To the Graduate Council:

I am submitting herewith a thesis written by David B. Hamilton entitled "Behavioral Responses of the Common Marmoset in the Presence of Different Environmental Enrichment Devices ." I have examined the final copy of this thesis for form and content and recommend that it be accepted in partial fulfillment of the requirements for the degree of Master of Science, with a major in Life Sciences.

Suzette D. Tardif

Suzette D. Tardif, Ph.D., Major Professor

We have read this thesis
and recommend its acceptance:

Accepted for the Council:

Associate Vice Chancellor
And Dean of the Graduate School

BEHAVIORAL RESPONSES OF THE COMMON MARMOSET IN THE PRESENCE OF DIFFERENT ENVIRONMENTAL ENRICHMENT DEVICES

A Thesis

Presented for the

Master of Science

Degree

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David B. Hamilton

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DEDICATION

This manuscript is dedicated to my best friend Dianne Craig, the marmosets in this study, all the animals I have worked with at the Knoxville Zoo, and my own canines, Tasha and Sandra.

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ABSTRACT

The purpose of this study was to examine the behavioral responses of common marmosets, *Callithrix jacchus*, when provided with different environmental enrichment devices. Four devices, foraging boxes, ropes, nature sounds and whiffle balls were tested. With this assessment, a few base components are suggested from which a more complex program can be built for the rest of animals in this colony or for any other facility holding common marmosets.

A facility housing many animals must necessarily objectively evaluate the costs and benefits of an enrichment device with a few animals before instituting a colony-wide enrichment program. This thesis demonstrated a method of assessing the ways that the different environmental enrichment items effected the behavior of the subjects. The small N research design utilized here can be used to test enrichment in research facilities or zoos where there is usually little time for extra projects.

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CHAPTER ONE

INTRODUCTION

> . . . the greatest possibility for improvement in our provision for captive primates lies in the invention and installation of apparatus which can be used for play or work. (Yerkes, 1925)

Research facilities, zoos, sanctuaries, and private individuals keep specimens of many of the world's estimated 265 species of primates. With this in mind, the Animal Welfare Act was amended to require that the primates in most captive situations be provided with conditions which will contribute to their well-being (USDA, 1991). European countries have laws requiring that the animals' "ethological needs" are taken into account (Poole, 1990). Apart from health regulations, one important arena of these laws is the required provision of environmental enrichment. This term has quickly evolved to encompass many diverse elements including devices to increase time spent foraging, cage furnishings that promote natural behavior, modes to increase positive stimuli in the surroundings and toys that increase manipulation.

In order to know which of a multitude of items and options is of actual benefit to a particular species or individual, an institution should have a method to test different ones. This thesis will show one such method of assessment and the ways different environmental enrichment items affected the behavior of common marmosets kept in a colony at The University of Tennessee in Knoxville, Tennessee.

Callithrix jacchus Natural History

The common marmoset, *Callithrix jacchus,* is a small South American primate. It belongs to the family Callitrichidae, which includes both marmosets and tamarins. These genera are identified by their size, dental formula, predominance of twin births, and by having claws rather than nails (Sussman and Kinzey, 1984). The callitrichids are all diurnal and arboreal. They will eat insects, small vertebrates, fruit, tree exudates, and nectar.

Common marmosets have a special dentition for gnawing holes in wood to get to tree sap (Sussman and Kinzey, 1984). They also have a specialized caecum for the digestion of those exudates (Ferrari and Ferrari, 1989). They weigh approximately 340 grams (Tardif, pers. comm.) have a body length of 18.5 cm and tails that are 27.4 cm long (Hershkovitz, 1977).

Callitrichids have a reproductive strategy that is unique among primates, which in turn influences their social organization. A female commonly has multiple births with twinning being the most common. Any additional offspring in a litter will usually not survive (Yamamoto, 1993). The capacity for twinning allows for a high offspring/mother weight ratio. Energetically this causes the mother to require assistance raising her young (Tardif, Harrison, and Simek, 1993). A typical social group composition is an adult male, an adult female, the most recent offspring and their older siblings (Yamamoto, 1993). The male and older siblings help in the care and transport of the young. This assistance relieves some of the burdens of parenting for the female. While the male stays with the female to help care for his offspring, he has the benefit of being near the female during her post-partum estrus. He has early and sometimes exclusive access to the female when this occurs nine to ten days after parturition. The older siblings benefit from protection and are continually learning from their parents. In particular, the allocare they give instills parenting skills that benefit them when raising their own young (Epple, 1975; Hoage, 1978; Tardif, Richter, and Carson, 1984).

***Callithrix jacchus* in Captivity**

This species is a popular one for research and zoo exhibition. There were at least 650 common marmosets in United States research facilities in 1996 (Jacobsen and Hamel, 1996; Tardif, pers. comm.). Common marmosets are well represented in the world's zoological gardens with 600 animals in 64 institutions (ISIS, 1995). Within the United States there are 13 zoological institutions holding 81 animals (ISIS, 1995). The species also makes up a notable part of the pet primate population.

