, or the addition of perches and swings. Passive enrichment may include exposure to pictures, television, or sounds (Lutz and Novak 2005).

Active enrichment, specifically feeding enrichment, is the most commonly used enrichment strategy present in captive environments and is also the most represented in the literature (Baker et al. 2009; Baker et al. 2006; Honess and Marin 2006; Hoy et al. 2010; Lutz and Novak 2005; Reinhardt and Roberts 1997). Feeding enrichment is the manipulation of food, or method of providing food, and is meant to promote the species-typical feeding and foraging behaviors of the individual (Hoy et al. 2010). Some devices require simple extraction of food, from an artificial turf board for example. Other types of feeding enrichment, like puzzle boards, require more complex foraging techniques to acquire food. Feeding enrichment can also involve puzzle feeders or food frozen in ice cubes and are utilized to prolong foraging behavior in captivity (Lutz and Novak 2005). Baker et al. (2006) reported that 82.0% of facilities provided all nonhuman primates with feeding enrichment, with 77.0% of those distributing the enrichment two to six times per week. The addition of fleece-covered and turf-covered foraging boards resulted in singly-caged rhesus macaques displaying fewer behavioral disorders when utilizing the foraging boards (Reinhardt and Roberts 1997). Puzzle feeders, which increase time foraging, were found to result in decreased aggression in chimpanzees and decreased stereotypic behavior in rhesus macaques (Honess and Marin 2006). However, the expression of abnormal behaviors returned to baseline levels when the foraging boards were removed and a slight increase in aggression was observed in rhesus macaques when puzzle feeders were present (Honess and Marin 2006).

Another popular form of active enrichment is the addition of toys or other manipulanda into the environment. Baker et al. (2006) found that 82.0% provided all primates with some form of manipulanda. Laboratories can often be barren environments and opportunities for manipulation and exploration are limited. The addition of items such as balls, rubber dog toys, or nylon bones, help to stimulate naturally curious nonhuman primates (Lutz and Novak 2005). In fact, olive baboons (*Papio anubis*) presented with an array of manipulanda (nylon bones, Kong toys, and Plaque Attackers) were found to decrease abnormal and cage-directed behavior (Honess and Marin 2006).

Structural enrichment is also a widely used form of active enrichment, found in 73.0% of twenty-two laboratories surveyed, and may include the addition of perches, swings, rope, or other climbing structures into the enclosure (Baker et al. 2006; Hoy et al. 2010). A more complex housing environment encourages spatial learning and reduces boredom and habituation, thereby promoting psychological well-being in captive primates (Honess and Marin 2006).

Many studies have explored the effectiveness of housing and feeding enrichment, as well as the benefits of introducing toys or other manipulanda into the environment, yet the majority of these studies discuss what is practical or possible without much insight into how these types of enrichment are used on a long-term basis, nor do they address possible differential responses due to species differences (Baker et al. 2006). Furthermore, active enrichment devices, such as foraging boards or manipulanda, help to reduce the expression of less severe forms of abnormal behavior, such as pacing, but were unsuccessful at ameliorating the exhibition of more severe abnormal behaviors (e.g., self-injurious behaviors) (Rommeck et al. 2009a).

There are also potential safety risks for animals with all forms of active enrichment. The addition of manipulanda and structural enrichment presents choking and strangulation hazards and have also lead to the death of some captive primates (Bayne 2005), resulting in closer examination of appropriate enrichment devices and possible alternatives. One such alternative is the implementation of a sensory enrichment program.

The effectiveness of sensory enrichment, specifically auditory enrichment, remains even less evaluated than forms of active enrichment (Wells 2009). Passive enrichment, visual and auditory stimuli, is less used in the captive environment than feeding enrichment or the addition of manipulanda. Of 219 zoological parks surveyed only about 4.0% provided auditory or visual enrichment daily (Hoy et al. 2010). Still underutilized, visual and auditory enrichment are more common in the laboratory setting, but the effects on psychological well-being are less understood (Wells 2009). Visual enrichment includes the addition of mirrors or exposure to pictures or video. When rhesus macaques were exposed to videotapes showing conspecifics they became more active and slept less (Platt and Novak 1997). It is hypothesized that these types of sensory enrichment distract the animals from engaging in abnormal behaviors (Rommeck et al. 2009a). Though many of the federally-funded nonhuman primate research centers utilize video enrichment, at present there are no studies to determine the frequency of use of visual enrichment in laboratories (Personal communication: Dr. Kristine Coleman, May 2010; Dr. Lawrence Williams, February 2011).

Auditory Enrichment

Auditory enrichment may include exposure to ecological sounds or various genre of music through a radio or stereo system (Lutz and Novak 2005). Auditory enrichment remains even less evaluated than visual enrichment and since captive primates are already exposed to some sort of auditory stimuli, such as noise from intercom systems, it is imperative to determine what sounds are beneficial to nonhuman primate well-being and what sounds might cause harm. The ambient sound level in zoos can increase from 62 decibels (dbl) to 72 dbl (e.g., conversational speech to moderate street traffic) when there is an influx of visitors (Morgan and Tromborg 2007). Furthermore, many zoological parks play ecological sounds throughout the park to enhance visitor experiences, yet little is known about how animals raised in captivity react to these sounds (Patterson-Kane and Farnworth

2006). In fact, current research suggests that captive-born nonhuman primates respond negatively to ecological or inter-species sounds by increasing agitation and displays (Drewsen 1989; Ogden et al. 1994).

Primates in laboratories are also exposed to a wide range of auditory stimuli. The noise of conspecifics or cage cleaning and other husbandry duties can raise the decibel level to 85 (e.g., subway) in some of these facilities, far beyond the average level recorded in the wild which ranges from 20 dbl – 40 dbl (e.g., whisper, buzz of a mosquito) (Morgan and Tromborg 2007). Furthermore, many laboratory-housed primates are routinely exposed to radio or stereo music that is played by animal care staff in the facility. Some laboratories have found that elevated noise levels from nearby construction or building maintenance has resulted in decreased breeding success or an observable change in the animals' behavior (Abbott et al. 2003). Research suggests that unpredictable noise in the laboratory can also increase the exhibition of coping mechanisms such as stereotypies (Patterson-Kane and Farnworth 2006).

Additionally, the auditory sensitivity of primates differs from that of humans (Coleman 2009). Some species have a greater sensitivity to high or low frequency sounds (Coleman 2009). It is commonly believed that apes, monkeys, and humans have identical auditory thresholds. Although these frequency thresholds may be similar across taxa, threshold differences between humans, apes, and monkeys are notable(Coleman 2009). For example, Old World monkeys hear an octave higher than humans (Prescott 2006). At 60 dbl the highest auditory frequency humans can perceive is 20 kilohertz (kHz), all frequencies above that are termed ultrasonic (Prescott 2006). Rhesus macaques can hear frequencies up to 42 kHz at 60 dbl (Prescott 2006). This means that sounds humans may not find bothersome or even acknowledge (e.g., air conditioners, computer monitors) could be a source of discomfort for primates housed in laboratories (Coleman 2009). The implementation of an auditory enrichment program may help to mask some of these noises as well as help to maintain a more constant decibel level in these facilities.

Music has been shown to have many positive physiological and behavioral effects in humans. Studies have shown that music is effective at reducing stress, reducing negative emotional states and decreasing hostility, fatigue, sadness, and tension (Avers et al. 2007; Labbe et al. 2007; McCraty et al. 1998). Exposure to music prior to clinical procedures resulted in lower anxiety scores and lower heart rates(Hayes et al. 2003; Wang et al. 2002). I suggest that auditory enrichment can result in similar positive effects for nonhuman primates.

Several studies have shown the positive effects of auditory enrichment for primates housed in captivity. Research conducted by Wells et al. (2009) found that classical music decreased conspecific-directed aggression and abnormal behavior in western lowland gorillas (*Gorilla gorilla gorilla*). In addition, radio music resulted in reduced aggression and agitation as well as an increase in social affiliations in chimpanzees (Howell et al. 2003). Radio music was also found to significantly lower heart rate in baboons (*Papio hamadryas anubis*)(Brent and Weaver 1996). Auditory enrichment utilizing white noise was found to improve working memory performance in stump-tailed macaques (*Macaca arctoides*) (Carlson et al. 1997). Furthermore, rhesus macaques increased affiliative behavior when exposed to light jazz music (Honess and Marin 2006).

However, despite positive effects regarding auditory enrichment, McDermott and Hauser (2006), found that when given a choice between slow tempo music and silence, tamarins and marmosets (Family: Callitrichidae) chose silence. However, when rhesus macaques were allowed to control the onset and offset of auditory enrichment they chose to play the music for more than half of the available time, preferring jazz and Dixieland selections over animal noises (Drewsen 1989). Yet, research found that radio music played at 70 to 80 dbl elevated salivary cortisol levels in marmosets suggesting an increase in stress (Patterson-Kane and Farnworth 2006). Furthermore, previous studies have resulted in an increase in stress related behaviors such as elevated activity and displays in captive lowland gorillas (Ogden et al. 1994). Exposing a group of macaques to Mozart resulted in negative effects in their ability to perform a delayed response task (Carlson et al. 1997).

Differences in individual preference make the implementation of an auditory enrichment program difficult. Just as all humans do not find the same genre of music enjoyable, it is a reasonable assumption that not all nonhuman primates find the same music enjoyable. Little is known about the individual musical preferences of captive primates, but with more research evaluating auditory enrichment, results may show that a variety of music is most beneficial for socially-housed animals. Indeed, a colony of captive chimpanzees significantly reduced rates of aggression and increased rates of social play when a variety of musical genre were played (i.e. classical, country, ethnic, oldies, and new age) (Howell et al. 2003; Ogden et al. 1994). However, some research suggests that monkeys respond favorably to music to which they have been previously exposed (Drewsen 1989; Wright et al. 2000). Similarly to humans, monkeys may prefer music that is most familiar to them. Still, it may not be the specific genre, familiarity, or novelty of music to which the monkeys respond, but to the tempo or specific instruments used in the selections. In fact, research has shown that marmosets and tamarins prefer lullabies and slow tempos over fast tempo techno music (McDermott and Hauser 2007). Furthermore, rhesus macaques were found to have a perception of tonality that is functionally similar to humans (Wright et al. 2000), demonstrating a sensitivity to tonal hierarchies that suggests a sophisticated musical ability.

There are many aspects of a musical passage and monkeys may respond more to tone or tempo than to melody (Wright et al. 2000).

Despite several studies that examine nonhuman primates and their reaction to music, many of these center on the ability of these animals to perform a task while exposed to a specific musical genre (Carlson et al. 1997; Kojima 1990; Wright et al. 2000). In other studies the animals are only briefly exposed to music, from 10 minutes to 50 minutes a day, or conversely, played music for eight or more hours per day (Brent and Weaver 1996; Ogden et al. 1994; Videan et al. 2007). With the duration of exposure to music being less than one hour or more than eight hours a day it becomes difficult to assess whether it is actually the auditory stimuli that is affecting the individual's behavior. If the time of exposure to the auditory stimuli is too short it is hard to determine whether there was an actual change in behavior. Conversely, if the time of exposure to the stimuli is too long there are a myriad of other variables that could have lead to a change in behavior. Furthermore, little research discusses differences in auditory sensitivity. A concise understanding of the interspecies differences among and between human and nonhuman primates' auditory sensitivity and function allows the determination of the best tempo, volume, frequency, intensity and genre of music that is expected to be most beneficial to a specific species of nonhuman primate. Acknowledging differences in auditory sensitivity among species, as well as behavioral differences, will allow for the selection of a species-appropriate choice of music.

A survey of zoological parks found that the factors limiting the provision of enrichment were time needed to prepare and distribute enrichment as well as the cost of producing enrichment (Hoy et al. 2010). Auditory enrichment, specifically playing music, provides laboratories with a low cost option for environmental enrichment that takes virtually no time to execute. And unlike foraging boards or manipulanda, music has the added benefit of being available to all animals within hearing range. Furthermore, most humans find music relaxing and entertaining. Thus, auditory enrichment can improve working conditions for animal technicians leading to more positive interactions with the animals in their care resulting in less stress for both humans and nonhuman primates.

I suggest that careful attention to musical selection and longer durations of exposure to these auditory stimuli will result in the implementation of an auditory enrichment program that will reduce contingent stress, increase affiliative behaviors, and decrease abnormal and self-injurious behaviors and aggression. In addition to improved animal welfare, the implementation of an effective auditory enrichment program will improve the quality of bio-medical research by reducing stress levels that can alter physiology in primates.

Purpose of Study

The purpose of this study was to determine if two types of auditory enrichment, white noise and designer music, were effective at reducing abnormal behaviors and aggression, while also increasing affiliative behaviors in group housed rhesus macaques (*Macaca mulatta*). Some research suggests that positive changes in behavior in response to auditory enrichment are the result of the masking effect of the music. Perhaps it is not the musical quality to which the animals are responding, but the ability of the music to block out noises from conspecifics or husbandry activities. White noise was selected for this study to test the hypothesis of a masking effect.

A genre of music described as "designer music" was chosen to test the effects of a specific genre on the behavior of nonhuman primates. Designer music is composed with the goal of improving human listeners' mental and emotional states and to improve cardiovascular function and enhance automatic nervous system function (McCraty et al.

1996). For example, Medical Resonance Therapy Music® uses sound frequency patterns built into musical soundtracks to stimulate brainwave frequencies associated with specific states of mind. The tracks selected for this study, composed by Doc Lew Childre, have been composed with the intended goal of improving listeners' mental and emotional states and to enhance autonomic nervous system function. Indeed, the autonomic nervous system affects cardiovascular, neuroendocrine, and immune system function (McCraty et al. 1998). This genre was found to reduce cortisol levels in humans by 23.0%, while also decreasing hostility, fatigue, and sadness, and increasing relaxation (McCraty et al. 1998). Another study found that exposure to designer music produced a significant increase in S-IgA, a class of immunoglobulin responsible for local immunity, in humans (McCraty et al. 1996).

Classical music was not chosen for this study due to the fact that it is the genre most represented in the literature and produces inconsistent results (Carlson et al. 1997; Hinds et al. 2007; Howell et al. 2003; Patterson-Kane and Farnworth 2006; Videan et al. 2007). Zoo visitors reported that nonhuman primate species seemed more relaxed and happy when played ecological sounds versus classical music. However, nature sounds were not selected for use in this study due to the fact that there is no reason to suspect that captive-born nonhuman primates would respond favorably to sounds of nature. Laboratory-housed primates are not familiar with rainforest sounds and the noise of other species on these tracks can be stressful for nonhuman primates who are not familiar with these species and cannot locate the source of these sounds.

I hypothesized that both genre of music, white noise and designer music, would result in decreased abnormal behaviors, decreased aggression and an increase in affiliative behaviors. I predicted that the masking effect of the white noise would yield greater decreases of abnormal and aggressive behaviors than designer music, but that designer music would have greater success at increasing affiliative behaviors. I predicted the designer music would result in similar behavioral changes in nonhuman primates as it did in humans, such as decreases in hostility, fatigue, stress, and tension (McCraty et al. 1998), and that the decrease of these behaviors would result in an increase in affiliative behaviors in nonhuman primates.

CHAPTER II

METHODS

Training and Compliance

This study was conducted at the Oregon National Primate Research Center (ONPRC) from May 25, 2010 to June 21, 2010. The ONPRC is one of eight National Primate Centers and houses 4300 monkeys, most of whom are group housed. The center employs approximately 110 animal care staff, including an enrichment staff of eight.

The ONPRC animal care program is compliant with the United States Department of Agriculture (USDA) and accredited by Association for Assessment and Accreditation of Laboratory Animal Care-International (AAALAC-International). The ONPRC Institutional Animal Care and Use Committee (IACUC) (IACUC code: 081) as well as the Texas State University-San Marcos IACUC (IACUC code: 1009_0329_08) approved this study.

I completed five training courses at the ONPRC to ensure that data were accurately acquired and to ensure that all safety measures were followed. Two of these courses, General Safety training and Non-Human Primate Biosafety training, were taught by a certified Environmental Health and Radiation Safety instructor at the ONPRC facility. The remaining three courses; General Safety, Laboratory Safety, Responsible Conduct of Research for All, and Responsible Conduct of Research Involving Animal Subjects, were online training modules. All laboratory workers are required to wear scrubs, as well as other mandatory personal protective equipment, including safety goggles, face mask, latex gloves, and a coverall.

Subjects

Subjects included 24 female and 16 male rhesus macaques housed in one of seven social groups of four to eight individuals. Females ranged in age from 7.8 months (m) to 8.1 years (y) of age at study onset with a sample mean age of 2.14y. The female sample included four infants (<1y of age), 17 juveniles (1y - <5y of age), and three sub-adults (>5y of age). Ten females were mother-reared in large outdoor social groups and ten were mother-reared in single cages with visual and sometimes tactile contact to conspecifics other than their mother. Four individuals were nursery-reared, with their mother less than eleven days and reared in the nursery until approximately seven months of age. Males ranged in age from 10m to 3y of age at study onset with a sample mean age of 1.1y. The male sample included four infants and 12 juveniles. Three males were mother-reared in group housing, eight were mother-reared in single or paired cages and five were nursery-reared.

The animals were fed standard monkey chow (High Protein Monkey Chow, Ralston-Purina, St. Louis, MO) twice a day, and were given fresh produce or other food enrichment daily. Water was provided freely through automatic Lixit® watering systems. The lights were on 12 h per day, from 07:00 h to 19:00 h and the temperature was maintained at 24 ± 2°C. Subjects participated in the ONPRC behavioral management program to ensure their psychological health and well being.

I maintained a hands-off policy with the animals, and had no physical contact with them throughout the duration of the study. Eye contact was also avoided with the subjects since monkeys consider direct eye contact a threat and eye contact tends to make primates fearful and agitated (Singh and Gupta 1980).

To understand the effectiveness of audio as enrichment the animals schedule was not changed or altered for this study. In other words, the animal care or clinical technicians were allowed to enter the room at anytime for feedings and to provide feeding enrichment. Observations were not recorded during cage cleanings. The veterinarians were also allowed to enter at any time to survey the animals as required by ONPRC policy.