There are many reasons why common marmosets are so prevalent in research. One is that the animals are inexpensive and easy to care for in comparison to some of the old world monkeys or apes. Another is that they require less space than their larger counterparts. They have been found in relatively large groups with up to 20 in a group (Koenig, 1995). Group compositions have been manipulated to test all possible combinations of breeding age adults. It was first thought that the natural social structure was a nuclear family. Such a group would have been an adult pair accompanied by offspring from recent litters. This seems to be the grouping with the lowest level of agonistic behaviors (Harrison and Tardif, 1988). For these reasons, the marmosets were initially and still are most commonly housed this way in research facilities and in zoos. This is a double advantage because it saves cage space and gives the animals a normal social grouping.

Many studies purport the common marmoset as a suitable animal-model for a multitude of different human and non-human primate ailments and systems. Aitkin and colleagues have studied different aspects in audition with common marmosets (Aitkin, Kudo and Irvine, 1988; Aitkin and Park, 1993). There are studies investigating causes and cures for particular diseases such as Alzheimer's disease (Baker et al., 1994) and malaria (Johnston et al., 1990). There are many research projects looking at different parts of their brains (Brysch et al., 1990; Jones et al., 1992; Guldin, Mirring, and Gruesser, 1993). There has also been an abundance of drug studies performed on common marmosets (Ridley, 1983; Barnes et al., 1987; Costall, Domeney, and Naylor, 1989; Carey et al., 1992).

There have been many studies investigating captive behavior and/or comparing it to wild behavior (Locke-Haydon, 1984; Sutcliffe and Poole, 1984; Erkert, 1989; Harrison and Tardif, 1994). In addition, reproductive studies have looked at different factors affecting reproduction and rearing (Tardif, Richter, and Carson, 1984; Dixson, 1986; Hubrecht, 1989; Smith, Lunn, and Fraser, 1990; Tardif, Harrison, and Simek, 1993).

Environmental Enrichment for Nonhuman Primates

Research facilities and zoos are required to address the needs of all nonhuman primates in captivity. The Animal Welfare Act was amended to include the following provision that deals specifically with primates:

> Dealers, exhibitors, and research facilities must, develop, document, and follow an appropriate plan for environment enhancement adequate to promote the psychological well-being of nonhuman primates. (USDA, 1991)

The meaning of the term "psychological well-being" has been pondered and debated by many scientists (see Segal, 1989). There appears to be no way of assessing it without being anthropomorphic. However, one approach is to look at situations that are assumed to be detrimental to psychological well-being. These could include isolation from a social unit, restriction of movement, limited food choice, lack of opportunity to express natural behaviors, and monotonous surroundings. Solutions, such as environmental enrichment, that address these problems should in effect lead to an improved psychological well-being. Here the term, environmental enrichment, is used to describe the provision of objects to captive animals to promote the expression of species-typical behaviors, to alleviate boredom, and to reduce the expression of stereotypic behaviors.

In addition to normal social groupings and adequate cage sizes, task-oriented feeding methods and manipulable objects are two of the many suggested techniques of providing primates with environmental enrichment. The need for careful consideration in choosing and subsequent testing of the devised environmental enrichment devices and options has been claimed by multiple authors (O'Neill and Price, 1991; Mench, 1994; Markowitz and Gavazzi, 1995; Novak, et al., 1995).

Examples of Primate Enrichment

There is an abundance of papers describing enrichment devices and options for almost every species of primate commonly held in captivity. These devices range from simple ice cubes and sticks to very elaborate sound systems and naturalistic outdoor enclosures. Researchers have published papers showing that most every primate from prosimians to the great apes have been furnished one thing or another. Other authors have attempted to compile lists of many of those devices provided to primates (Boysen, 1989; Reinhardt, 1991, Novak, Drewsen and Beckley, 1991). Only an overview of the many devices will be presented here.

Sifakas at the Duke University Primate Center were examined for activity budget differences between indoor and outdoor housed animals. Macedonia (1987) showed that animals held outdoors had higher levels of locomotion, feeding, and playing. Novak et al. (1995) compared rhesus monkeys housed under different conditions. Some were in small social groups in a laboratory, others lived in a large group in a five acre outdoor enclosure. They found that the outdoor group spent more time foraging. To increase foraging time, wood shavings were added to the indoor enclosure as a foraging substrate. O'Neill and Price (1991) also studied rhesus monkeys but were looking for age and sex differences between indoor and outdoor monkeys.

Suarez (1994) increased vertical cage space by adding PVC tubing to rhesus macaque enclosures. Five gallon plastic buckets were hung from the tubing to create swings and perches. Pig-tailed macaques were tested with a monkey chow biscuit forage feeder which was designed to make the monkeys work for their ration (Murchison, 1994). The animals demonstrated that they would work for food. They even used the forage feeder more often with less wasted food than the standard feeder.

Brent and Eichberg (1991) constructed a plastic puzzleboard as an enrichment device for chimpanzees. The chimpanzees reached through small holes to move food treats around until they could be retrieved through larger holes. Manipulable novel objects provided to chimpanzees by Paquette and Prescott (1988) decreased inactivity and self grooming. However, frequency of manipulation did decrease with object familiarity. Novel objects were also presented to older rhesus monkeys in order to measure their rates of manipulation. (Novak et al., 1993).

Gorillas were observed in different naturalistic exhibits to determine the physical features the animals preferred (Ogden, Lindburg, and Maple, 1993). This study revealed the features that should be incorporated into new exhibits to provide opportunities for species-typical behaviors. Ogden, Lindburg, and Maple (1994) tested auditory enrichment by looking at the effects of "ecologically relevant sounds" on gorilla behavior. They compared quiet, ventilation sounds, caretaker noises, and bonobo vocalizations, to the conditions of rain forest sounds on and off. The sounds did act as masking for two infants in the study but increased activity and displays in two adults.

Enrichment for Callitrichids

Some enrichment strategies have been aimed at callitrichids. Molzen and French (1989) looked at differences in behavior of golden lion tamarins when presented with a suspended foraging box. McGrew and McLuckie (1986) were primarily investigating social behavior, but they also provided social enrichment and an opportunity for exploration when they constructed tunnels for cotton-top tamarins. Those tunnels allowed them to travel from home cages to cages in other rooms. Caine and O'Boyle (1992) examined play behavior in red bellied tamarins. They determined that play was more varied on naturalistic exhibit features and substrates.

A few researchers have offered ideas for environmental enrichment options specifically for use by common marmosets. Heath and Libretto (1993) used fruit on chains, pieces of hollow tubing, foraging boxes and wooden perches or platforms. Lehti (1992) investigated differences between two marmoset enclosures. One was termed "ordinary" and the other "environmental enrichment." The second was more challenging with increased psychological space, whole fruits, and a suspended dry food dispenser. Poole (1990) reviewed the use of whole fruits, suspended dispensers, mealworm dispensers, and food concealed in woodchip substrate. He also proposed the use of a motorized training apparatus. McGrew, Brennan and Russell (1986) designed an artificial "gum tree" for marmosets. This device promoted the natural behavioral patterns of exudate feeding. Chamove and Rohrhuber (1989) looked at an aspect of common marmoset and cotton-top tamarin enrichment by comparing indoor cages to outdoor areas.

Enrichment Devices in this Study

The investigator scrutinized enrichment devices for possible health concerns, interference with other ongoing procedures, and suitability for this study. The utmost concern was that a device did not jeopardize an animal's health in any way. It was a requirement that enrichment fit within the scope of other studies and not introduce new variables or effects. Due to the design of this study, it was necessary that the devices be reusable, easily presented, and easily maintained.

Four different classes of enrichment devices were chosen for examination in this study. The first was a task-oriented device, a foraging box with treats of raisins and marshmallows hidden in wood chips. The foraging boxes were expected to increase time spent searching for food and to decrease time spent inactive or passive. The second type was a cage furnishing, usually a more or less permanent fixture in a cage. Ropes were chosen in an attempt to simulate the substrates common marmosets encounter in the wild, vines and small branches. Ropes strung throughout the cage increased dramatically the avenues for locomotion and perching locations. The ropes were meant to stimulate species-typical behaviors by increasing agility and balance in animals more accustomed to a fixed, rigid, static environment. The third type was an external environmental stimuli. Sounds were chosen over smells and other stimuli because of ease and consistency in presentation. A commercial tape recording of rain forest sounds was played to mask other distracting non-naturalistic sounds in the animals' environment. It was not known what effect this variable might have on the behavior of the animals. The fourth type was a toy or manipulatory apparatus. Plastic whiffle balls were placed in the cage to give the animals additional opportunities for object manipulation. Balls are a common, perhaps the most common, enrichment device for captive animals in laboratories and zoos. There were no long term effects when small whiffle balls were presented to two other callitrichids, *Leontopithecus rosalia* and *Callithrix kuhlii* (French, pers. comm.). Investigation was necessary to determine their effects with this colony of common marmosets.

CHAPTER TWO

METHODS

Subjects

Subjects for this study were four adult pairs of common marmosets between the ages of two and six years (Table 2.1). The groups had been paired together for varying lengths of time prior to the study. Female subjects that were not predicted to give birth during the study were chosen so that the effect of nursing and rearing behaviors would not interfere with the behaviors investigated in the study.

Table 2.1. Marmoset subjects in environmental enrichment study.

Group	Colony Identification Number	Sex	Date of Birth	Additional Cagemates
A	033	Female	08/30/93	None
	027	Male	02/03/90	
B	001	Female	10/26/92	None
	034	Male	11/03/90	
C	002	Female	01/30/89	056
	010	Male	04/24/91	(Juvenile Male)
D	035	Female	07/29/89	073 & 074
	017	Male	08/05/89	(Infant Females)

Housing

The animals used for this study were housed in the Animal Care Facility at The University of Tennessee, Knoxville. The four groups were kept in separate rooms; each room had two or three additional groups not included in this study. All groups within a room were visually isolated from each other. Groups within a room were at least partially aurally isolated from groups in other rooms. Any auditory contact between rooms was dampened or muffled.

The animals were kept in cages made of plastic-coated metal mesh supported by an aluminum framework (Figure 2.1). The cages' dimensions were 184.15 cm x 91.45 cm x 152.4 cm. The legs and wheels raised the bottom of the cage to 54 cm off the floor. Each cage was partitioned in two parts by a center wall with a sliding door that could be closed to isolate the animals on one side or removed to allow access to the entire cage. In the front-center of each half of the cage was a hinged lexan door through which caretakers and researchers could gain access to the cage. Each cage had a removable lexan nestbox in the upper right corner of the right compartment. All cages had two or three natural wood perches in each side with varying positions and configurations.