Housing

The subjects were housed in Colony Run 6 at the ONPRC. Run 6 is a wing of the Colony Housing building with eight pens, four on each side of the room allowing the subjects visibility of conspecifics (Figure 1). There are two 56sqft pens, two 60sqft pens and four pens measuring 84sqft. Each pen was outfitted with an enrichment swing and perches as well as Kong toys and rubber balls. The subjects rotated cages while maintaining the same social group, however changing of cages was random and did not occur over the last two weeks of the study.

Figure 1. Run 6. Clockwise from the left: Pen 8 (out of view), Pen 7 (out of view), Pen 6, Pen 5, Pen 4, Pen 3, Pen 2 (out of view), Pen 1 (out of view).

All eight pens were occupied by the seven groups with one group occupying both pen 1 and 2. Group A housed four females mother-reared in large, outdoor social groups (MRG) ranging in age from 2y to 8y with an average group age of 5.13y (Table 1). Group B housed four females and one male, all MRG and ranging in age from 2y to 3y with an average group age of 2.78y. Following preliminary observations one female was removed from the group after suffering a broken leg. She was not returned until the study was completed. Group C housed one female and four males all nursery-reared: with their mother less than eleven days and reared in the nursery until approximately seven months of age (NUR). All subjects in group C were around 1y of age with an average group age of 1.18y. Group D housed five females and two males. Five subjects were mother-reared in cages and had visual and in some cases tactile contact with conspecifics other than their mother (MRC), one NUR, and one MRG. The subjects in group D ranged in age from 7.8m to 1y with an average group age of 11.0m. Group E housed three females and five males ranging in age from 10m to 1y with an average group age of 1.20y. Two subjects were MRG, one NUR, and five MRC. Group F housed two females and three males aged 11m to 1y with an average group age of 1.80y. All subjects in group F were MRC. Group G housed five females and one male ranging in age from 1y to 3y with an average group age of 2.56y. Three subjects were MRC, two NUR, and one MRG.

Group G was housed in pens 1 and 2, Group A in pen 3, and Group B in pen 4, all on the left side of Run 6. Groups C, D, E, and F were housed on the right side on Run 6 and rotated among pens 5-8 for the first two weeks of the study.

Table 1. Run 6 demographics.

Group	**Average Age**	♂	♀	**Rearing History**
A	5.13y	---	4	All MRG
B	2.78y	1	4	All MRG
C	1.18y	4	1	All NUR
D	11.0m	2	5	5 MRC, 1 NUR, 1 MRG
E	1.20y	5	3	5 MRC, 2 MRG, 1 NUR
F	1.80y	3	2	All MRC
G	2.56y	1	5	3 MRC, 2 NUR, 1 MRG

(y = years, m = months. MRG = mother-reared in social groups, MRC = mother-reared in single cages, NUR = reared in the nursery from 1-11 days of age until approximately seven months of age.)

Behavioral Measures

Preliminary observations were recorded from May 19, 2010 to May 22, 2010 to acclimate the animals to my presence. By acclimating the animals to my presence prior to collecting formal observations it reduced the possibility the any change in the study subjects behavior may was a result of increased familiarity with myself. Formal observations were recorded May 25, 2010 to June 21, 2010, Monday through Friday, with the exception of replacing two Fridays for Saturdays during the second and third weeks of the study due to unforeseen conflicts at the ONPRC. Observations were recorded from 09:30 to approximately 16:30. I recorded observations using a clipboard and a check sheet of behaviors (see Appendix B).

A group scan sampling method was used to record behavior. I scanned each social group, starting with pen 1 and instantaneously recorded the behavior of each subject in the group. I then moved counter clockwise on to the next pen until one scan sample was collected for each social group ending at pen 8. It took 30 seconds to scan each social group, or pen, and 4 minutes 30 seconds total to scan all seven social groups. There were 2 minute 30 second intervals between scans, allowing for 10 scans per group per hour. There were a total of 70 scans per hour (10 for each social group), 350 scans per day, and 1,750 scans per week, for a total of 6,650 scans (950 per group) over the four week study. The order of scans was not changed throughout the study in order to familiarize the subjects with the researcher and the methods of observation.

Scan samples were recorded in three time blocks each day that included one hour in the morning where no sound was played starting at approximately 09:30 to determine baseline levels of behaviors for that day (PRE period). Scans were then restarted between 12:00 and 12:30 and lasted for three hours (TEST period). The auditory enrichment was played only during TEST. Fifteen minutes after TEST, approximately 15:15, observations were recorded for another hour without any sound to determine if changes in behavior were residual (POST period) (Table 2). Distribution of feeding enrichment typically occurred during TEST, and regular night feeding during POST.

Table 2. Schedule of music exposure during the WN phase and the DS phase.

09:30am – 10:30am	PRE
12:00pm – 13:00pm	TEST
13:00pm – 14:00pm	TEST
14:00pm – 15:00pm	TEST
15:15pm – 16:15pm	POST

Since I was initially unfamiliar with the subjects, the monkeys were scored as a number indicating how many animals in that group were performing a specific behavior during that exact scan. Each subject's behavior and relative location to its cage-mates was recorded for each scan. Behaviors were recorded using a rhesus macaque ethogram that was devised by ONPRC researchers and modified for this specific study (see Appendix B). During each scan subjects were recorded in one of five locations: alone, in proximity, touching, huddling, or in ventral contact with another. The behavior of each subject at the time of the scan was recorded as one of twenty-one possible behaviors detailed in the ethogram. For example, one scan of the eight individuals in group E would yield the following results: 2 in proximity eating, 3 alone foraging, 2 touching sleeping and 1 in proximity locomoting. For abnormal behaviors, the specific type of abnormal behavior displayed by the individual was recorded in the notes section of the ethogram (e.g., pacing, eye-poking, self-sucking, etc.).

In addition to formal scans, instances of aggression were recorded *ad libitum* throughout the observation times. The instances of aggression recorded outside of the formal scan times, termed aggressive bouts, needed to meet certain criteria to be included in the analysis. Aggressive bouts had to include two or more individuals and last for a period of > 10 seconds. Bouts also had to include at least two different aggressive behaviors (e.g., chase and grab; bite and hit).

Auditory Enrichment

The study was split into four phases (Table 3). Phase 1 consisted of no music or sound and provided baseline behavior levels for the study. During Phase 2 white noise was played for three hours a day for five days. During Phase 3 designer music was played for three hours a day for five days. Phase 4 consisted of no sound to see if any changes in behavior were residual.

Table 3. Auditory enrichment schedule.

	Phase	**Monday**	**Tuesday**	**Wednesday**	**Thursday**	**Friday**	**Saturday**
Week 1	1	---	X	X	X	X	---
Week 2	2	WN	WN	WN	WN	---	WN
Week 3	3	DS	DS	DS	DS	---	DS
Week 4	4	X	X	X	X	X	---

(X = No music played, WN = white noise, DS = designer music, --- = no observations taken).

Subjects were exposed to two types of sound for two weeks of the study (Phase 2 and Phase 3). Following the observations that occurred during week 1 of the study (Phase 1) animals were played white noise from a CD entitled “White Noise for Babies” (see

Appendix C for details). The track "Ocean Waves" was looped to play for the complete three hours of the TEST period. Scans were started thirty seconds after the sound had begun playing to ensure the researcher was in position to accurately record the behavior of the first social group. The white noise (WN) was played for five days during the TEST period for a total of fifteen hours in Phase 2.

Following the WN, the subjects were played tracks from composer Doc Lew Childre's CD's "Heart Zones", "Quiet Joy", and "Speed of Balance". This music is termed "designer music" (DS) and is described by the composer as instrumental music designed to physiologically benefit the listener (McCraty et al. 1996). This genre was found to decrease cortisol levels by 23.0% and increase salivary IgA, a class of immunoglobulin responsible for local immunity, in humans (McCraty et al. 1996). Thirteen tracks were selected and the playlist was looped to last the entire TEST period for a total of fifteen hours in Phase 3. Certain tracks were not used in the study. These tracks were eliminated using the researchers' discretion. Tracks that included excessive bass, loud crescendos, or were perceived to be too fast pace were eliminated (see Appendix C for details and playlist).

With minimal vocalizations and minimal activity from the subjects the decibel level (dbl) averaged between 65 and 72dbl in Run 6, reaching a high of 87 dbl. In conjunction with approval from the ONPRC IACUC, I decided that all audio would be played at 70-72dbl. This decibel level assured that the music could be heard by all subjects, but was not loud enough to cause any harm to the animals. The decibel level was at a range where I could hear all the subjects but I was no longer able to here announcements made over the intercom system that broadcasts into the hallway outside Run 6. Using a dbl level meter, dbl levels were recorded in front of each pen once the sound was on to ensure the music was being distributed evenly across all eight pens.

Experimental Materials

Auditory enrichment in the form of music was played to the monkeys via an Apple® iPod® 34GB and transmitted to the subjects using a Creative® Gigaworks® T20 Series II dual speaker system. The speakers and iPod® were placed on a service cart in the middle of Run 6. Each speaker was angled with one pointing to the left and one to the right and plugged in using an extension cord. Decibel levels were determined using a RadioShack® Digital-Display-Sound-Level decibel meter (model no. 33-2055). Upon approval from the ONPRC, video and pictures were taken using a Pure Digital Flip® camcorder during times observations were not being conducted to help identify individuals and obtain video and photographic evidence of observed behaviors.

Statistical Analysis

Upon completion of the study, data were entered into SPSS® for analysis. The data were combined for each social group by hour. The ten scans collected in each observation hour were combined to give a total number of behaviors for each group for the given hour. The three hours in the TEST period, from 12:00 to 15:00, were also combined. This allowed for comparisons across each time period: PRE, TEST, and POST. Eleven of the original twenty-six locations and behaviors were statistically analyzed (Table 4). The locations analyzed included whether the subject was alone (i.e., not in proximity to another individual) and whether the subject was in proximity (i.e., was the subject within arm's length from any other individual(s)). The behaviors included: abnormal, aggression, groom, play, approach, explore, sleep, locomotion, and stationary. These behaviors were selected for analysis to determine the effectiveness of the auditory stimuli to reduce abnormal behaviors and aggression and also increase affiliative behaviors. Analyses of rearing effects were only run on the groups that housed similarly reared individuals: Group A and B for mother-reared in groups, Group C for nursery-reared, and Group F for mother-reared in single cages.

Table 4. Ethogram of Behaviors observed in Run 6 that were Included in Statistical Analyses.

Behavior	**Class**	**Operational Definition**
Alone	Non Social	Individual is not in proximity to any other individual.
Proximity	Social	Individual is within 1 meter (at arm's length) of another individual(s) with any part of the body.
Aggression	Social	Rough behavior: Involving slight physical contact. May include: facial or vocal components.
Groom	Social	Manipulation of the hair of another individual(s) with hands and/or mouth.
Play	Social	Individual is engaged in social interactions that are characterized by apparent low tension; may be accompanied by a "*play face*" (facial gesture in which mouth is open and facial features are relaxed). May include: *grunting, wrestling, sham-biting, jumping on, jumping over, chasing, fleeing*.
Affiliative approach	Social	Individual moves toward another individual(s) with apparent intention of one or more of the following: grooming the individual, moving within proximity, or moving closer in proximity to initiate physical contact with the individual(s).
Explore	Non Social	Individual inspects or manipulates object other than food; specifically enrichment objects. May include: balls, dog toys, swings, or manipulation of locks or feeders on cage doors.
Sleep	Non Social	Individual appears to be sleeping; is stationary with eyes closed.
Locomotion	Non Social	Individual engages in movement from one location to another while using its entire body.
Stationary	Non Social	Individual is inactive; not engaged in full body, mobile movement. May involve head or arm movement.
Abnormal	Non Social	Individual is engaged in atypical behavior.

Abnormal Behavior	**Operational Definition**
Pacing	Repetitious, patterned back and forth locomotion or circling of the cage. Requires at least two repetitions.
Eye-Poking	A self-injurious behavior, typically characterized by a "saluting" gesture of the monkey's hand over the eye. May include: pressing of the knuckle or finger into the orbital space above the eye socket.

Table 4 continued.

Self/digit-sucking	Some part of the animal's own body-typically the digits of the hand or foot-are placed in the individual's mouth and sucked.
Circling	Animal bends hind limbs and spins self in a clockwise or counter-clockwise direction at a fast pace for at least three rotations.
Cage-directed	Repetitive licking or scratching of walls or bars of the enclosure. Does not occur following cage washings and there are no visible food items or other material on the surface.
Back Flipping	Three or more repeated forward or backward somersaults. May include: grabbing the top of the cage and swinging the body through the arms.
Rocking	A back and forth movement of the upper body with feet stationary.
Threat Bite	Aggressive behavior that involves biting the monkey's own body-typically the hand, wrist, or forearm-while staring at the observer or conspecific in a threatening manner.

The data were then divided using the split file function in SPSS® to allow for comparisons between groups, phases (e.g., white noise phase and designer music phase) and time periods (e.g., PRE, TEST, and POST periods). The data were analyzed using the weekly total per group for each behavior or location (i.e., how many abnormal behaviors occurred in the control week compared to how many abnormal behaviors occurred in the WN Phase for Group B). The time periods were also analyzed to determine if changes in behavior were significantly correlated with the TEST periods when the music was played.

To determine the percentage of time the animals were engaged in a given behavior, the number of times that behavior was observed during the week was divided by the total number of behaviors for that week. The total number of behaviors possible in the population for one hour was 390. A total of 7800 behaviors were recorded in the twenty observation hours of the control phase and a total of 9750 behaviors in the twenty-five hours of observation in the white noise, designer music, and final phase of the study. The percentage of time an animal spent in a given behavior for the time periods (e.g., PRE, TEST, or POST) was calculated by dividing the total number of times that behavior was observed during that time period by the total number of behaviors for that period. There were 390 behaviors possible for the population in the PRE and POST periods and 1170 behaviors possible in the TEST period for one week of observations.

Analysis of Variance (ANOVA) determined if any change in behavior or location occurred across the study and if the changes were significant. Univariate ANOVA and post hoc Tukey HSD tests determined which groups showed significant changes in behavior or location over the course of the study and in which Phase. ANOVA and Tukey HSD tests also determined if changes in behavior were significantly correlated with any of the time periods: PRE, TEST, or POST. Significance was set at the $\alpha = 0.05$ level for all statistical tests.

CHAPTER III

RESULTS

Results show that the auditory stimuli played during this study, white noise and designer music, significantly affected the behavior of the rhesus macaques. The designer music, in Phase 3, resulted in statistically significant positive behavioral changes for the population. Reduction of abnormal behaviors from baseline levels remained in the population in the week after the cessation of the designer music.

Changes in Behavior across the Study

Abnormal Behaviors

Several abnormal and stereotypic behaviors were observed across the seven groups. These include self-sucking behaviors which occurred with the most frequency over the four phases. In fact, 47.26% of all abnormal behaviors observed over the four phases were self-sucking behaviors (e.g., digit sucking). This was followed by pacing (24.73%), cage directed behaviors (e.g., cage or wall licking) (9.49%), eye-poking (8.49%), back flipping (4.74%), circling (1.09%), and rocking (1.09%). Approximately three individuals exhibited eye-poking, a self-injurious behavior. Two individuals were observed displaying threat bites, also a self-injurious behavior. All groups were observed to pace, usually in response to a technician or veterinarian entering the room. Pacing was also observed in response to others engaging in aggressive interactions.

When the entire population, all seven social groups, was analyzed the expression of abnormal behaviors significantly decreased over the course of the study (F: 8.740, df: 3, 652, $p=\leq 0.000$) (Figure 2). This reduction in abnormal behaviors across the study was significant in the TEST period, from 12:00 – 15:00 (F: 8.535, df: 3, 393, $p=\leq 0.000$).

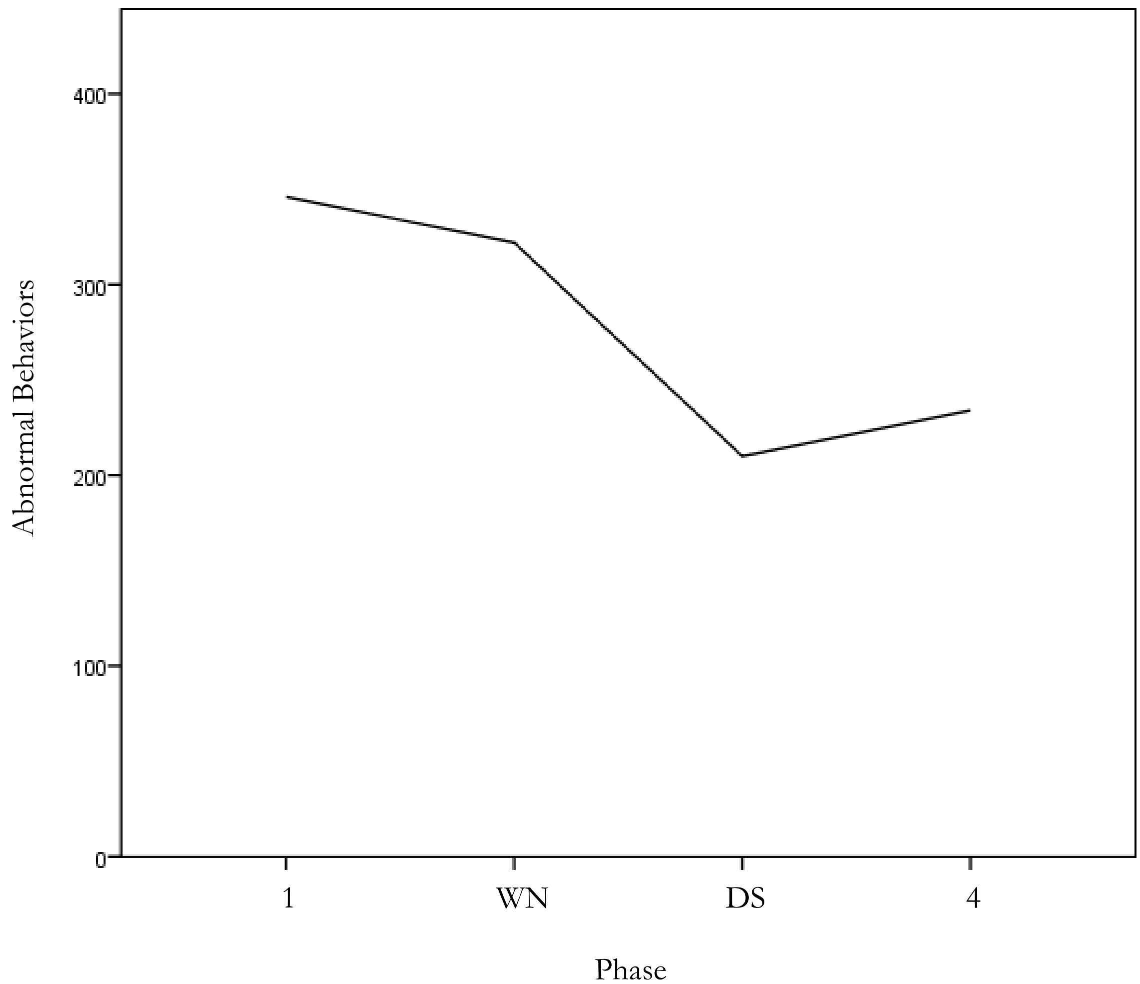

Figure 2. Instances of abnormal behaviors observed for all groups during each phase across all time periods (PRE, TEST, and POST). Phase 1: Control, Phase 2: White Noise, Phase 3: Designer Music, Phase 4: No Music.