Dependent Variables - The Behaviors and Position

The behaviors recorded (Table 2.2) were easily distinguished and readily discernible on videotape. The behavioral classes were chosen because of their common use in the evaluation of environmental enrichment devices for other primate species

Figure 2.1. An example of a marmoset cage.

Table 2.2. Ethogram for *Callithrix jacchus* environmental enrichment study.

Drink - The ingestion of water.

Feed - The ingestion of food. Either the normal diet or raisin and marshmallow treats found within the foraging box.

Gnaw - Repeated biting or chewing on an object other than food, such as the cage mesh or a device. This also includes the gouging of wooden perches.

Groom - Inspecting pelage and/or the repeated scratching or picking at a body part.

Investigate - Inspecting or intently looking at, but not manipulating an object, most typically the enrichment device.

Locomote - Moving about by any method. No distinction is made between climbing, walking, running, or leaping.

Manipulate - Grasping and moving an object with the hands and/or moving it about by intentionally pushing it with the head.

Not Visible - Animal currently not visible to the observer.

Play - Exaggerated movements such as wrestling or mock fighting. Usually initiated by by an infant or juvenile, intent of adult may not be known.

Mark - Marking an object by rubbing anogenital scent glands on an object. Usually preceded by gnawing or inspecting a gnaw mark on the wood. Could be on a diversity of substrates.

Stationary - Not moving. This could be a momentary stop between periods of locomotion or long periods of sitting on the floor or perches or clinging to the side of cage. It also includes sleeping and lying still.

Stereotypy - Repetitive expression of a behavior at potentially deleterious levels. An idiosyncratic expression of a behavior.

(Macedonia, 1987; Paquette and Prescott, 1988; Boinski et al., 1994). The behaviors Mark and Gnaw were added because these are common behaviors of *Callithrix jacchus*.

For some of the behaviors, the object or substrate involved was also noted. Feeding was distinguished as to whether it was the normal diet or treats found within the enrichment device. With Gnaw, Locomote, Mark, and Stationary the object or substrate was noted as either cage, wood, or device. Manipulation, Investigation, and Handling were distinguished as to either food, device, or other. Allogrooming and autogrooming were differentiated for Groom. Not Visible was distinguished as to whether the animal was in the nestbox, out of the field of view of the camera, or other. For analysis, Manipulation and Investigation were combined and termed Handling; and the term Inactive was used to describe the combined duration of Not Visible (in the nestbox) and Stationary. In addition to scoring the behaviors and modifiers, position relative to the enrichment device (Table 2.3) was also measured.

Experimental Design

This study utilized a small N repeated measure multiple baseline research design. This type of design requires that baseline data be collected before introducing the experimental variable. Then the variable is introduced and repeated measures continue (Saudargas and Drummer, 1996). This procedure is duplicated for each of the four stages. For this study the stages have eight sessions in each baseline and each condition. The design is illustrated in Table 2.4.

Table 2.3. Position (Relevant to enrichment device).

Contact - Touching the enrichment device with the hands, sitting upon it or leaning against it. This does not include inadvertently touching the device with the tail.
Distal - Positioned greater than one body length away from the enrichment device. This does not include the length of the tail.
Proximal - Positioned one body length or less away from the object. Body length does not include the tail.
Indeterminable - Device is not present or a distance is not applicable as in the presentation of nature sounds.

Table 2.4. Study design.

$B1_{1\text{-}8}$, $C1_{1\text{-}8}$, $B2_{1\text{-}8}$, $C2_{1\text{-}8}$, $B3_{1\text{-}8}$, $C3_{1\text{-}8}$, $B4_{1\text{-}8}$, $C4_{1\text{-}8}$
B = Baseline C = Condition

Observation Procedure

Data were collected using Observer 3.0 TM, a behavioral event recording software program (Noldus, 1994). The data collection method was a continuous focal animal sampling. Focal samples were 1500 seconds in length. Within a group, the subject observed initially each day was alternated by sex.

Data were collected between September 1, 1995 and December 15, 1995. Observations were made on Mondays, Wednesdays and Fridays between the hours of 1000 and 1630. There were two sessions per individual per day, one designated morning and the other afternoon. Actual observation time was also noted. Due to scheduling difficulties it was occasionally necessary for there to be five days in which to accomplish the eight observation sessions in each condition. The fifth day was used to make up any sessions that were missed.

An observation session would begin shortly after the presentation of the enrichment device. Both sessions, one for the female and one for the male, were recorded and then the device was removed or the animals were moved to the opposite side of the cage.

There were both live observations and taped observations with approximately equal numbers of each. The live observations were made from within a blind, a large box on wheels with a tinted window. The animals were habituated to the presence of the blind prior to the data collection. Once the blind was placed in front of the cage and the observer was in position, the animals no longer paid attention to its presence.

The taped observations were made by filming with a VHS camcorder. The camera was placed opposite the cage and angled to get the optimum field of view with the least amount of obstructions and distortion. Animals were restricted to one side of the home cage for optimal viewing during both the live and the taped sessions. The time and date of the original taping were used as reference for day of collection.

Independent Variables - The Devices

Four different types of environmental enrichment devices were chosen for testing: a foraging box, ropes, nature sounds, and a whiffle ball. Each device varied in the type of behavioral responses it required or elicited and the sensory stimuli it provided.

The foraging box required moderately complex manipulation skills and attention. It was unique in that it was the only device that could return a food reinforcement. This device was a 10 x 10 x 5 cm plastic box with compartments of differing shapes and sizes (Figure 2.2). Each of these compartments had one to three holes of 1.25 cm diameter. Wood-chip bedding was placed inside each of the compartments along with small pieces of raisins and marshmallows. The objective was for the animals to reach through the holes and search for treats in the wood chips. Shaking the box would move the bedding to reveal bits of the treats. Two foraging boxes were presented to each group in order to minimize aggressive acts between subjects.

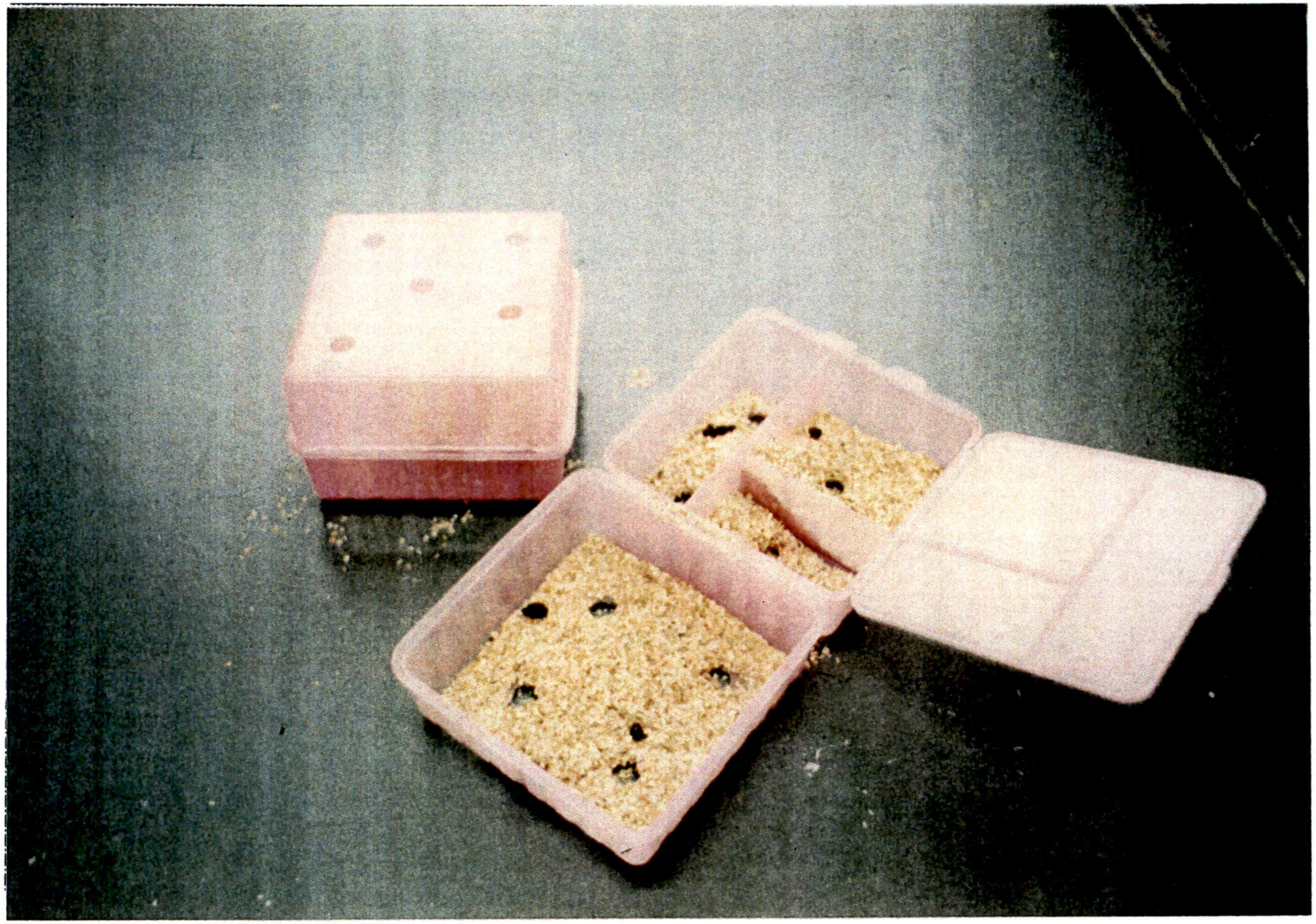

Figure 2.2. Foraging boxes with wood chips and treats in the compartments.

Ropes were used in an attempt to simulate vines or small branches. The ropes allowed simple manipulation, but more importantly required motor skills for balance. They also gave the subjects new routes for locomotion and additional sites for perches. Two polypropylene ropes, approximately nine meters in total length, were randomly placed in the cage (Figure 2.3). They were attached to the cage by metal snap clasps for ease of installation and removal.