Aggression

The amount of aggressive interactions recorded during the formal scans across the population did not significantly decrease over the course of the study (F: 2.179, df: 3, 652, p=0.089) (Figure 3). However, Groups B and E significantly decreased rates of aggression over the course of the study during the TEST period (Group B: F: 4.229, df: 3, 56, p=0.009; Group E: F: 2.826, df: 3, 56, p=0.048).

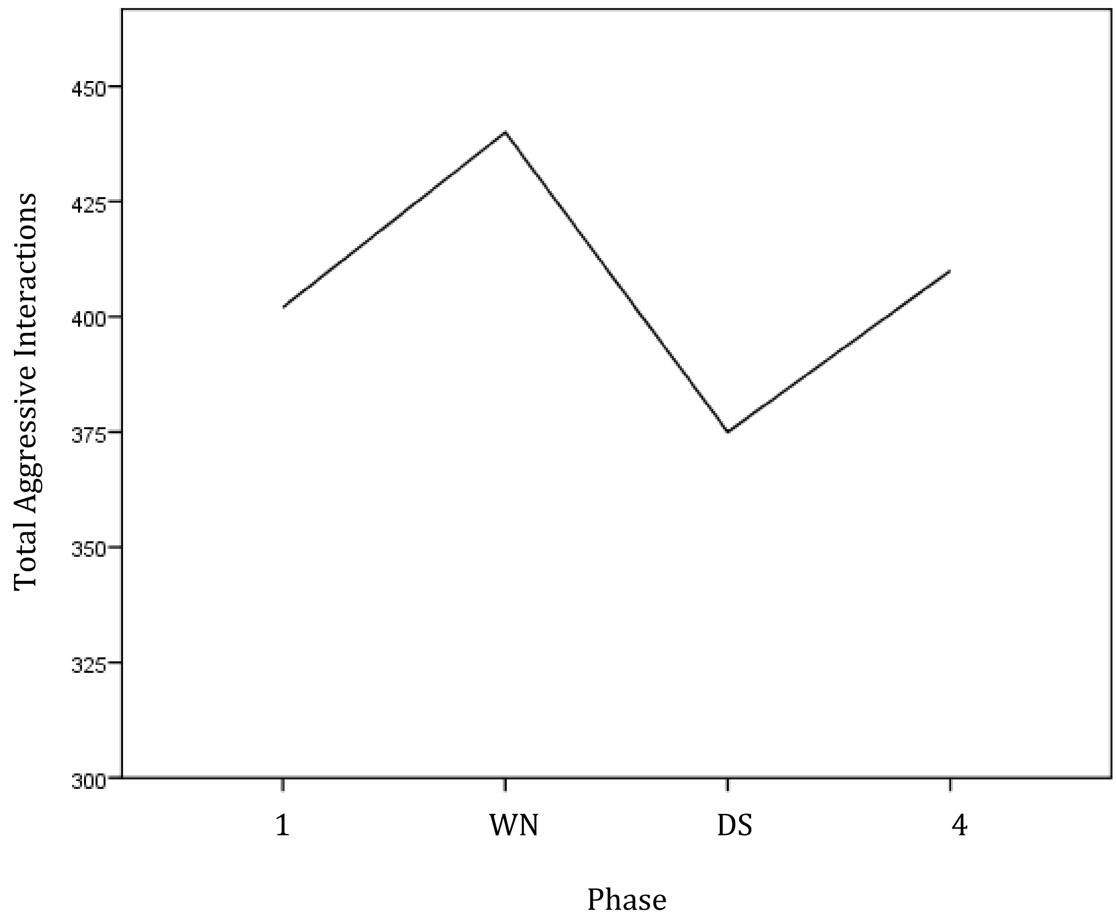

Figure 3. Instances of total aggressive interactions observed for all groups across each phase across all time periods.

Affiliative Behaviors

Over the course of the study all groups significantly increased the rate of approach (F: 19.089, df: 3, 393, p=≤0.000). This increase in approach was significant for all groups during the PRE, TEST, and POST time periods (PRE: F: 3.530, df: 3, 393, p=0.017; TEST: F: 13.052, df: 3, 393, p=≤0.000; POST: F: 7.694, df: 3, 393, p=≤0.000).

The rate of grooming also significantly increased across the population over the course of the study (F: 4.219, df: 3, 393, p=0.006). Furthermore, the results also show that during exposure to both types of auditory stimuli the population significantly increased rates of social play (F: 7.673, df: 3, 652, p=≤0.000) (Figure 4).

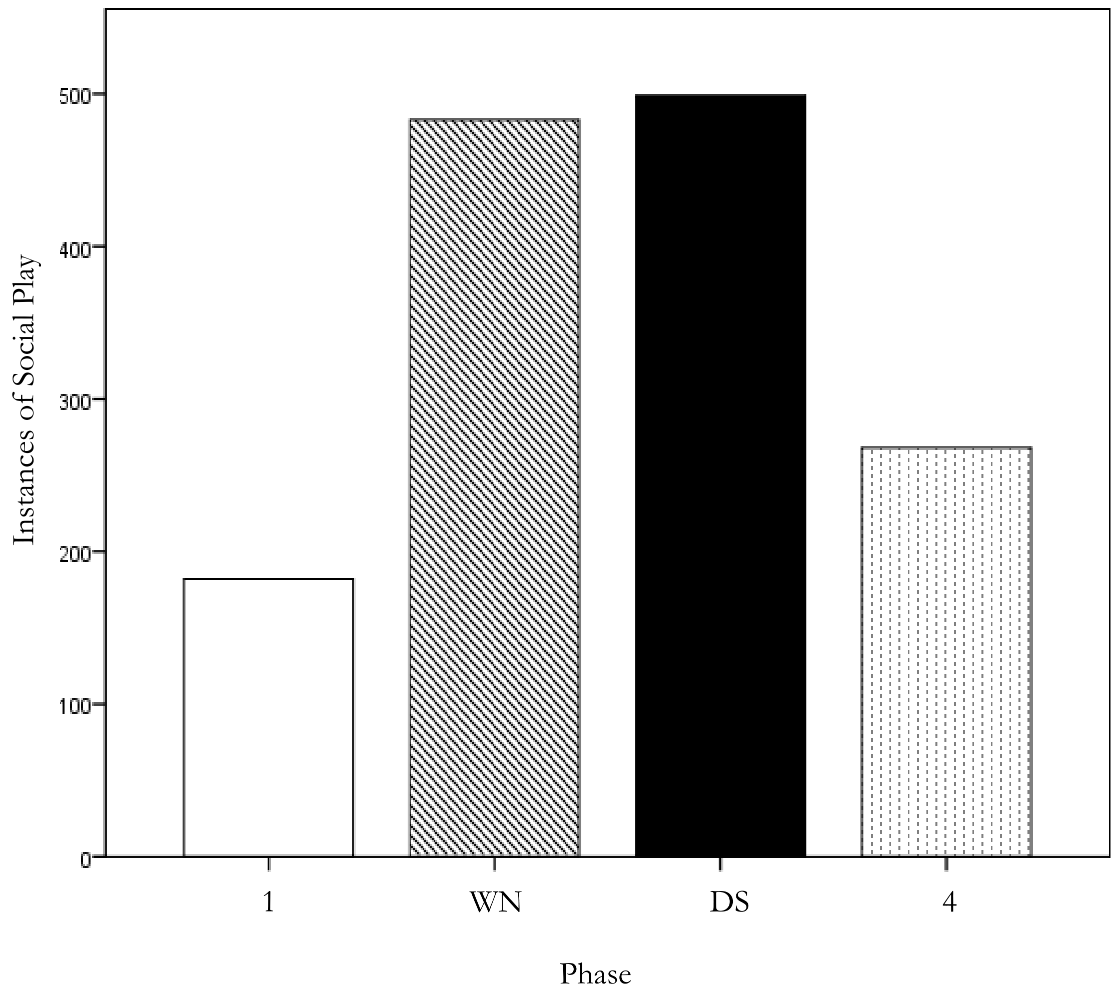

Figure 4. Total number of instances the population was engaged in social play during each phase across all time periods.

Changes in Behavior by Phase

Abnormal Behaviors

Phase 1: Control

The data show the population exhibited 362 abnormal behaviors in the control phase. The percentage of time the animals spent engaged in abnormal behavior in the control phase was 4.64%. Groups B, C, and G displayed the most abnormal behaviors when compared to the other groups on this phase (Figure 5). For Groups B, C, E, and F, the data show individuals in these groups displayed their most abnormal behaviors during the control phase. Post hoc Tukey tests found that abnormal behaviors were at their highest during the TEST period in the control phase (F: 8.535, df: 3, 393, p=0.008).

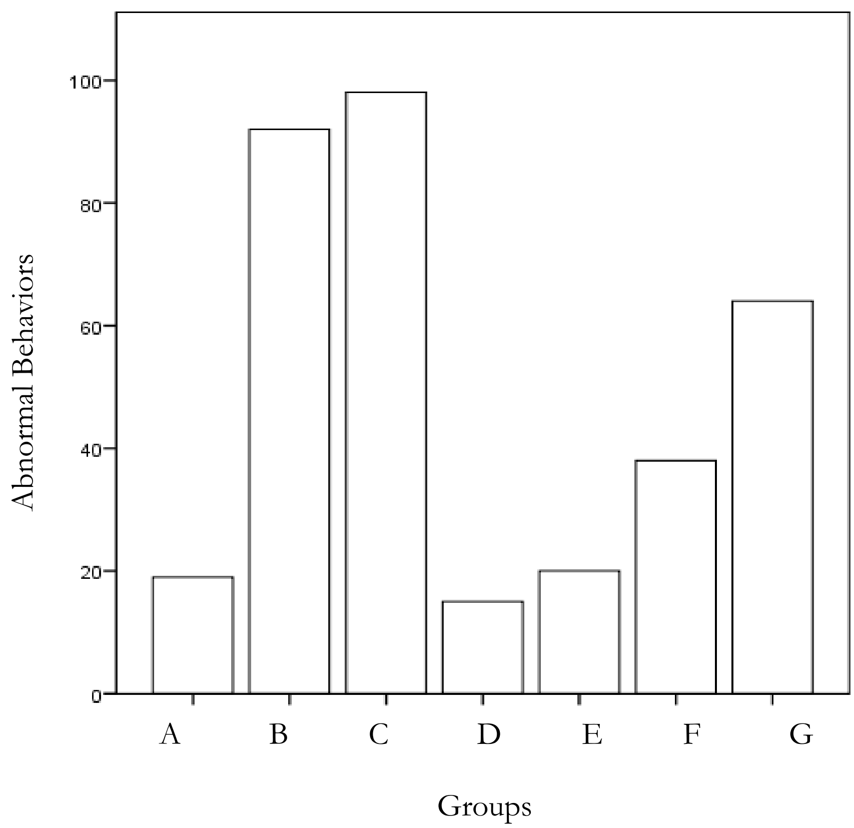

Figure 5. Total number of abnormal behaviors observed for each group during Phase 1 across all time periods.

Phase 2: White Noise

There were 322 abnormal behaviors observed across all groups in the white noise phase. The population spent 3.30% of their time in the white noise phase engaged in abnormal behavior, an 11.0% decrease from baseline levels. However, this decrease was not statistically significant. For Groups D and G the data show the individuals in these groups displayed their most abnormal behaviors during this phase. The data do show that Group B significantly reduced the expression of abnormal behaviors from baseline levels during the TEST period (F: 6.428, df: 3, 93, p=0.001) (Figure 6). Conversely, Groups C, E, and G displayed the most abnormal behaviors in the TEST period.

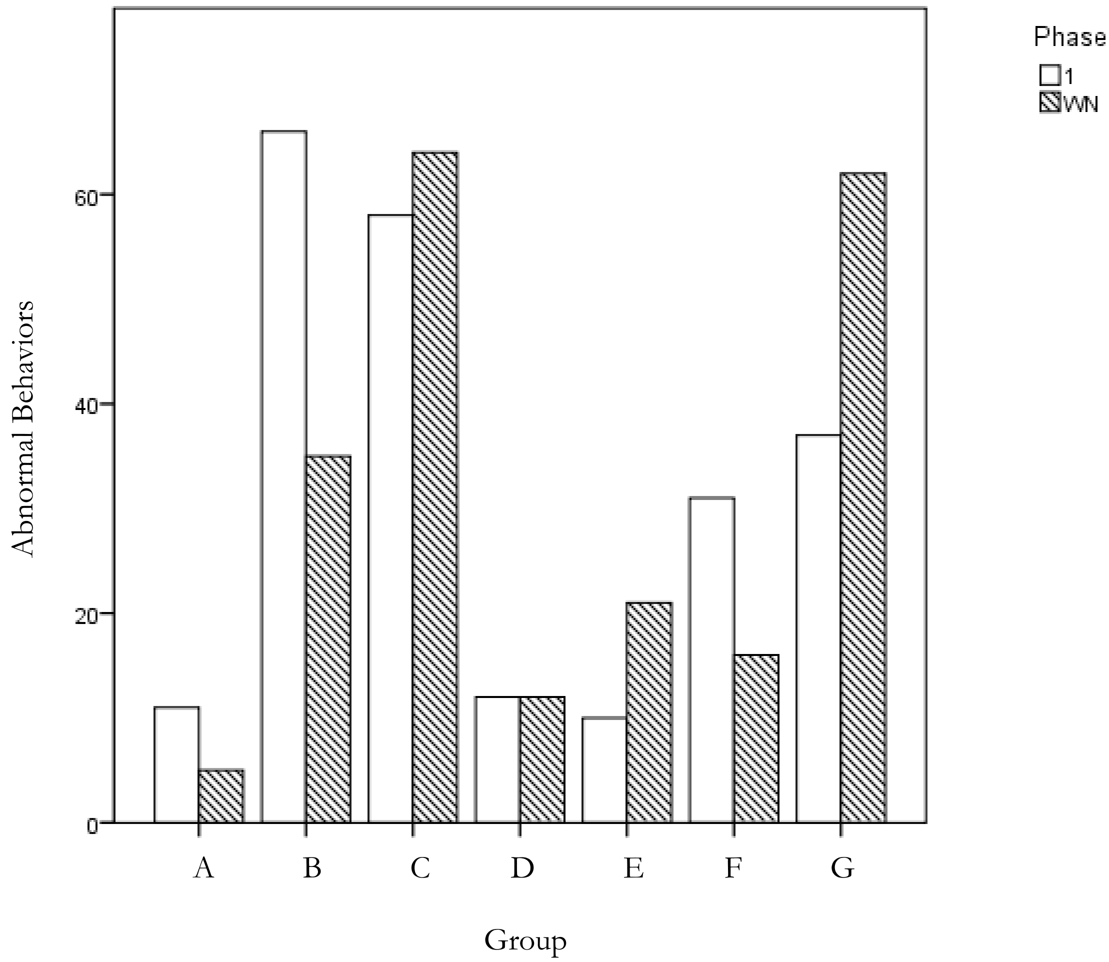

Figure 6. Comparison of total number of abnormal behaviors observed per group between Phase 1 and Phase 2, the white noise (WN) phase, during the TEST period from 12:00 to 15:00.

Phase 3: Designer Music

There were 237 abnormal behaviors observed across all groups in the designer music phase. This was a significant decrease of 34.5% from baseline levels, with the subjects spending just 2.43% of their time in the designer music phase engaged in abnormal behavior (F: 8.740, df: 3, 393, p=≤0.000) (Figure 7).