Nature sounds were intended to serve as either a novel auditory stimulus and/or a masking noise for the sounds of other groups of animals, people in the hallway, and ventilation noises. A normal cassette tape player provided the nature sounds. The tape was a commercial version of actual rain forest sounds. The cassette player was placed to the right of the cage and played at the same volume level for all observation sessions and all groups (Figure 2.4).

The whiffle ball required simple manipulation skills. Commonly used as a children's toy, it was a large 7.5 cm diameter plastic ball with several holes (Figure 2.5). Two whiffle balls were presented to each group in order to minimize aggressive acts between subjects. The objective was for the animals to roll the balls around the cage, wrestle with them, look in the holes, and perhaps carry or walk on the them.

The devices were presented to the groups in different sequences so that if there were an order effect it would not confound the effects of the main variable. No device was immediately followed by the same device in any two groups. The order in which the devices were presented can be seen in Table 2.5.

Figure 2.3. Ropes shown inside a cage.

Figure 2.4. Cassete player shown next to a cage.

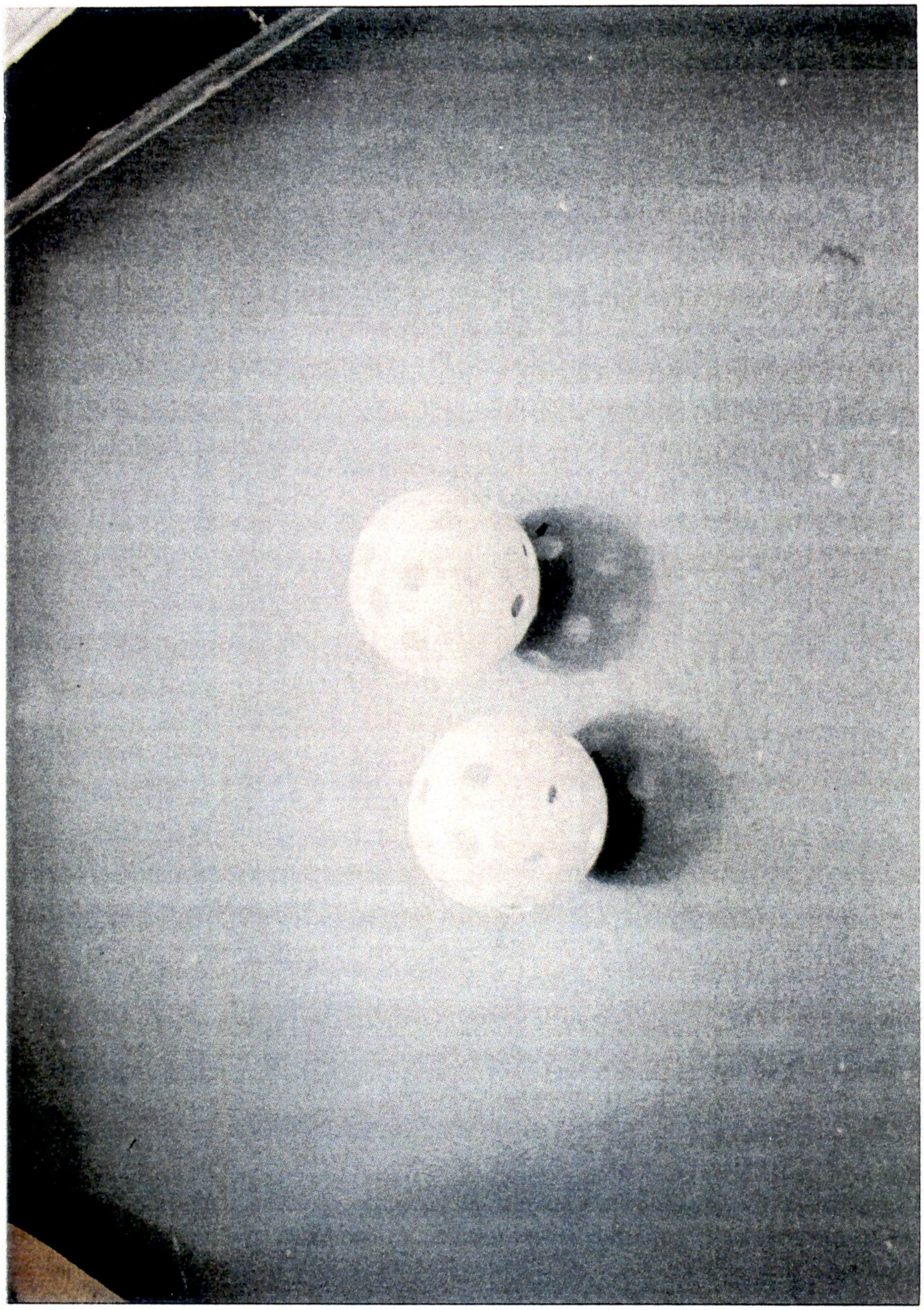

Figure 2.5. Whiffle balls.

Table 2.5. Order of device presentation.

Group	Condition 1	Condition 2	Condition 3	Condition 4
A	Foraging Box	Whiffle Ball	Nature Sounds	Ropes
B	Whiffle Ball	Ropes	Foraging Box	Nature Sounds
C	Nature Sounds	Foraging Box	Ropes	Whiffle Ball
D	Ropes	Nature Sounds	Whiffle Ball	Foraging Box

Data Analyses

Treatments were analyzed with regard to the total behavior duration per session for each of the subjects. Comparisons were made between each **Baseline** and its corresponding condition. These data were analyzed using a two way repeated measures ANOVA. A $p < .05$ significance level was used for all tests.

Positional data were analyzed with regard to total duration spent in each of the position categories: <u>Contact</u>, <u>Proximal</u>, and <u>Distal</u>, for each of the subjects in each session. These data were analyzed using a nested two way ANOVA with a $p < .05$ significance level for all tests. Since the only positional category scored in the **Baselines** and the **Nature Sounds** condition was <u>Indeterminable</u>, comparisons were only made with the data from the **Foraging Box**, **Ropes**, and **Whiffle Ball** conditions. The proximity data were used to show trends in interest levels for the devices. These data were also used to investigate gender differences in device use.

Positional data for females and males were also analyzed using nested two way ANOVAs. The ANOVAs were first applied to the duration of time spent in Contact with the enrichment device and then to the duration of time spent Proximal to the enrichment device.

CHAPTER THREE

RESULTS

Analyses of Dependent Variables by Condition

Foraging Box

The data from the **Foraging Box** condition show a significant increase in Investigation, (F(VR treatments) = 217.6549, $p < 0.0001$), increasing from zero seconds in the **Baseline** to an average of 314 seconds in the condition. The regression line shows a slight decrease over the course of the condition (Figure 3.1). Manipulation also showed a significant increase, rising from 3.97 to 269.92 seconds, (F(VR treatments) = 154.3827, $p < 0.0001$). The regression line for Manipulation reveals a slight decrease over the condition (Figure 3.2).

Inactivity decreased significantly between the **Baseline** and the **Foraging Box** condition, (F(VR treatments) = 188.1154, $p < 0.0001$). The trend increased over the eight condition sessions (Figure 3.3), but was still below the **Baseline** levels, falling from an average of 1190.16 seconds to 627.95 seconds.

There was no significant difference between **Baseline** and the **Foraging Box** condition for Feeding, (F(VR treatments) = 0.0336, $p = .8549$). The **Baseline** average was 84.629 seconds, increasing to only 88.079 seconds in the condition. The regression lines for **Baseline** and the condition illustrate this with both lines flat across all sessions (Figure 3.4).