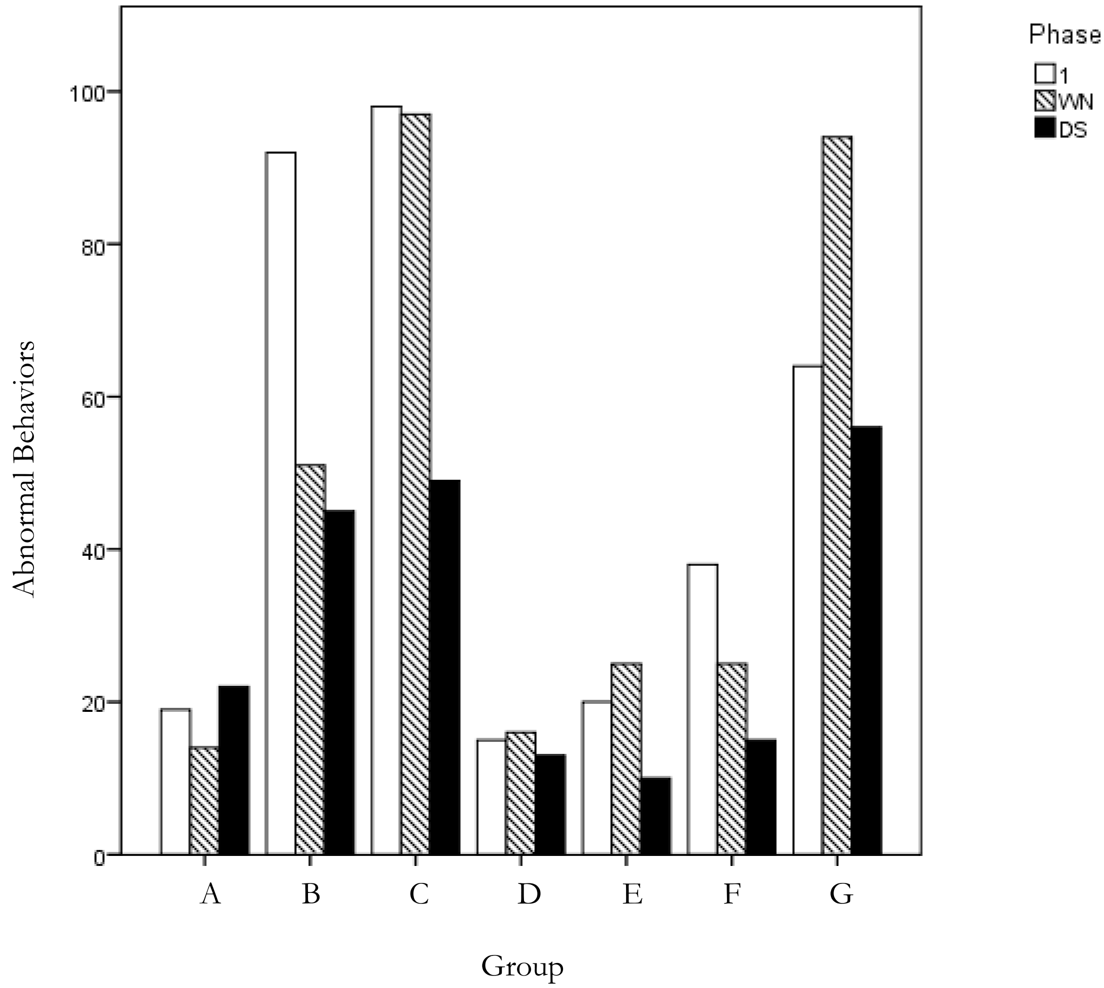

Figure 7. Comparison of the total number of abnormal behaviors observed across all time periods per group between Phase 1, the WN phase, and the designer music (DS) phase.

Groups D, E, and G exhibited their least amount of abnormal behaviors during this phase (Figure 7). However, only Groups B, C, and F significantly reduced the expression of abnormal behaviors from baseline levels (Group B: F: 6.428, df: 3, 93, p=0.001; Group C: F: 4.357, df: 3, 93, p=0.019; Group F: F: 4.009, df: 3, 93, p=0.032) (Figure 7). The data further show that the expression of abnormal behaviors across the population was not only at its lowest frequency during the designer music phase, but was lowest during the TEST period, at 13:00, when the DS music was actually being played to the animals (Figure 8). In fact, all groups, with the exception of Group A, had lower rates of abnormal behaviors in the TEST period of the designer music phase (Figure 8).

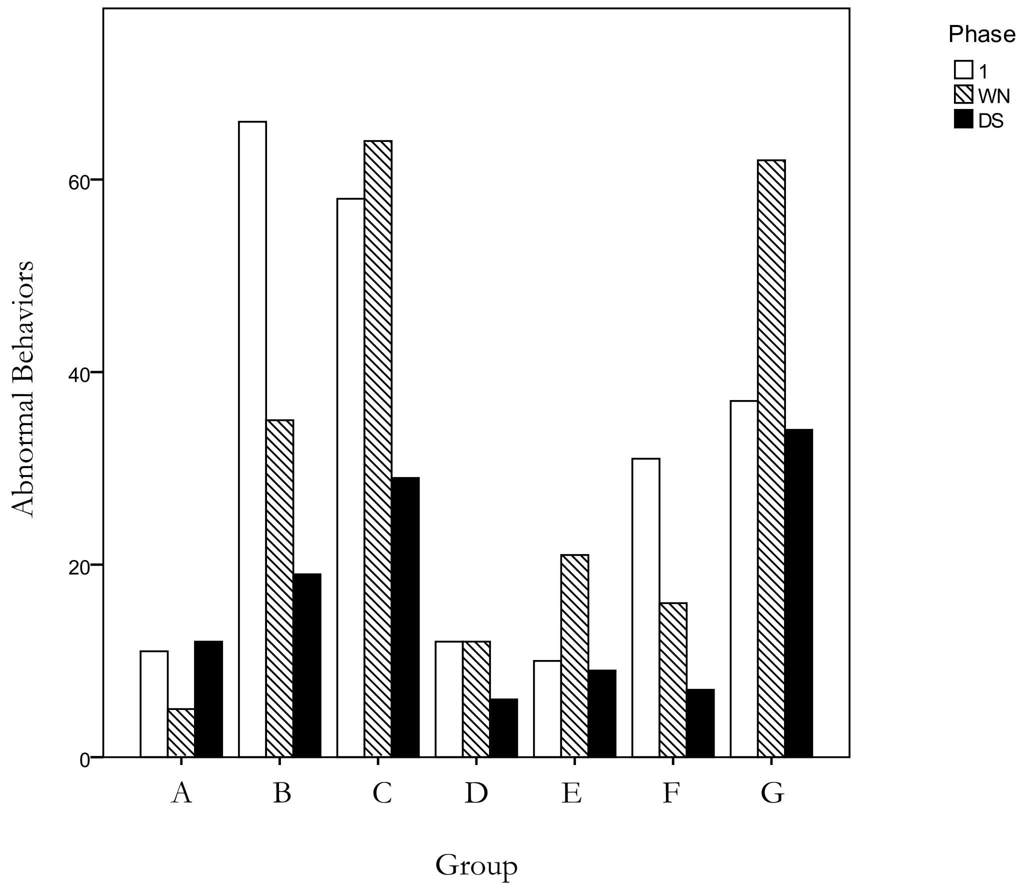

Figure 8. Comparison of the number of abnormal behaviors observed in the TEST period per group in Phase 1, the WN phase, and the DS phase.

The data show the expression of abnormal behaviors was significantly lower in the population in the TEST period of the designer music phase than in the TEST period of either the control or the white noise phase (F: 8.535, df: 3, 393, p=<0.000) (Figure 9).

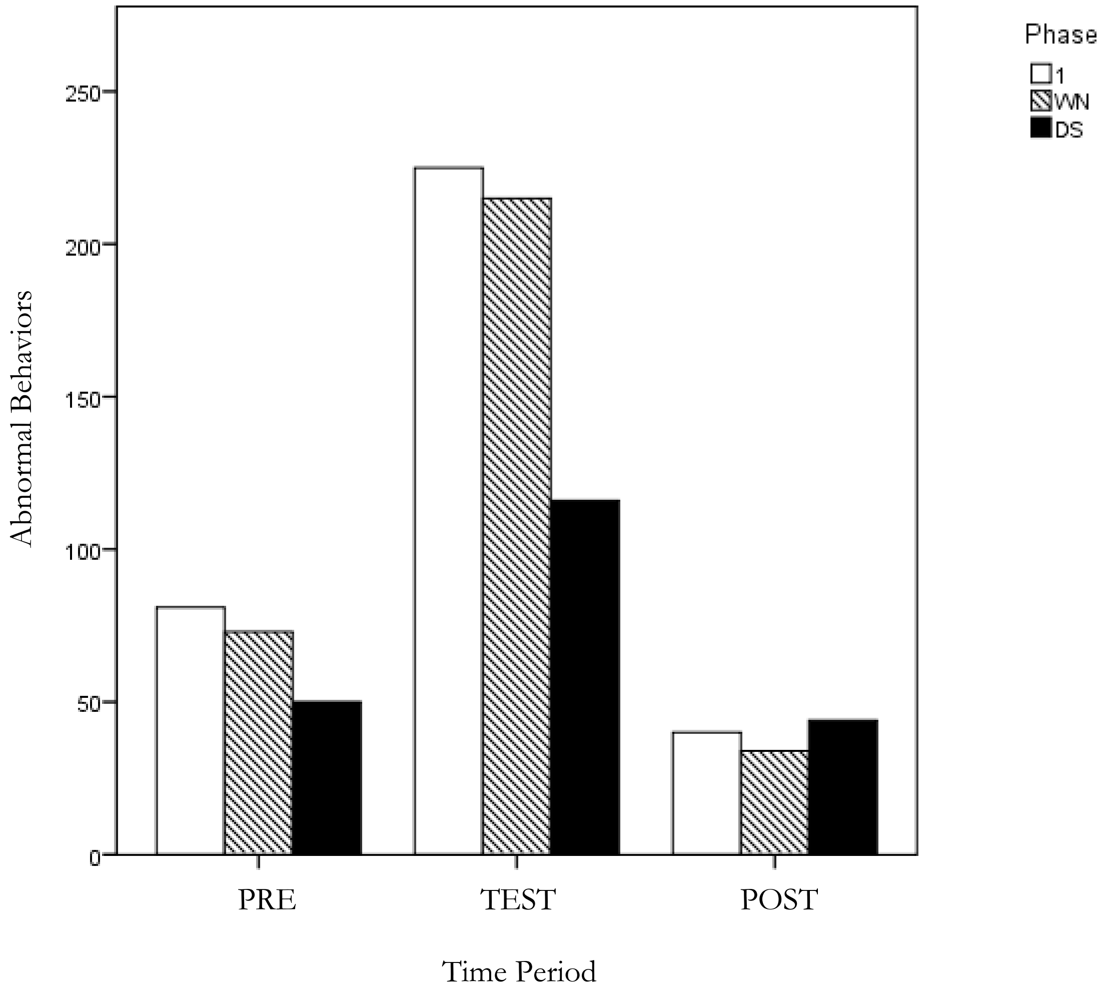

Figure 9. Comparison of the total number of abnormal behaviors observed for the whole population in the PRE (9:00-10:00), TEST (12:00-15:00), and POST (15:15-16:15) time periods for Phase 1, the WN phase, and the DS phase.

Phase 4: No Music

There were a total of 241 abnormal behaviors observed in Phase 4. This was a statistically significant decrease from baseline levels observed in the control period with the animals engaged in abnormal behavior 2.47% of the time in the final phase of the study compared with 4.64% of the time in the control phase (F: 8.740, df: 3,652, p=≤0.000). Post hoc Tukey tests revealed that Group F displayed their lowest number of abnormal behaviors during this phase, significantly reducing the number of abnormal behaviors from baseline levels (F: 4.009, df: 3, 56, p=0.009 (Figure 10). Groups B and C were also found to significantly reduce the expression of abnormal behaviors from baseline levels in the final phase of the study (Group B: F: 6.428, df: 3, 56, p=0.002; Group C: F: 4.357, df: 3, 56, p=0.020).

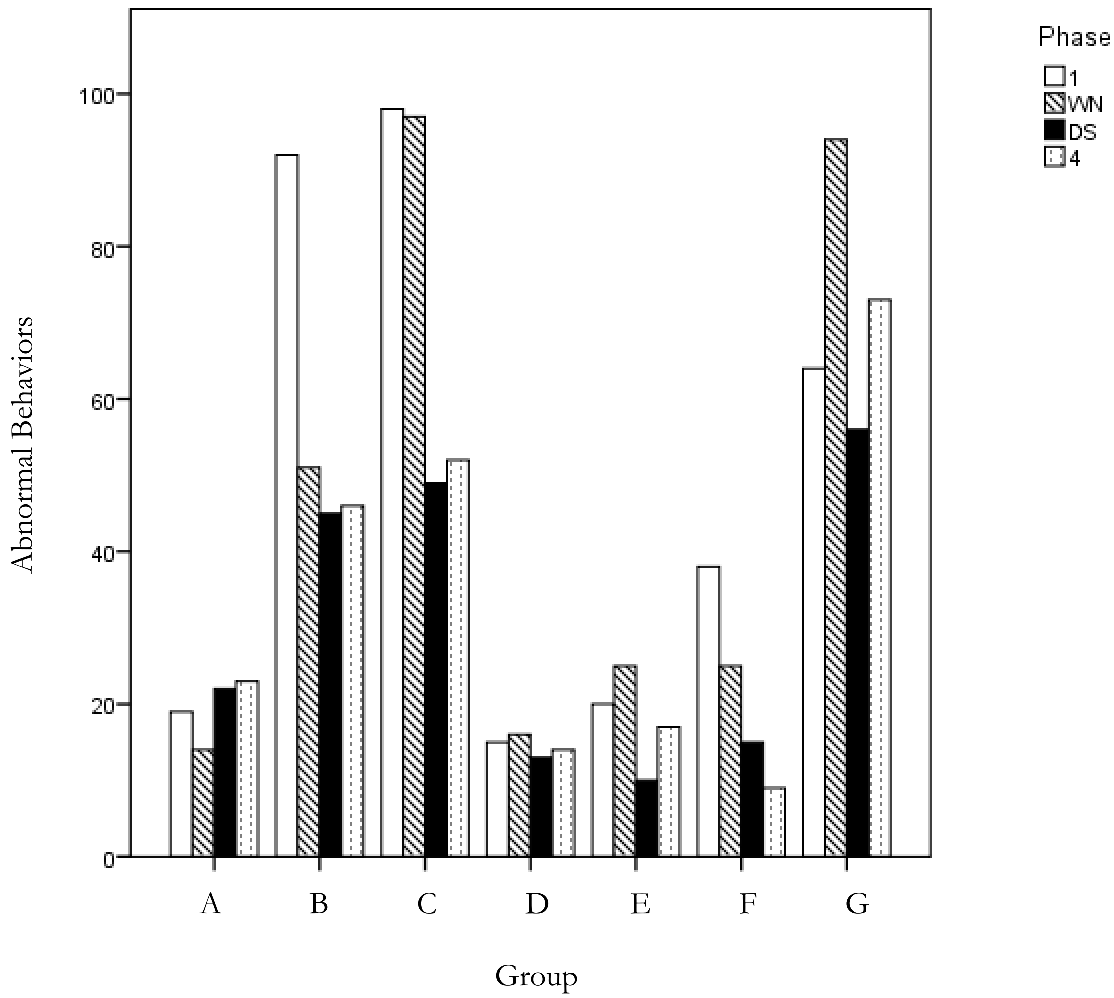

Figure 10. Comparison of the total number of abnormal behaviors observed across all time periods per group across all Phases.

Aggression

Phase 1: Control

There were 324 aggressive interactions observed during formal scans. When aggressive interactions observed during formal scans are combined with aggressive bouts (total aggression) there were 462 aggressive interactions observed in Phase 1.This accounted for 5.92% of the total amount of behaviors observed in the control phase. For Groups A, B, and G the data show they exhibited the highest frequency of total aggressive interactions per group during the control phase. Groups C and F displayed their lowest rates of total aggressive interactions per group during this phase.

Phase 2: White Noise

Group E was found to significantly increase rates of aggressive interactions in the white noise phase (F: 4.679, df: 2,24, p=0.020).The white noise did not significantly affect rates of aggression during the TEST period when the music was actually being played (Figure 11). Post hoc Tukey HSD tests revealed that Group B displayed more aggression in the PRE period than in the TEST period when the music was actually played (p=0.029). The white noise did not affect rates of aggression for any of the remaining groups.

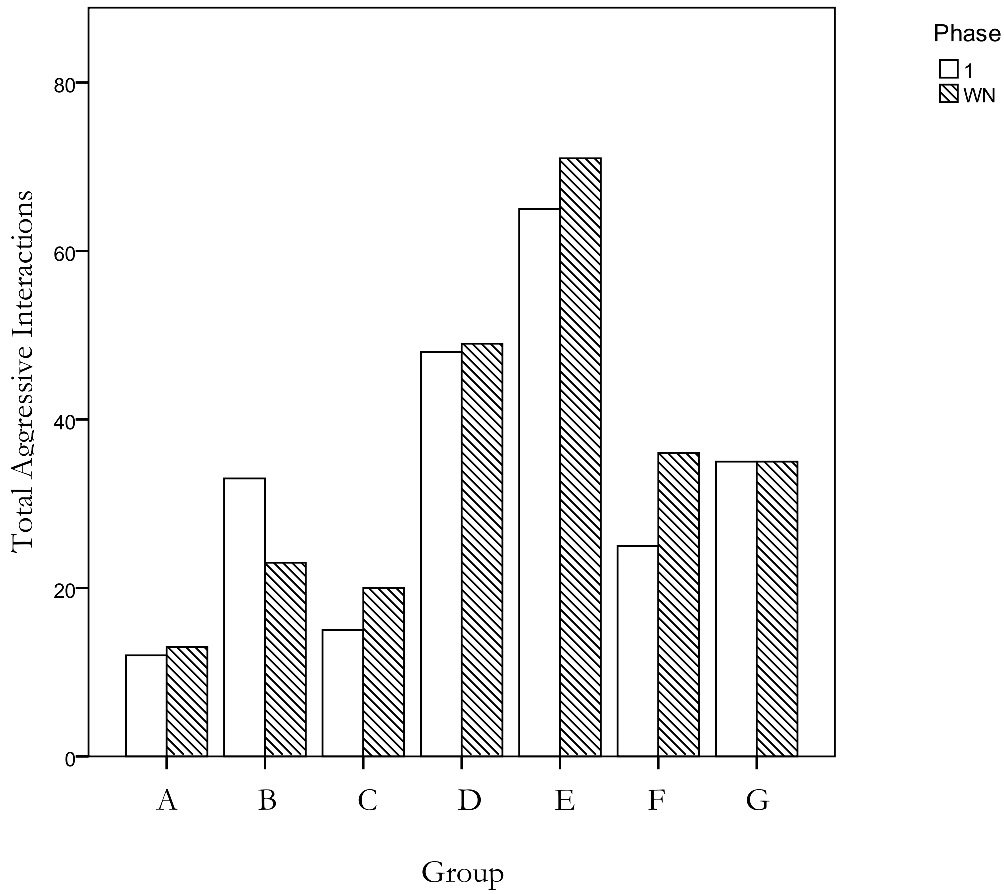

Figure 11. Total number of aggressive interactions observed during the TEST period for all groups in Phase 1 and the WN phase.

Phase 3: Designer Music

There was a 17.8% reduction in the frequency of total aggressive interactions across all groups in the designer music phase and data show a trend towards a statistically significant result (F: 2.179, df: 3, 93, p= 0.054). Group B was found to significantly reduce rates of aggression in the designer music phase but this was not correlated with any time period (F: 4.538, df: 2, 24, p=0.022). Group E was also found to significantly decrease rates of aggression with significantly more aggressive interactions taking place in the POST period than in the TEST period when the designer music was played (F: 6.899, df: 2, 24, p=0.005).

Phase 4: No Music

Rates of total aggressive interactions increased from the designer music phase. In fact, Group C displayed the highest rates of aggression during Phase 4, but the increase was not statistically significant (F: 2.008, df: 3, 93, p=0.119). There was an 11.26% decrease of total aggressive interactions from baseline levels across the whole population, but this was also not significant (F: 2.179, df: 3, 93, p=0.089). However, Groups D and G did display their lowest rates of aggression during Phase 4.

Affiliative Behaviors

Phase 1: Control

There were 143 instances of social play and 6 of solitary play in the control phase. The data show the population spent 1.91% of their time in the control phase engaged in either social or solitary play. Groups A, B, and G were not observed to engage in social or solitary play during this phase.

Phase 2: White Noise

The population was found to have the highest rates of grooming in the white noise phase, increasing by 22.9% from baseline levels (F: 4.219, df: 3, 652, p=0.006) (Figure 12). Group E had significantly higher rates of grooming in the white noise phase than in either the designer music phases or Phase 4, when no music was played (F: 5.509, df: 2, 24, p=0.023).

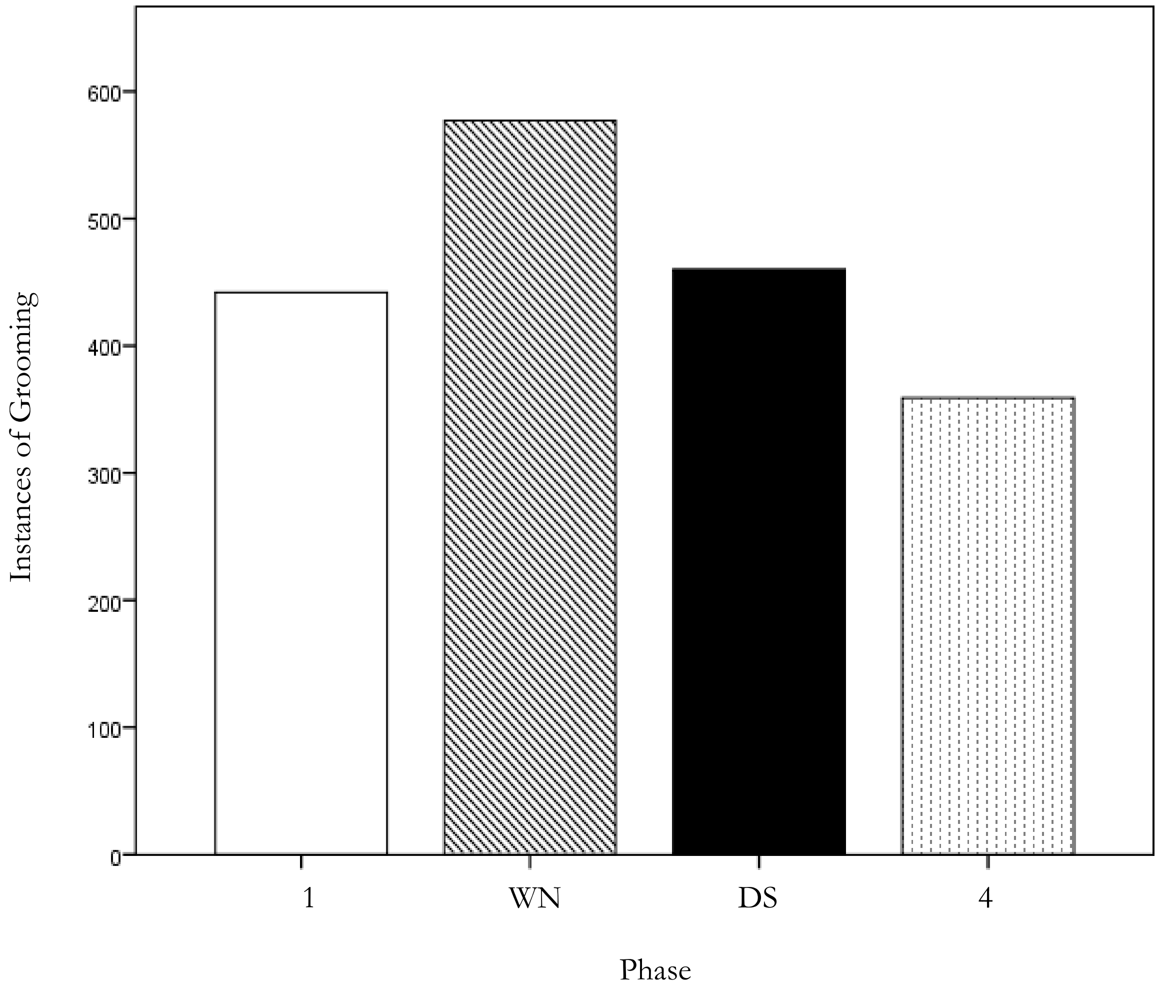

Figure 12. Instances of grooming for the whole population across each phase for all time periods.

The data show the population significantly increased rates of social play during the white noise phase (F: 7.673, df: 3, 652, p=0.003). Group F increased rates of social play and was observed to exhibit their highest rates of play behaviors in the TEST period, 12:00p to 3:00p, when the white noise was being played.

Phase 3: Designer Music

The population was found to significantly increase the rate of affiliative approach in the designer music phase (F: 19.089, df: 3, 93, p=≤0.000). Groups C, E, and B had significantly higher rates of approach in this phase than in the control phase (Group B: F: 4.486, df: 2, 24, p=0.002; Group C: F: 4.229, df: 2, 24, p=0.008; Group E: F: 5.973, df: 2, 24, p=0.001).

The population significantly increased time spent engaging in social play in the TEST period of the designer music phase (F: 4.625, df: 3, 652, p=≤0.000) (Figure 13). Groups C and F also significantly increased rates of social play from baseline levels (Group C: F: 4.627, df: 2, 24, p=0.005; Group G: F: 3.646, df: 2, 24, p=0.015).

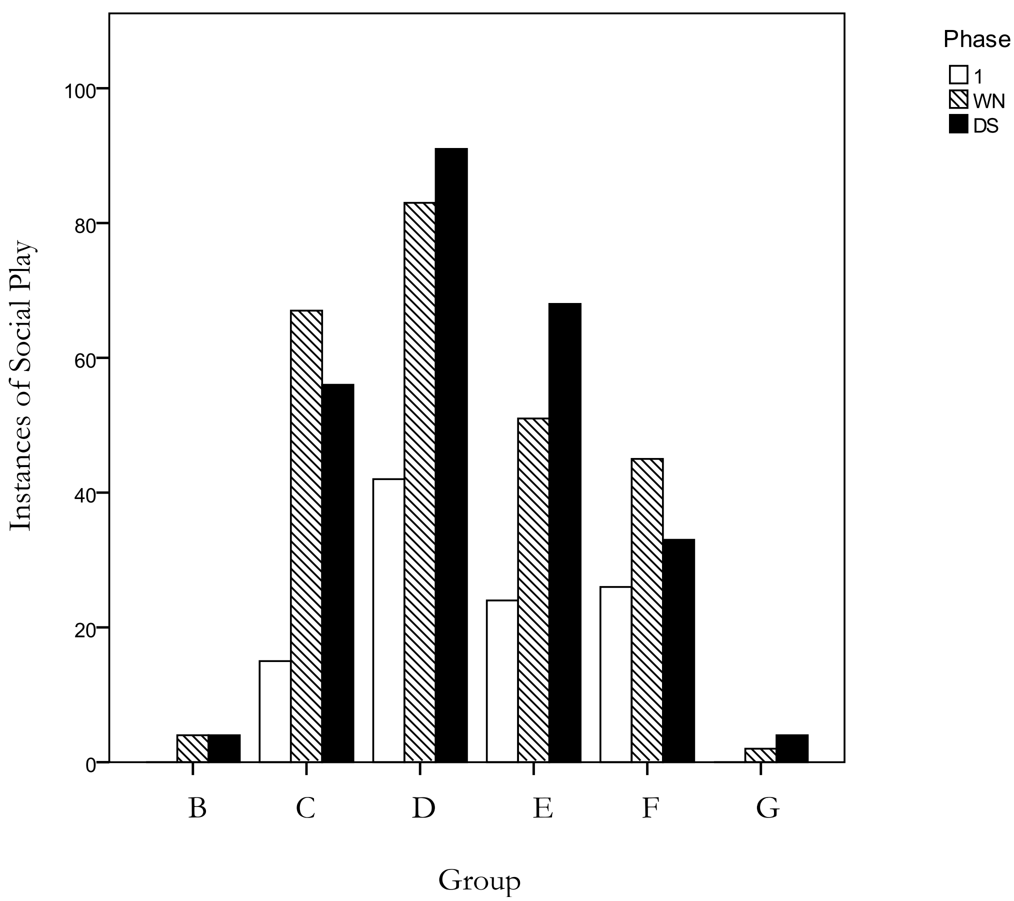

Figure 13. Comparison of instances each group was engaged in social play during the TEST period in Phase 1, the WN phase, and the DS phase. Group A was excluded since they were not observed to engage in play over the course of the study.

Phase 4: No Music

Group A was found to significantly increase time spent in proximity to another individual from the designer music phase in this final phase of the study (F: 4.352, df: 3, 93, $p=0.003$). However, Group B was found to spend less time in proximity to another individual in this phase than in the control period (F: 10.814, df: 3, 93, $p=0.009$).

All groups, with the exception of Group A, decreased time spent engaged in social play in the TEST period from the white noise phase and the designer music phase in this final phase (Figure 14). Group C was found to significantly decrease rates of social play from the designer music phase (F: 4.627, df: 3, 93, $p=0.031$). In this phase, Group F was found to spend significantly more time engaging in social play in the PRE period than in either the TEST or POST periods (F: 5.349, df: 2, 24, $p=0.048$).

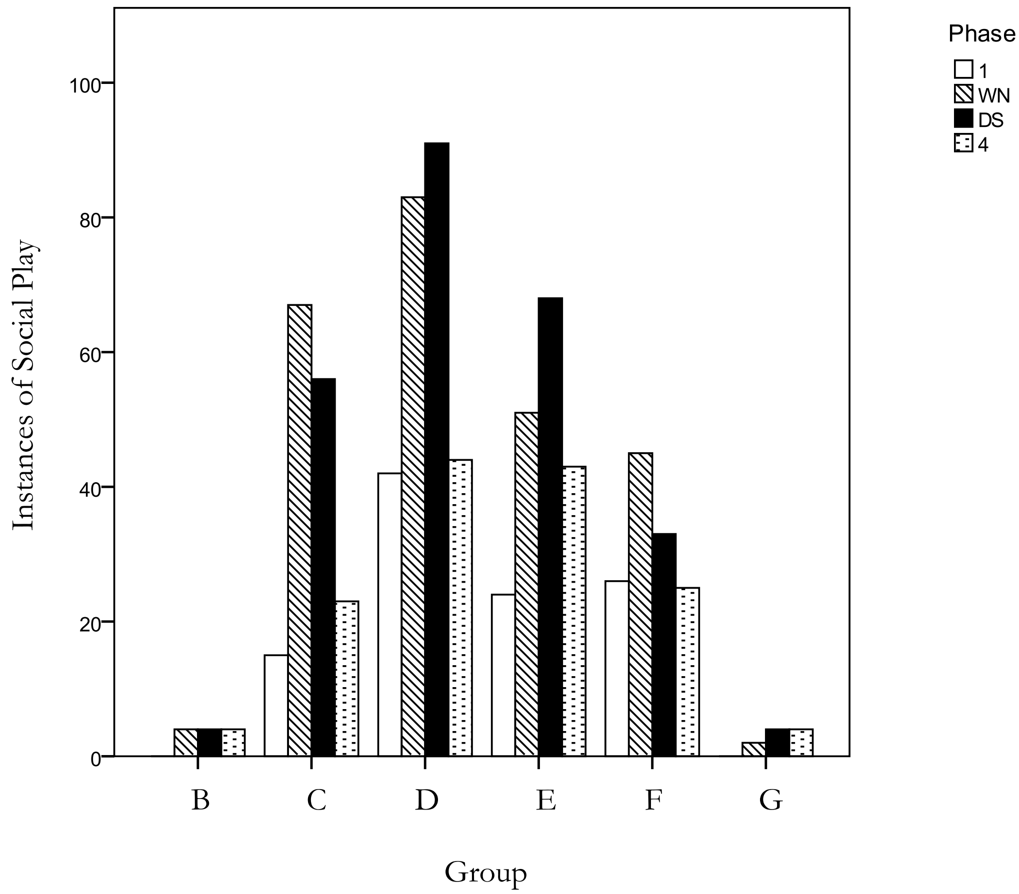

Figure 14. Comparison of instances each group was engaged in social play during the TEST period across all Phases. Group A was excluded since they were not observed to engage in play throughout the study.

Other Behaviors:

Phase 2: White Noise

Groups B and D were found to significantly decrease time spent locomoting during the white noise phase (Group B: F: 3.711, df: 3, 93, p=0.008; Group D: F: 5.546, df: 3, 93, p=0.040). Group D was also found to significantly increases rates of exploration during the white noise phase (F: 6.539, df: 3, 93, p=0.006).

Phase 3: Designer Music

Groups C and D were found to significantly decrease rates of locomotion from baseline levels in the designer music phase (Group C: F: 3.734, df: 3, 93, p=0.014; Group D: F: 5.546, df: 3, 93, p=0.001).

The population spent significantly more time in exploration in the TEST period of the designer music phase (STAT) (Figure 15).Groups A, E, F, and G spent significantly more time engaged in exploration than in the control phase (Group A: F: 6.556, df: 3, 93, p=0.009; Group E: F: 5.072, df: 3, 93, p=0.003; Group F: F:5.245, df: 3, 93, p=0.020; Group G: F: 5.835, df: 3, 93, p=0.001).

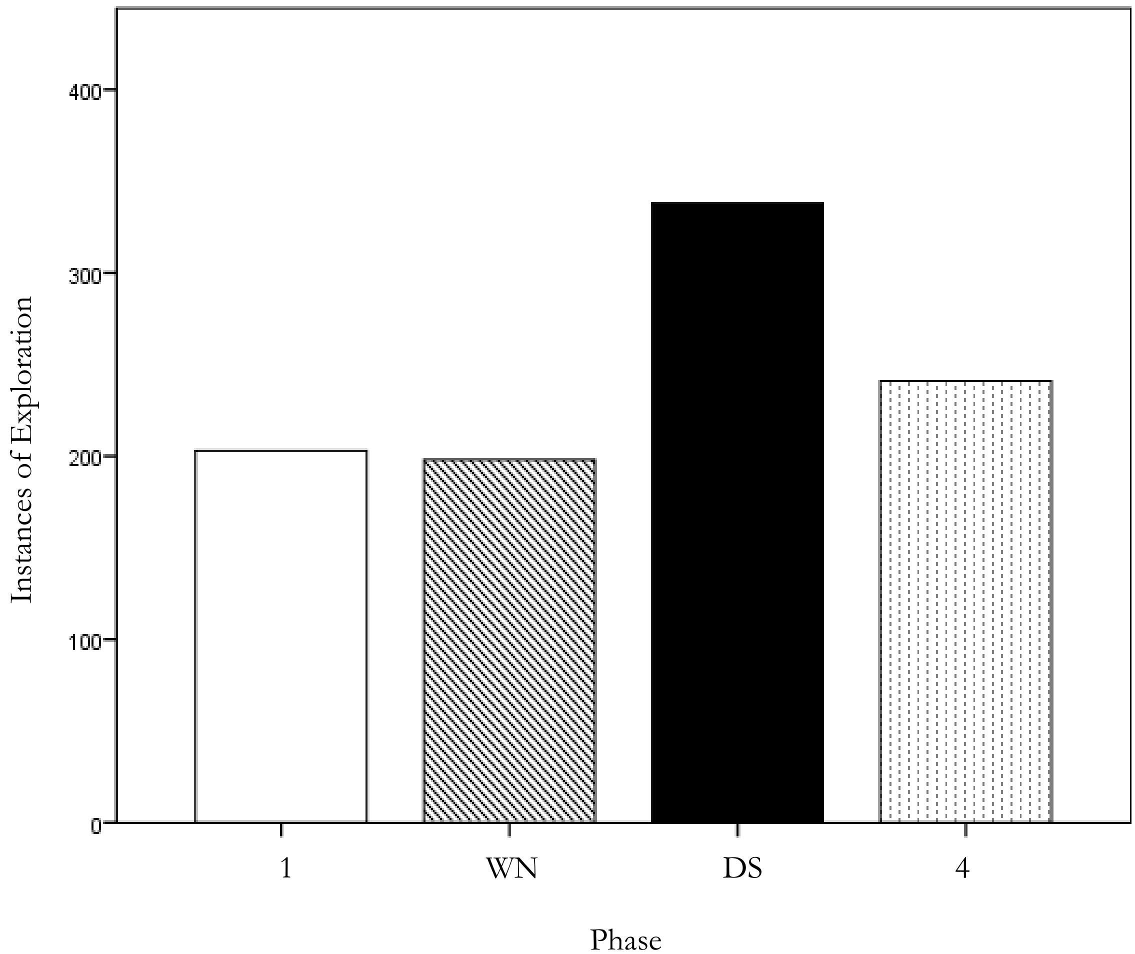

Figure 15. Instances the population was engaged in exploration in the TEST period for each Phase.

The data show Groups B and E were found to spend significantly more time stationary in the TEST period of the designer music phase, when the music was actually played, than in either the PRE or POST phases (Group B: F: 3.462, df: 2, 24, p=0.040; Group E: F: 3.851, df: 2, 24, p=0.031).

Phase 4: No Music

Groups A and G were found to significantly decrease time spent engaged in exploration from the designer music phase (Group A: F: 6.556, df: 3, 93, p=0.045; Group G: F: 5.835, df: 3, 93, p=0.026).

The data show Group C significantly reduced rates of social play from the designer music phase (F: 4.627, df: 3, 93, p=0.031). Group F was found to spend significantly more time engaged in social play in the PRE period than in either the TEST or POST periods (F: 5.349, df: 2, 24, p=0.013).

Group D significantly decreased time spent locomoting in Phase 4, when no music was played, from baseline levels (F: 5.546, df: 3, 93, p=0.009). Group D was also found to significantly increase time spent sleeping in this phase than in the control period (F: 3.908, df: 3, 93, p=0.010).

Effects of Rearing History

Four of the seven social groups housed similarly-reared individuals. Groups A and B were all mother-reared in social groups (MRG). The individuals in Group C were all nursery-reared (NUR), weaned to the nursery from 1 to 11 days of age to approximately 7 months of age. Group F housed individuals that were all mother-reared in cages (MRC) but had visual, and in some cases tactile, access to conspecifics other than their mother. This allowed for analysis regarding the effects of rearing history on the expression of abnormal behaviors. Results showed that rearing history had a significant effect on the types of abnormal behaviors exhibited as well as the frequency they were displayed (F: 24.182, df: 2, 113, p=≤0.000).

Nursery-Reared Individuals

NUR individuals (Group C: N=5), were all observed to self-suck. Self-sucking of the big toe appeared to be habitual, seemingly not in response to any stressor, in at least two individuals. Two individuals were observed to back flip in response to aggressive interactions in other groups or in response to loud noises coming from outside Run 6. One of these individuals also exhibited circling, but the behavior was rare, occurring less than 10 times over the four phases. Only one incidence of pacing was observed.

These individuals exhibited the most abnormal behaviors, 64.4 abnormal behaviors per individual across the four phases. NUR individuals exhibited 98 abnormal behaviors during the control phase. NUR individuals spent 9.80% of their time engaged in abnormal behavior in the control phase. Expression of abnormal behaviors remained constant into the WN phase. The frequency of abnormal behaviors observed significantly decreased in the DS phase (F: 4.357, df: 3, 113, p=0.019).

Post hoc Tukey tests revealed that NUR individuals significantly decreased display of abnormal behaviors in the designer music phase during the TEST period, when music was actually played (F: 3.454, df: 3, 138, p=0.014) (Figure 16).

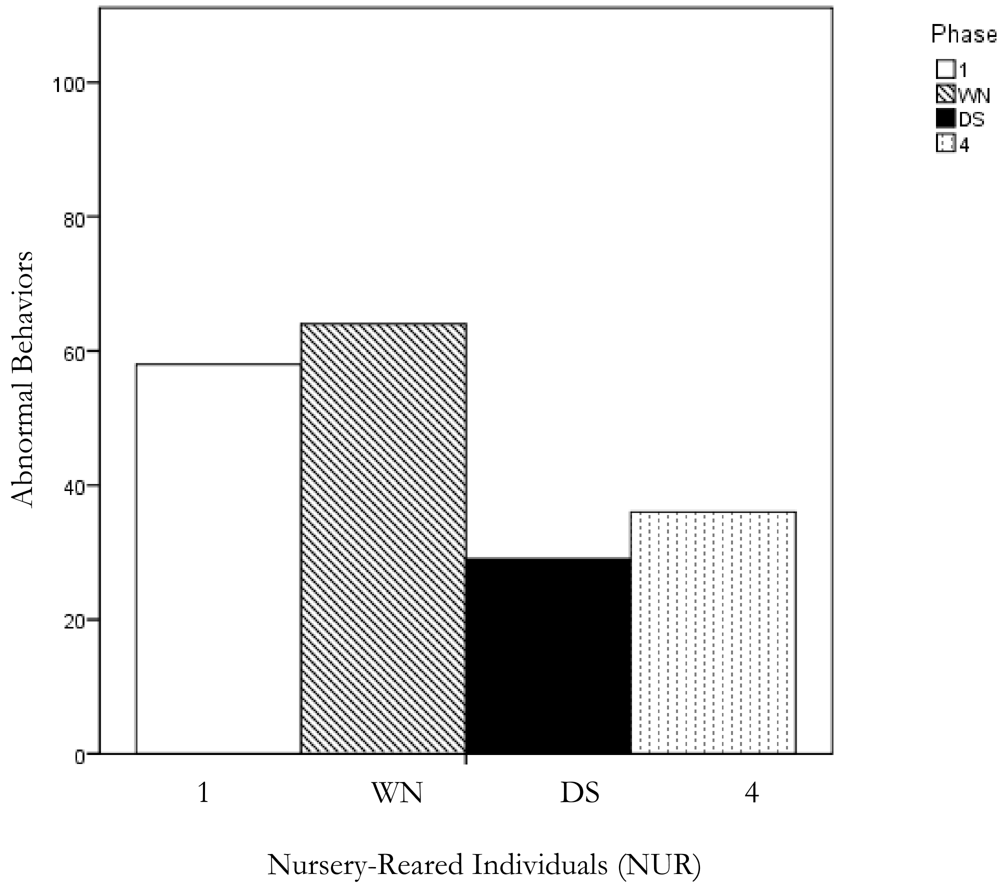

Figure 16. Amount of abnormal behaviors observed in nursery-reared individuals (Group C) for each phase during the TEST period.

The data show an overall significant decrease in the expression of abnormal behaviors of 46.94% from baseline levels in Phase 4 (F: 4.357, df: 3, 93, p=0.020). Across the entire study NUR individuals were found to have significantly higher rates of approach in the TEST period (F: 3.331, df: 3, 94, p=0.023). Furthermore, NUR individuals had the highest rates of approach in the TEST period during the designer music phase (F: 3.331, df: 3, 94, p=0.027).

Individuals Mother-Reared in Groups

MRG individuals (Groups A and B: N=8), were all observed to pace, typically in response to humans entering Run 6 or in response to other groups engaging in aggressive interactions. One female exhibited eye-poking in response to other individuals engaging in aggressive interactions, including those in her pen, as well as in response to humans in Run 6. The individual was also observed to eye poke in response to more minimal disturbances, such as unidentifiable noises occurring outside Run 6. One individual was observed to consistently suck on the ear of another individual when sleeping in a huddle with two other individuals. These groups were also observed to engage in cage directed behaviors (e.g., cage licking). One individual was observed displaying a threat bite, a self-injurious behavior.

These individuals exhibited an average of 39 abnormal behaviors per individual over the course of the study. MRG individuals exhibited 111 abnormal behaviors per individual during Phase 1, accounting for 6.93% of their time in the control phase. There was an initial decrease in the expression of abnormal behaviors by 41.4% from baseline levels in the WN phase. The expression of abnormal behaviors remained relatively constant across the WN, DS, and final phase of the study, with an overall decrease of 37.84% in the amount of abnormal behaviors observed from the control phase. The exhibition of abnormal behaviors significantly decreased from baseline levels over the course of the study (F: 4.520, df: 3, 184, p=0.004). During the TEST period, abnormal behaviors were significantly higher in the control phase than in any other phase of the study (F: 5.292, df: 3, 113, p=0.007) (Figure 17).

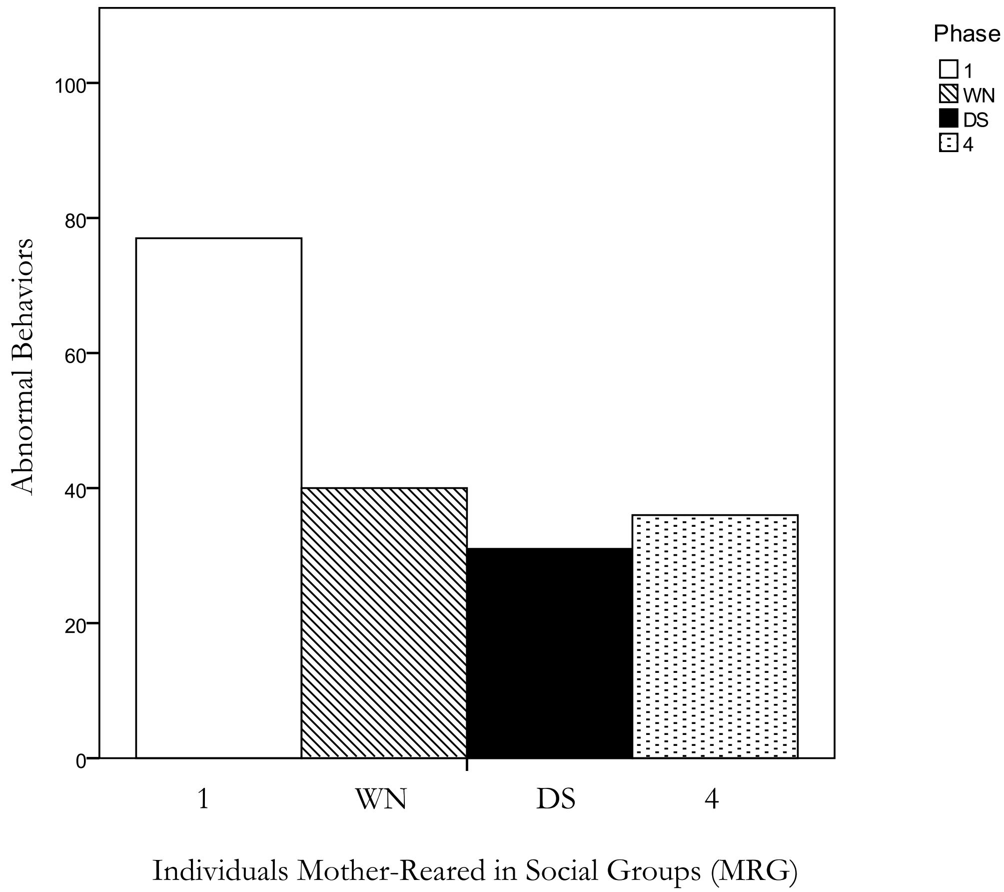

Figure 17. Amount of abnormal behaviors observed in individuals mother-reared in social groups (Groups A and B) for each phase during the TEST period.

Individuals Mother-Reared in Cages

MRC individuals (Group F: N=5), were all observed to pace and huddle in response to humans in Run 6, when sleeping, or in response to other groups' aggression. Several individuals were also observed to self-suck their big toe, while one was observed to suck the crook of her left arm. This typically occurred in response to stressors such as humans in Run 6 or in response to other groups engaging in aggression. Stereotypies, such as back flipping, rocking, and circling, were observed typically in response to the same stressors mentioned previously. Two individuals were observed to eye-poke. This was usually in response to major aggressive interactions occurring in neighboring groups.

MRC individuals exhibited the least amount of abnormal behaviors, 17.4 abnormal behaviors per individual over the course of the study. MRC individuals exhibited their highest frequency of abnormal behaviors, 38, in the control phase which accounted for just 3.80% of their time in the control phase. The expression of abnormal behaviors decreased by 34.21% into the white noise phase. The expression of abnormal behaviors continued to significantly decrease from baseline levels into the DS phase by 40.0% (F: 4.009, df: 3,171, p=≤0.000).

Post hoc Tukey tests showed that abnormal behaviors were significantly lower in the TEST period in the designer music phase then in either the PRE or POST periods (F: 5.292, df: 3, 113, p=0.003) (Figure 18). Overall, there was a significant decrease of 76.3% in the expression of abnormal behaviors from baseline levels (F: 4.009, df: 3, 166, p=<0.000). This overall decrease was the largest when compared with all rearing strategies. Rearing history did not have an effect on rates of aggression.

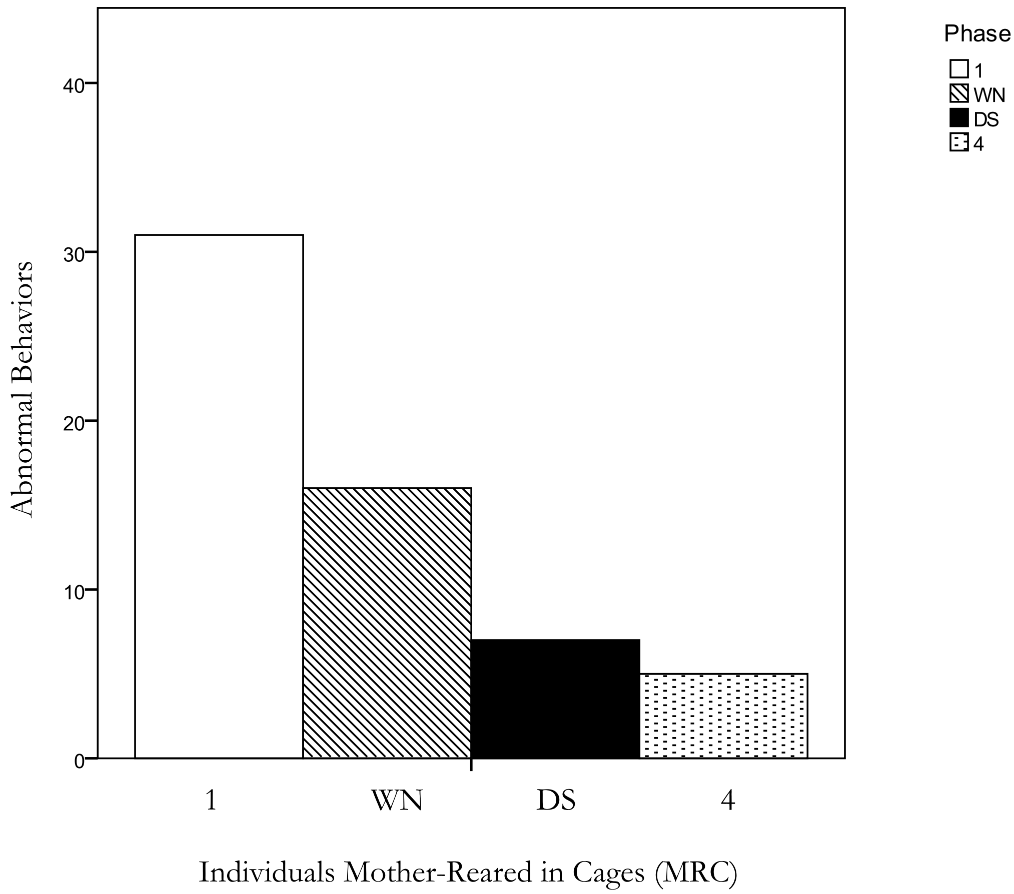

Figure 18. Amount of abnormal behaviors observed for individuals mother-reared in cages (Group F) for each phase during the TEST period.

Effects of Age

Mean group age was found to have a significant effect on rates of social play (F: 36.753, df: 6, 646, p=<0.000). Group C had a mean group age of 1.18y and was found to have significantly higher rates of play in the designer music phase than in both the control phase and the final phase of the study (F: 4.627, df: 3, 88, p=0.005). Group A had the highest group mean age, 5.13y, and was not observed to engage in either social or solitary play throughout the study. Group B, with a group mean age of 2.78y was only observed to engage in social play four times over the course of the study. In addition, Group G, with the third highest mean group age of 2.56y, was also observed to play significantly less than the four remaining groups that have mean group ages of < 1.80 years (F: 36.753, df: 3, 88, p=≤0.000). Those groups with a mean group age of < 2.0 years, Groups D, E, C, and F (Mean group age: 0.11 months, 1.20 years, 1.18 years, and 1.80 years, respectively), were found to engage in social play at significantly higher rates than those groups with an average age of > 2.0 years (F: 36.753, df: 3, 88, p=≤0.000) (Figure 19).

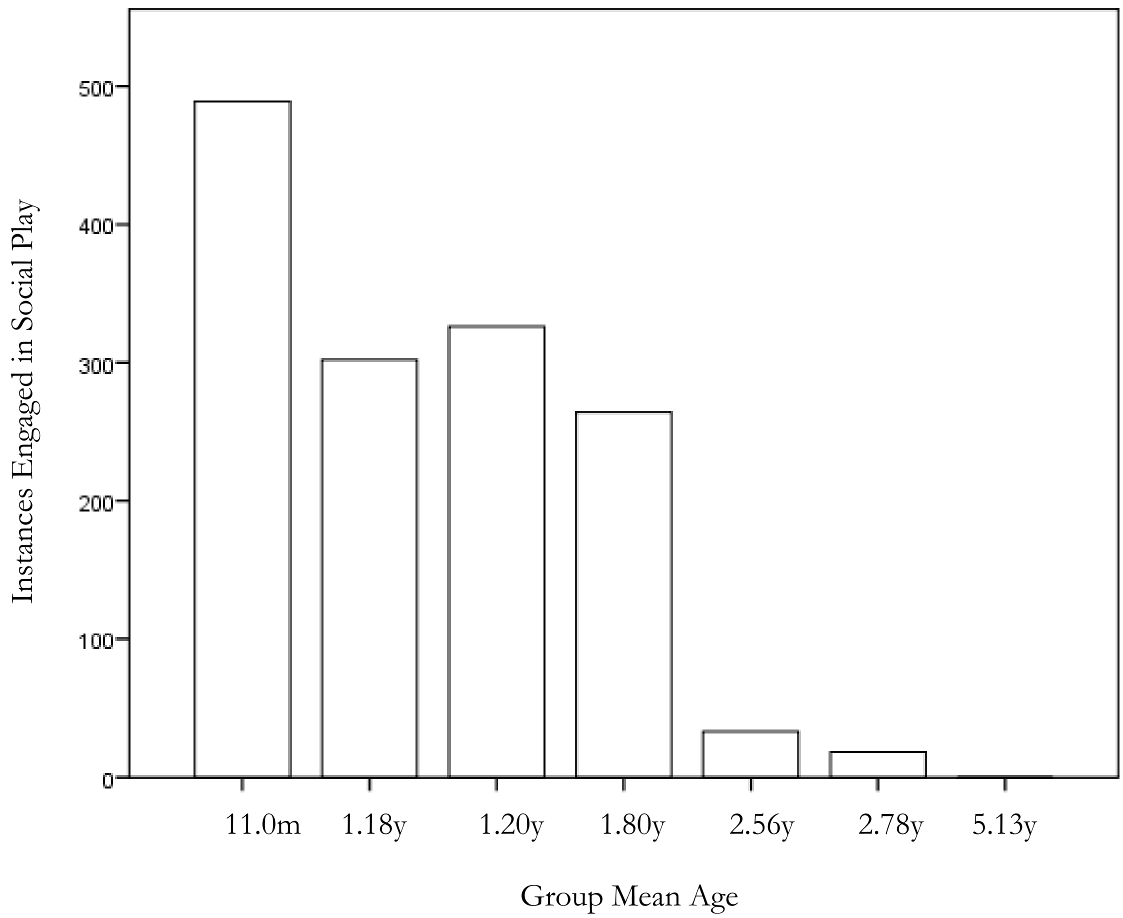

Figure 19. Instances of social play behavior observed by mean group age across the study for all time periods.

Mean group age also significantly affected rates of aggression (ANOVA: 40.842, df: 6, p=0.05). Group D, with a mean group age of 11.0 months, was found to have significantly higher rates of aggression than all other groups with the exception of Group E (Tukey HSD: 40.842, df: 6, p=0.05). Group A, with the highest mean group age, 5.13 years, had significantly lower rates of aggression than all other groups (Tukey HSD: 40.842, df: 6, $p=0.05$). Age did not have an effect on the amount of abnormal behaviors displayed.

CHAPTER IV

DISCUSSION

Past studies of auditory stimuli, specifically music, as an effective enrichment strategy for captive primates have had inconclusive results (Honess and Marin 2006; Patterson-Kane and Farnworth 2006; Wells 2009). This study found that auditory enrichment significantly affected affiliative and abnormal behaviors, as well as rates of exploration and locomotion, in laboratory-housed rhesus macaques. There was a significant reduction in the expression of abnormal behaviors and significant increases in affiliative behaviors, such as rates of social play, grooming, and approach. This study supports the use of auditory enrichment as a behaviorally beneficial enrichment strategy. However, each genre, white noise and designer music, affected behavior in different ways and had different effects on each social group.

White Noise

White noise (WN) was chosen for this study to test the masking effect of music. The masking hypothesis posits that auditory enrichment leads to positive behavioral changes simply because it masks other sounds, such as noise from conspecifics or husbandry activities, and that the actual genre of music has produces no beneficial effect

(Carlson et al. 1997; Honess and Marin 2006; Howell et al. 2003; Ogden et al. 1994). The masking hypothesis is only mildly supported in this study.

White noise was found to increase rates of grooming and also significantly increase time spent engaging in social play. Unpredictable increases in sound lead to high levels of stress in nonhuman primates and the ability of the WN to maintain a more constant sound level may have reduced stress in these animals and allowed them to relax and increase time engaging in affiliative behaviors (Coleman 2009; Lutz et al. 2003; Patterson-Kane and Farnworth 2006). Jazz and radio music were also found to increase affiliative behaviors, such as play behaviors and active exploration, in rhesus macaques and chimpanzees (Honess and Marin 2006; Howell et al. 2003)

Though the WN did have some positive effects on behavior, there was an observed increase in rates of aggression. In fact, Group E exhibited their highest frequency of total aggressive interactions during the WN phase. Management of aggression is a constant concern for those working with laboratory primates and though the increase observed in this study was not statistically significant it is still of some concern (Bloomsmith and Else 2005). Research has suggested that auditory enrichment is beneficial because it provides a distraction and enables relaxation (Videan et al. 2007). However, with WN, the sound is constant and unchanging. So while it may mask outside noise, it does not provide the animal with a distraction. There are no novel sounds or change in melody or tempo that might divert the animal's attention like classical or jazz music might. Increases in aggression may in fact, be due to the masking effect of the WN. Stress levels may have risen in these subjects due to the fact that they could no longer hear sounds they had become accustomed to. And though they could hear the sounds of conspecifics, the WN may have made it harder to communicate with the other social groups across the room, which may have elevated stress levels for these individuals. An increase in stress may have resulted in the observed increase of aggressive interactions.

In addition, there was only a mild decrease in the expression of abnormal behaviors and Groups D and G displayed the most abnormal behaviors during the WN phase. Moreover, abnormal behaviors were expressed at the highest frequency in the WN phase during the TEST period (12:00 to 15:00) when the WN was actually being transmitted to the subjects. This implies that, though there was an overall reduction in the amount of abnormal behaviors expressed from baseline levels, the frequency of behaviors was higher when the WN was on during the TEST period than in either the PRE or POST periods. There are multiple studies that suggest that once abnormal behaviors manifest they tend to persist and are hard to ameliorate (Baker et al. 2009; Coleman and Maier 2010; Lutz et al. 2003; Rommeck et al. 2009a). Abnormal behaviors are thought to develop as a coping mechanism in laboratory primates (Bloomsmith and Else 2005; Lutz and Novak 2005). The findings of this study suggest that the noise from husbandry activities or other outside noise, that the WN masked, are not the main catalyst for the expression of abnormal behaviors. Still, well-being is not solely the absence of negative effects, but the presence of positive affects; such as the observed increase in play, grooming, and rate of approach (Boissy et al. 2007).

Designer Music

The designer music (DS) used in this study had multiple positive behavioral effects on these individuals. Similar to results observed in chimpanzees, the DS music significantly increased the time subjects spent engaging in social play (Videan et al. 2007). Furthermore, Groups C, D, and E, displayed their highest rates of play behaviors during the TEST period (12:00 – 15:00) while the music was playing than in either the PRE or POST periods. Similar to the WN, the DS music may have reduced stress and allowed the animals to relax leading to an increase in social play and other affiliative behaviors. An increase in affiliative behaviors has been shown to lower heart rate in macaques which signifies a decrease in stress levels (Boccia 1989). The DS music was also found to significantly increase rates of affiliative approach, which is in accordance with Videan et al. (2007) who demonstrated that instrumental music was effective at increasing positive social interactions in laboratory-housed chimpanzees. Indeed, research has shown that engagement in play and other affiliative behaviors are the best indicators for assessing positive experiences (Boissy et al. 2007; Schapiro et al. 1995). Furthermore, the added complexity of the DS music may have caught the animal's attention enough to distract them from engaging in abnormal behaviors. The ability of the DS music to create a distraction may have allowed for even higher rates of play and also decreased aggression and abnormal behaviors during the DS phase.

Aggression was reduced by 17.8% from baseline levels during the DS phase. Groups A and E exhibited their least amounts of aggression and Groups B and E significantly reduced aggression during this phase. These results support findings that auditory enrichment (classical and radio) reduced aggression in gorillas and chimpanzees (Howell et al. 2003; Wells 2009). The DS music (which consisted of a playlist of thirteen tracks) provided the animals with novel, constantly changing, auditory stimuli that may well have served as a distraction, or caught their attention enough to reduce aggressive impulses. Another factor that may be related to a reduction in aggression is the time individuals spent alone. The population was found to spend significantly more time alone in the DS phase than in any other phase. Though increased time alone can be interpreted as a negative result in social primates, since there was an observed increase in affiliative behaviors (i.e. play and approach), more time spent alone can be understood as a function of decreased stress levels.

Research has shown that increased stress levels lead to coping behaviors, such as huddling (Lutz et al. 2003). Therefore, when stress and anxiety are low, individuals are more comfortable spending time alone and do not need to seek the companionship of a conspecific to help them cope, thereby reducing aggressive interactions.

In addition, there was a statistically significant reduction in time spent in locomotion from baseline levels, with the lowest frequency of locomotion observed during the DS phase. A decrease in activity level may also be interpreted as a negative effect of the DS music. However, similar to the increase in time spent alone, when individuals have a reduction in stress and anxiety they seem to be able to relax and do not feel the need to be constantly in motion. In fact, ecological sounds lead to increased locomotion in gorillas that was interpreted as indication of increased stress levels (Ogden et al. 1994). Moreover, when aggression is low, tension in social groups also reduces. Therefore, these individuals may have spent less time relocating around the enclosure in an attempt to avoid conflict.

The increase in play was coupled with an increase in active exploration across the population, supporting similar findings observed in chimpanzees (Howell et al. 2003). Groups A, E, F, and G were observed to spend significantly more time engaged in exploration during the DS phase. Enrichment helps to stimulate naturally curious primates (Lutz and Novak 2005) and the complexity and novelty of the DS music may have promoted an increase in explorative behavior. Indeed, Brent et al. (1989) found that the presence of a television stimulated chimpanzees to visually explore their environment. Platt and Novak (1997) suggested that the similar increase in exploration they observed in rhesus macaques to television may represent species-typical vigilance behavior. The DS music in this study may have stimulated the subjects in a similar way leading to higher rates of exploration.

Designer music had the greatest effect on the expression of abnormal behaviors. There was an extremely significant 34.5% reduction in the exhibition of abnormal behaviors across the population from baseline levels recorded in the control phase. Furthermore, Groups B, C, and F significantly reduced time spent engaging in abnormal behaviors from the control phase. The literature asserts that once abnormal behaviors develop they are extremely hard to alleviate, and when enrichment is effective at reducing abnormal behaviors it is typically not consistent and only provides results for the time that the animals is actually engaged with the enrichment device (Coleman and Maier 2010; Lutz and Novak 2005; Rommeck et al. 2009a). This is one of the many benefits of auditory enrichment versus feeding enrichment or the addition of manipulanda. Auditory enrichment is equally available to all individuals who are within hearing range and it does not add the risk of increased aggression to gain access to the enrichment. In addition, auditory enrichment can be available for long periods of time, unlike feeding enrichment which runs out relatively quickly. Classical music was found to decrease stereotypic and self-mouthing behavior in rhesus macaques (Honess and Marin 2006), but at present, there are no other studies that have evaluated auditory enrichment with the specific goal of reducing abnormal behaviors.

The results of this study have important implications for management of laboratory primates, where 80.0% of primates in one National Primate Center were found to exhibit at least one type of abnormal behavior (Lutz et al. 2003). Auditory enrichment has been insufficiently researched and under-utilized as an enrichment strategy (Wells 2009). Yet, this study shows that auditory enrichment, specifically designer music, is effective at satisfying the two main goals of environmental enrichment: promoting species-typical behaviors and preventing, eliminating, or reducing abnormal behavior (Baker et al. 2006).

There are multiple hypotheses to explain the reduction in the expression of abnormal behaviors observed in the DS phase. Again, it may be the complexity and novelty of the DS music that distracts the individual enough to reduce engagement in abnormal behaviors. The reduction may also be a factor of increased rates of play. The study subjects spent significantly more time engaged in play during the DS phase than during the control phase; more time interacting with cage-mates and participating in social play leaves less time to engage in abnormal behaviors. However, if an increase in play were the sole reason for the decrease in abnormal behavior, we would expect to see a similar decrease in abnormal behavior in the WN phase which also yielded significant increases in play. Yet, we do not. Therefore, the decrease in abnormal behaviors in the DS phase must be attributed to the designer music.

The specific tracks of designer music selected were composed with the specific goal of improving mental and emotional states (McCraty et al. 1998). Though no physiological data were collected for this specific study, if the benefits of listening to this genre are similar to those observed in humans (23.0% reduction in cortisol levels)(McCraty et al. 1998), then we can assert that a reduction in cortisol (i.e., stress) would explain the decrease in the frequency of abnormal behaviors expressed in these study subjects. Improvements in welfare are hard to assess in captive primates (Rommeck et al. 2009a). However, a decrease in the amount of abnormal behaviors displayed in a population is an excellent indicator of improved well-being.

Furthermore, the decrease in abnormal behaviors during the DS phase was most significant in the middle of the TEST period, at 13:00. Significantly, during the control phase and also during the WN phase, this was the time period the most abnormal behaviors were observed. Therefore, the decrease in abnormal behaviors cannot be explained just by the time of day. In other words, the first two weeks of the study the expression of abnormal behaviors was at its highest at 13:00. During the DS phase, when the DS music was played, the expression of abnormal behaviors was significantly lower at 13:00 in the TEST period than in either the PRE or POST period. The finding that abnormal behaviors increased into the POST period supports previous research that posits that environmental enrichment is only effective at alleviating abnormal behaviors while the animal is interacting with the enrichment device (Baker et al. 2009; Lutz et al. 2003; Rommeck et al. 2009a). Though this study did not use a device that the individual could physically interact with, the most significant reduction in the frequency of abnormal behaviors was during TEST when the DS music was being transmitted to the subjects.

However, the most significant result of this study is that the reduction in the expression of abnormal behaviors observed in the DS phase seems to have been residual. That is, the frequency of abnormal behaviors remained low after the subjects were no longer exposed to the auditory stimuli. While there was a slight increase in abnormal behavior in the POST period in the DS phase and into Phase 4, importantly, these behaviors remained significantly decreased from baseline levels. Abnormal behaviors were significantly lower in the TEST period during the last week of the study than they were in the control phase. This result suggests that DS music produces positive changes in behavior well after access to the enrichment has ended. The ability of designer music to maintain behavioral changes when access to the enrichment has ceased has not been observed with more popular forms of environmental enrichment, such as feeding enrichment or the addition of manipulanda (Honess and Marin 2006; Reinhardt and Roberts 1997).

As with the other behavioral changes observed there was concern that the decrease in abnormal behavior was only due to increased familiarity with myself. Rhesus macaques are xenophobic and it is possible that any increase in abnormal behavior was a reaction to my being in the enclosure for an extended time (Singh and Gupta 1980). I spent approximately 25 hours conducting preliminary observations of the population in the days prior to starting the formal study. Therefore, the animals were at least somewhat familiar with me by the time observations began in the control phase. Interestingly, there were only four more abnormal behaviors observed in Phase 4 than in the DS phase. If the reduction in abnormal behaviors was due to the subjects becoming more relaxed and comfortable with my presence we would expect to see the frequency of abnormal behaviors observed continue to drop into Phase 4, but we do not. The expression of abnormal behaviors does not return to baseline levels either, which further supports that the DS music was the influencing factor. Moreover, rates of aggression increased into Phase 4 as well. If the decrease in abnormal behaviors was a result of the animals becoming more relaxed and accustomed to my presence we should not have seen the increase in aggression.

Effects of Age

Mean group age had a significant effect on rates of aggression and social play. Groups with a high mean age spent significantly less time engaged in play behavior than those with a mean group age of < 1.80 years. In fact, Group A with the highest mean group age (5.13y) was not observed to engage in social play throughout the entirety of the study and Group B (mean age 2.78y) was found to engage in play just four times over the course of the study. Despite the fact that infants and individuals under the age of two engage in play at significantly higher rates than older conspecifics(Pellegrini and Smith 2006), younger individuals may respond more favorably to auditory enrichment. In fact, while rainforest sounds lead to negative behavioral effects in adult gorillas, infants were found to cling significantly less (Ogden et al. 1994). Future research may find that nonhuman primate infants and juveniles have increased auditory sensitivities that simultaneously lead to higher stress levels when confronted with unpredictable or loud, intermittent noise, but are also more responsive to auditory enrichment that may mask certain sounds and help to maintain a more constant decibel level.

Age also had a significant effect on rates of aggression. Group D, with the youngest mean group age (11.0m), had significantly higher rates of aggression than groups with a higher mean age. Conversely, Group A, with the highest mean group age, had significantly lower rates of aggression than all other social groups. Formation of, or transfer into, new social groups can be met with periods of increased aggression as the individuals in the group fight to determine or maintain their place in the social hierarchy (Augustsson and Hau 1999). Although I do not know the actual date of the formation of Group D, it is a reasonable assumption that with a mean group age of 11.0m, the individuals in Group D have only been in that specific social group for a short period of time and may still be settling in to their roles.

However, the rates of aggression may be more affected by group size than age. Group D had the second largest group size, with seven individuals. Large group size coupled with limited housing space can lead to increases in aggression (Southwick 1967).

Rearing History

Rearing history had an extremely significant correlation with not only the amount of abnormal behaviors displayed in the control period, but the effectiveness of the auditory enrichment to reduce the expression of these behaviors.

The results of this study is in accordance with the majority of the literature that suggests adverse experiences in early life, such as nursery-rearing, are a substantial risk factor for the development of abnormal behaviors (Baker et al. 2006; Bloomsmith and Else 2005; Coleman and Maier 2010; Lutz et al. 2003; Olsson and Westlund 2006; Rommeck et al. 2009b). Though there are seven social groups in this study, only four housed individuals from similar rearing histories. Individuals in Groups A and B were all mother-reared in social groups (MRG). Group C housed individuals that were all nursery-reared; reared in the nursery from <11 days of age until approximately 7 months (NUR). And Group F housed individuals that were all mother-reared in single cages (MRC). The three remaining groups housed individuals reared from each of the three rearing styles. Indeed, this study found that NUR individuals exhibited more abnormal behaviors over the entirety of the study than both MRG and MRC individuals.

Group C (NUR) exhibited significantly more abnormal behaviors over the course of the study than the MRG and MRC groups. Individuals that are reared without their mothers have been shown to develop abnormal behaviors as a coping mechanism and as a means to self-soothe (Baker et al. 2009; Bloomsmith and Else 2005; Morgan and Tromborg 2007). Interestingly, NUR individuals significantly reduced displays of abnormal behaviors across the study, with the lowest rates of abnormal behaviors expressed during the DS phase. Furthermore, abnormal behaviors were at their lowest during the TEST period when the designer music was actually played. NUR individuals may have responded favorably to the novel environment the DS music created. NUR individuals are reared in a static environment and though they had been housed in Run 6 for at least a couple months they may have reacted more positively to changes in environmental stimuli. The frequency of abnormal behaviors observed in Phase 4 was 46.94% less than what was observed in the control phase. This suggests that individuals that develop abnormal behaviors from negative experiences in early life can reduce the time spent engaging in abnormal activity and furthermore, this change in behavior remains even after the individual is no longer actively exposed to the enrichment.

Mother-rearing in large social groups is generally said to be the ideal rearing strategy for captive primates (Rommeck et al. 2009b). Groups A and B housed individuals that were MRG, yet Group A displayed significantly fewer abnormal behaviors than Group B. In addition, Group B significantly decreased the expression of abnormal behaviors from the control phase, whereas Group A exhibited the lowest frequency of abnormal behaviors during the WN phase and then continued to increase display of abnormal behaviors for the remainder of the study. There does not seem to be a clear explanation of these differences. Group A housed four females and Group B, three females and one male. Group B may have exhibited more abnormal behaviors in an effort to cope with higher rates of aggression that may have arose from competition to gain access to the only male. Furthermore, and perhaps more significantly, Group B had one female removed following preliminary observations after she suffered a broken leg. The change in the social dynamic of Group B may have resulted in a higher frequency of abnormal behaviors as the individuals attempt to stabilize their newly altered social group (Augustsson and Hau 1999). However, these differences in similarly reared individuals may represent differences in preference of auditory stimuli. Group A was the only group to display the least amount of abnormal behaviors in the WN phase. It may be that Group A did not like the DS music and responded by increasing display of abnormal behaviors. There are other catalysts that may have lead to the differences in the amount of abnormal behaviors expressed in these two groups.

The difference in the rate of abnormal behaviors may also be due to differences in age at weaning. Monkeys who are weaned from their mothers at a young age have been shown to develop abnormal behaviors (Rommeck et al. 2009b). Furthermore, abnormal behaviors have been shown to develop in response to multiple cage relocations, as well as in individuals who have their first relocation at a young age (Rommeck et al. 2009b). Though these individuals were raised with their mothers in large social groups Group B may still have undergone adverse conditions in early life that left them more susceptible to develop abnormal behaviors.

Group F, which housed MRC individuals, exhibited the least amount of abnormal behaviors over the course of the study. Abnormal behaviors were displayed significantly less in the DS phase during the TEST period when the music was played, with the least amount of behaviors observed in Phase 4, the final phase of the study. This Group decreased the expression of abnormal behaviors by an astonishing 76.30% from baseline levels at the culmination of the study. These individuals have experienced unfavorable rearing conditions, reared in a single cage with their mother. However, unlike NUR individuals who also experienced adverse early life conditions, they displayed the least amount of abnormal behaviors. Unlike NUR individuals, who are also reared without a large group of conspecifics, MRC individuals are still in their mothers care. Remaining in the care of the mother has been attributed to be the single most important factor to prevent the development of abnormal behaviors (Rommeck et al. 2009b). The low amount of abnormal behaviors observed in these individuals who were reared in adverse housing conditions highlights the importance of the mother-infant relationship.

The Groups with rearing histories that the majority of the literature suggests leave them at greater risk for the development of abnormal behaviors (NUR and MRC) were found to respond extremely favorably to the designer music used in this study (Rommeck et al. 2009b). These behaviors have been said to be extremely hard to ameliorate and when decreases in abnormal behaviors are observed they tend to return to baseline levels following the end of exposure to the enrichment (Lutz et al. 2003). These Groups, C and F, not only significantly reduced the expression of abnormal behaviors, but these reductions persisted into Phase 4, after the auditory stimuli was no longer available to the animals. This finding is important for laboratory-housed primates who, out of necessity, are often reared in sub-optimal conditions (Rommeck et al. 2009b). This study finds that designer music yields positive lasting and residual effects on abnormal behavior in individuals that are at the greatest risk for decreased welfare.

Conclusion

The auditory enrichment utilized in this study significantly affected the behavior of the individuals in this study. There was a significant reduction in the number of abnormal behaviors displayed from frequencies observed during the control period. In addition, there was a significant increase in affiliative behaviors, such as play and grooming, and also increases in exploration. Many of the positive effects of auditory enrichment on the behavior of laboratory primates have been attributed to the masking effect of the music rather than the music itself (Carlson et al. 1997; Ogden et al. 1994; Patterson-Kane and Farnworth 2006). However, results of this study indicate that the designer music was far more effective at positively altering behavior in laboratory-housed rhesus macaques than the masking effect of the white noise. The significant increase in affiliative behaviors along with significant reductions in the expression of abnormal behaviors indicates that auditory enrichment, specifically designer music, is an effective enrichment strategy for laboratory-housed rhesus macaques. These results show that the groups with the most abnormal behaviors overall exhibited the least behaviors when listening to designer music. Enrichment has had minimal success at the reducing abnormal behaviors in captive primates (Baker et al. 2009; Laule 1993; Lutz et al. 2003; Rommeck et al. 2009a; Rommeck et al. 2009b). However, this study shows that designer music is not only an extremely effective enrichment strategy, but an ideal one for laboratories that lack the time, money, and resources to implement other more complex enrichment programs. Furthermore, other more popular forms of enrichment, such as feeding enrichment, have not been shown to improve the suite of behaviors that designer music was able to ameliorate in this study.

Future research should aim to determine the length of time the auditory enrichment should be available to the animals that is most beneficial. It should also be determined precisely how long changes in behavior tend to persist. In addition, while the designer music was effective for group-housed laboratory rhesus macaques, we cannot assume that all species in all housing conditions will benefit in the same way. Since designer music was so effective at ameliorating abnormal behaviors, future research should continue to test the effectiveness in other populations and other species. Designer music may also be useful as a preventative measure for the development of abnormal behaviors. This genre should be tested with those reared in nurseries or with singly-housed individuals to determine if the designer music might be successful at not only reducing, but preventing the development of these behaviors. Future studies should also aim to have stricter control of the animals' schedule. In the present study, enrichment, feeding, and husbandry activities were not confined to a specific schedule. Though these activities did not seem to have a significant effect on the results of this study, to thoroughly understand the complete effects of designer music more controls need to be in place to eliminate as many variables as possible. It should also be determined to what aspect of the designer music the animals are responding. Determining whether it is the tone, tempo, instruments used, melody, or some other factor that influences the animals behavior will allow not only a better understanding of how nonhuman primates perceive music, but will also allow those who care for primates in captivity to make an informed decision when selecting other genre as part of an auditory enrichment program.

On the basis of the current study, designer music should be implemented in laboratories for groups of juvenile and infant rhesus macaques to meet both main goals of environmental enrichment: an increase in species-typical behavior and a reduction of abnormal behavior. Designer music should be utilized to increase affiliative and other species-typical behaviors, while also decreasing time spent engaging in abnormal behavior, thus increasing psychological well-being, reducing stress, and improving the welfare of laboratory-housed rhesus macaques.

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APPENDIX A

DEMOGRAPHIC DATA

Table 5. Age, sex, and rearing distribution of subjects in Colony Run 6. (Rearing: MRG = mother-reared in social groups, NUR = nursery-reared, MRC = reared with mother in either single or paired cages, Age: IN = infant; <1 year, J = juvenile; >1 year - <5 years, SA = subadult; >5 years)

ID Number	**Group**	**Sex**	**Age (Years)**	**Age Category**	**Rearing**
23230	A	F	8.10	SA	MRG
25195	A	F	5.10	SA	MRG
25521	A	F	5.20	SA	MRG
26572	A	F	2.11	J	MRG
26404	B	F	3.00	J	MRG
26413	B	M	3.00	J	MRG
26475	B	F	3.00	J	MRG
26569	B	F	2.11	J	MRG
26581	B	F	2.10	J	MRG
27757	C	F	1.20	J	NUR
27772	C	M	1.20	J	NUR
27783	C	M	1.20	J	NUR
27901	C	M	1.10	J	NUR
27902	C	M	1.10	J	NUR
27911	D	F	1.00	J	MRC
27976	D	F	1.00	J	MRC
27997	D	F	1.00	J	MRC
28076	D	F	0.11	IN	MRC
28084	D	M	0.11	IN	MRC
28190	D	M	0.10	IN	MRG
28565	D	F	0.78	IN	MRC
27708	E	F	1.50	J	MRC
27939	E	M	1.00	J	MRC
27946	E	M	1.00	J	MRC
28085	E	M	0.11	IN	MRC
28192	E	M	0.10	IN	MRC
28194	E	F	0.10	IN	NUR

28398	E	F	1.00	J	MRG
28405	E	M	1.00	J	MRG
27745	F	M	1.30	J	MRC
27874	F	M	1.10	J	MRC
27877	F	M	1.10	J	MRC
27097	F	F	1.00	J	MRC
28144	F	F	0.11	IN	MRC
26407	G	M	3.00	J	NUR
26425	G	F	1.20	J	NUR
26436	G	F	2.11	J	MRC
26451	G	F	2.11	J	MRC
26516	G	F	2.11	J	MRC
26759	G	F	2.11	J	MRG

APPENDIX B

BEHAVIORAL MEASURES

Table 6. Behavioral ethogram.

Behavioral Class: Social (Initiating or Receiving)

Behavior	**Class**	**Code**	**Operational Definition**
aln: alone	Social	State	Individual is not in proximity to any other individual.
grm: groom	Social	State	Manipulation of the hair of another individual(s) with hands and/or mouth.
prx: proximity	Social	State	Individual is within 1 meter (at arm's length) of another individual(s) with any part of the body.
ply: play	Social	State	Individual is engaged in social interactions that are characterized by apparent low tension; may be accompanied by a "*play face*" (facial gesture in which mouth is open and facial features are relaxed). May include: *grunting, wrestling, sham-biting, jumping on, jumping over, chasing, fleeing*.
tch: touch	Social	State	Individual is in physical contact with another individual(s) with any part of the body.
ven: ventral	Social	State	Individual is in huddling and/or close stationary contact other than grooming, with one other individual.
hud: huddle	Social	State	Individual is in close ventral stationary contact other than grooming with multiple individuals.

Behavioral Class: Non Social

Behavior	**Class**	**Code**	**Operational Definition**
eat: eat/drink	Non Social	State	Individual is ingesting liquid or solid food material (common usage).
exp: explore	Non social	State	Individual appears to be attempting to gain information about its environment or an object, the individual inspects or manipulates object other than food; specifically enrichment objects. May include: balls, dog toys, swings.
for: forage	Non Social	State	Individual is searching floor, presumable for food.
loc: locomotion	Non Social	State	Individual engages in movement from one location to another while using its entire body.
sfg: self-groom	Non Social	State	Picking through and/or slowly brushing aside own hair with hands and/or mouth.

slp: sleep	Non Social	State	Individual appears to be sleeping; is stationary with eyes closed.
sta: stationary	Non Social	State	Individual is inactive; not engaged in full body, mobile movement. May involve head or arm movement.
abn: abnormal	Non social	State	Individual is engaged in atypical behavior.
pac: pacing	Non social	State	Repetitious, patterned and usually unidirectional movement around enclosure.
cir: circling	Non Social	State	Animal bends hind limbs and spins self in a clockwise or counter-clockwise direction at a fast pace for at least three rotations.
thrbt: threat bite	Non Social	State	Aggressive behavior that involves biting the monkey's own body-typically the hand, wrist, or forearm-while staring at the conspecific or conspecific in a threatening manner.
eye: eye-poking	Non Social	State	A self-injurious behavior, typically characterized by a "saluting" gesture of the monkey's hand over the eye. May include: pressing of the knuckle or finger into the orbital space above the eye socket.
roc: rocking	Non Social	State	A back and forth movement of the upper body with feet stationary.
ss: self/digit sucking	Non social	State	Some part of the animal's own body-typically the digits of the hand or foot-are placed in the individual's mouth and sucked.
cge: cage/wall bite/lick	Non social	State	Repetitive licking or scratching of walls or bars of the enclosure. Does not occur following cage washings and there are no visible food items or other material on the surface.
bfl: backflipping	Non Social	State	Three or more repeated forward or backwards somersaults. May include: grabbing the top of the cage and swinging the body through the arms.

Behavioral Class: Events (Social: Initiating or Non Social: Receiving)

Behavior	**Code**	**Operational Definition**
chs: chase	Event	Behavior that involves pursuit past the location the recipient maintained at the start of the interaction.
dsp: displace	Event	Individual leaves or avoids another individual(s) promptly upon being approached.
fg: fear grimace	Event	Individual bares teeth.
ls: lipsmack	Event	Facial expression involving rapid movement of the lips.
scr: scratch	Event	Movement of the hand or foot during which the fingers/fingernails or toes/toenails are rapidly drawn across the hair or skin.
vol: vocalization	Event	Individual makes a sound. May include: *grunts, barks, coos, geckers, screams.*
thr: threat	Event	Expression containing facial, vocal, or physical components. May include: *head-thrusting, open-mouth threat, scream, raised eyebrow, ground beating, lunge.*

agr: aggression	Event	Rough Behavior: involving slight physical contact without facial or vocal components Bite: during which the skin/limb of another individual is grasped with the teeth; may be accompanied by head shaking.
mnt: mount	Event	Individual positions itself on another animal such that their genitalia are in contact. Behavior is of short duration with no pelvic thrust observed.

Table 7. Sample behavioral check sheet used during observations. One sheet was used per group per hour.

	Location					Class: Social/Non Social States											Class: Events				
Time	Alone	Proximity	Touch	Ventral	Huddle	Abnormal	Groom	Eat/Drink	Explore	Forage	Approach	Locomotion	Self groom	Play	Sleep	Stationary	Aggressive	Displace	Fear grim	Lipsmack	Threat
0:00	aln	prx	tch	ven	hud	abn	grm	eat	exp	for	app	loc	sgr	ply	slp	sta	agr	dsp	fg	ls	thr
aln																					
prx																					
tch																					
ven																					
hud																					
0:06	aln	prx	tch	ven	hud	abn	grm	eat	exp	for	app	loc	sgr	ply	slp	sta	agr	dsp	fg	ls	thr
aln																					
prx																					
tch																					
ven																					
hud																					
0:12	aln	prx	tch	ven	hud	abn	grm	eat	exp	for	app	loc	sgr	ply	slp	sta	agr	dsp	fg	ls	thr
aln																					
prx																					
tch																					
ven																					
hud																					
0:18	aln	prx	tch	ven	hud	abn	grm	eat	exp	for	app	loc	sgr	ply	slp	sta	agr	dsp	fg	ls	thr
aln																					
prx																					
tch																					
ven																					
hud																					
0:24	aln	prx	tch	ven	hud	abn	grm	eat	exp	for	app	loc	sgr	ply	slp	sta	agr	dsp	fg	ls	thr
aln																					
prx																					
tch																					
ven																					
hud																					
0:30	aln	prx	tch	ven	hud	abn	grm	eat	exp	for	app	loc	sgr	ply	slp	sta	agr	dsp	fg	ls	thr
aln																					
prx																					
tch																					
ven																					
hud																					
0:36	aln	prx	tch	ven	hud	abn	grm	eat	exp	for	app	loc	sgr	ply	slp	sta	agr	dsp	fg	ls	thr
aln																					
prx																					
tch																					
ven																					
hud																					

0:42	aln	prx	tch	ven	hud	abn	grm	eat	exp	for	app	loc	sgr	ply	slp	sta	agr	dsp	fg	ls	thr
aln																					
prx																					
tch																					
ven																					
hud																					
0:48	aln	prx	tch	ven	hud	abn	grm	eat	exp	for	app	loc	sgr	ply	slp	sta	agr	dsp	fg	ls	thr
aln																					
prx																					
tch																					
ven																					
hud																					
0:54	aln	prx	tch	ven	hud	abn	grm	eat	exp	for	app	loc	sgr	ply	slp	sta	agr	dsp	fg	ls	thr
aln																					
prx																					
tch																					
ven																					
hud																					

APPENDIX C

AUDITORY ENRICHMENT

Table 8. Auditory enrichment CD selections.

CD Title	Composer	Copyright	Genre
"Heart Zones"	Doc Lew Childre	1994	Designer music
"Speed of Balance"	Doc Lew Childre	1995	Designer music
"Quiet Joy"	Doc Lew Childre	2001	Designer music
"Natural White Noise for Babies"	----	2009 Crain and Taylor	White noise

Table 9. Designer music playlist.

Track Number	Track Title	CD	Track Length (minute: second)
1	Effects on the Immune System	Heart Zones	3:46
2	Effects on the Cardiovascular System	Heart Zones	4:55
3	Bonus Track #1	Heart Zones	3:09
4	Bonus Track #2	Heart Zones	3:47
5	Bonus Tack #3	Heart Zones	4:55
6	Bonus Track #4	Heart Zones	3:05
7	Global Anthem	Quiet Joy	2:21
8	Heart Zones: Song One	Quiet Joy	3:46
9	Heart Zones	Quiet Joy	2:50
10	Heart Zones: Song Four	Quiet Joy	3:07
11	Street Sax	Speed of Balance	3:08
12	Intentional Yet Sensitive	Speed of Balance	4:40
13	Heart March	Speed of Balance	2:42

Figure 20. “Natural White Noise for Babies” cover art.

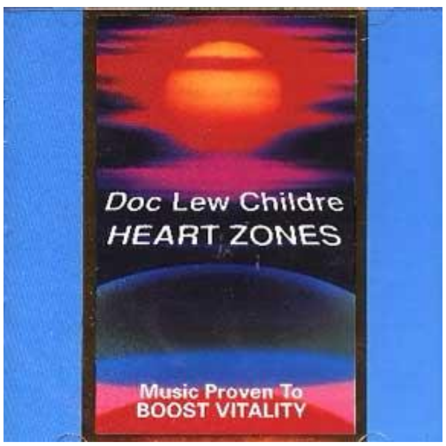

Figure 21. “Heart Zones” cover art.

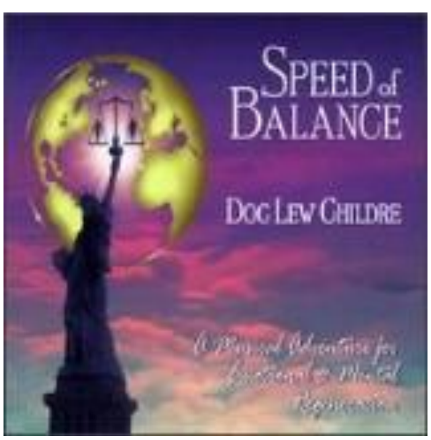

Figure 22. “Speed of Balance” cover art.

Figure 23. "Quiet Joy" cover art.

VITA

Laura Marie Graves was born in Walnut Creek, California, on July 25, 1981, the daughter of Margret Rinner Graves and Jon Warren Graves. After completing her work at College Park High School, Pleasant Hill, California, in 1999, she entered Diablo Valley College in Pleasant Hill, California. In August 2003 she entered San Diego Mesa College in San Diego, California. After completing her general education requirements, she entered San Diego State University in San Diego, California. She received the degree of Bachelor of Arts in Anthropology from San Diego State in December 2008. In August 2009, she entered the Graduate College of Texas State in the Anthropology Department to earn the degree of Master of Arts in Anthropology with a Physical Anthropology specialization.

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