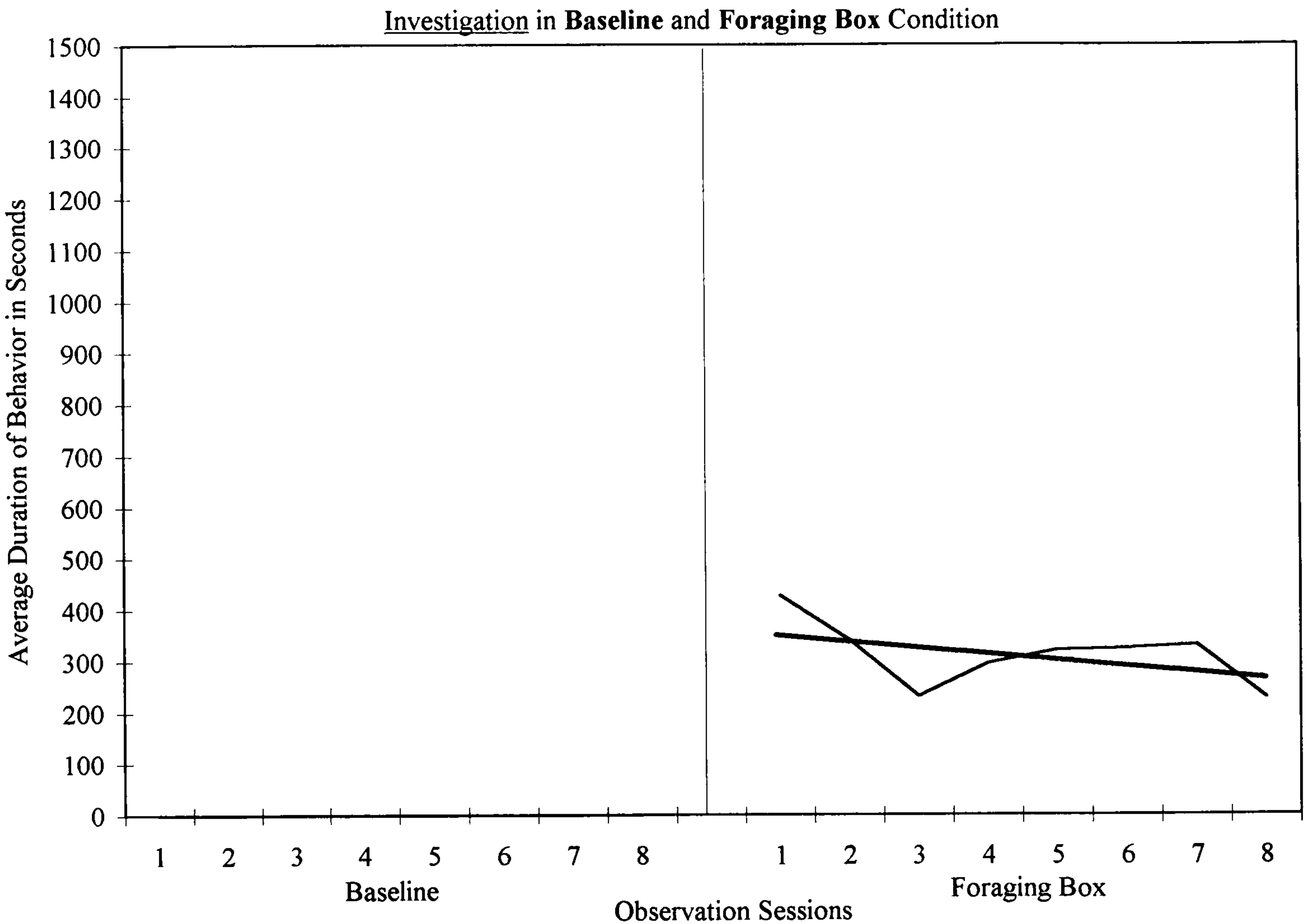

Figure 3.1. Duration averages (in seconds) of <u>Investigation</u> in **Baseline** and **Foraging Box** condition.

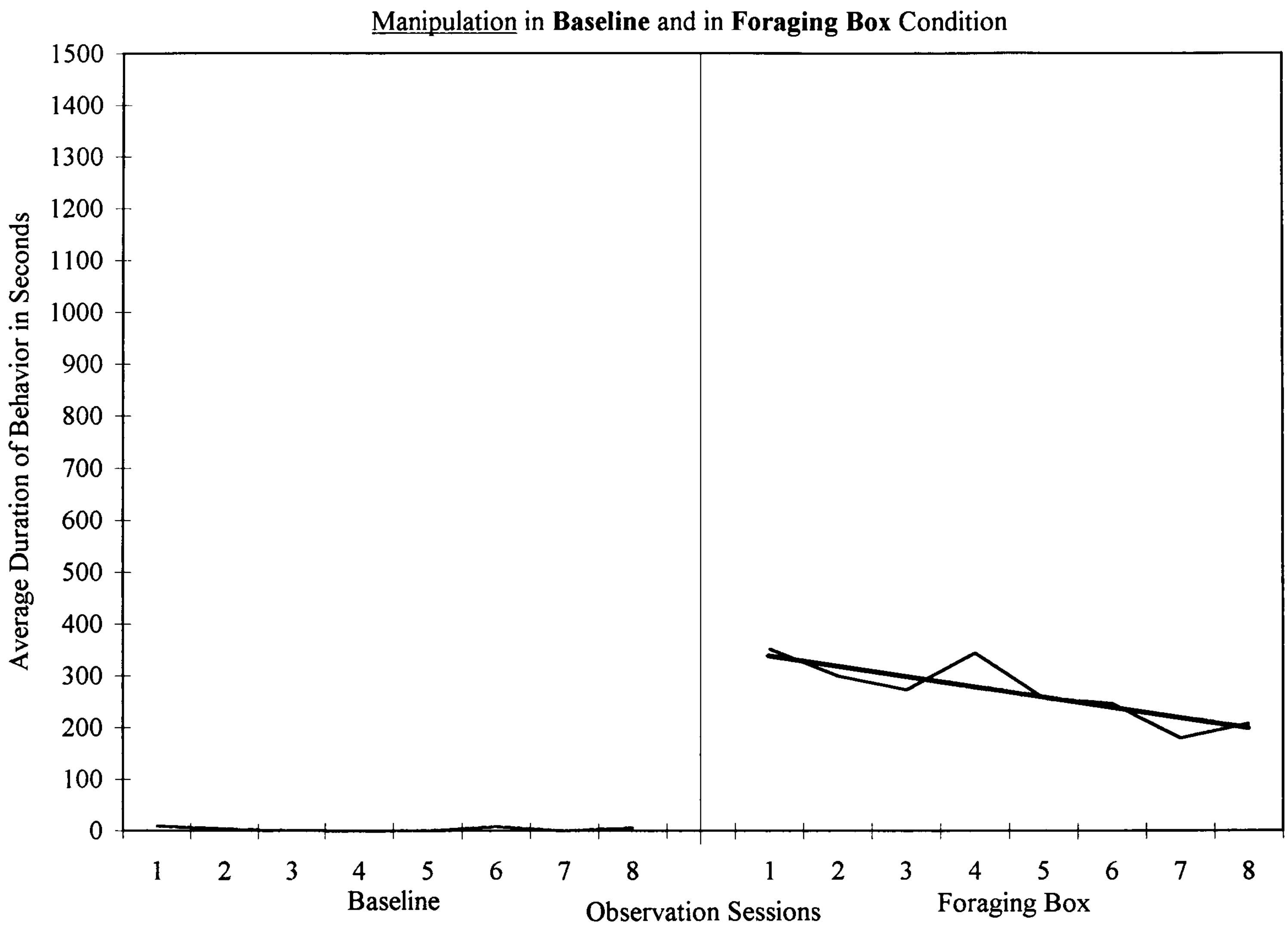

Figure 3.2. Duration averages (in seconds) of Manipulation in **Baseline** and **Foraging Box** Condition.

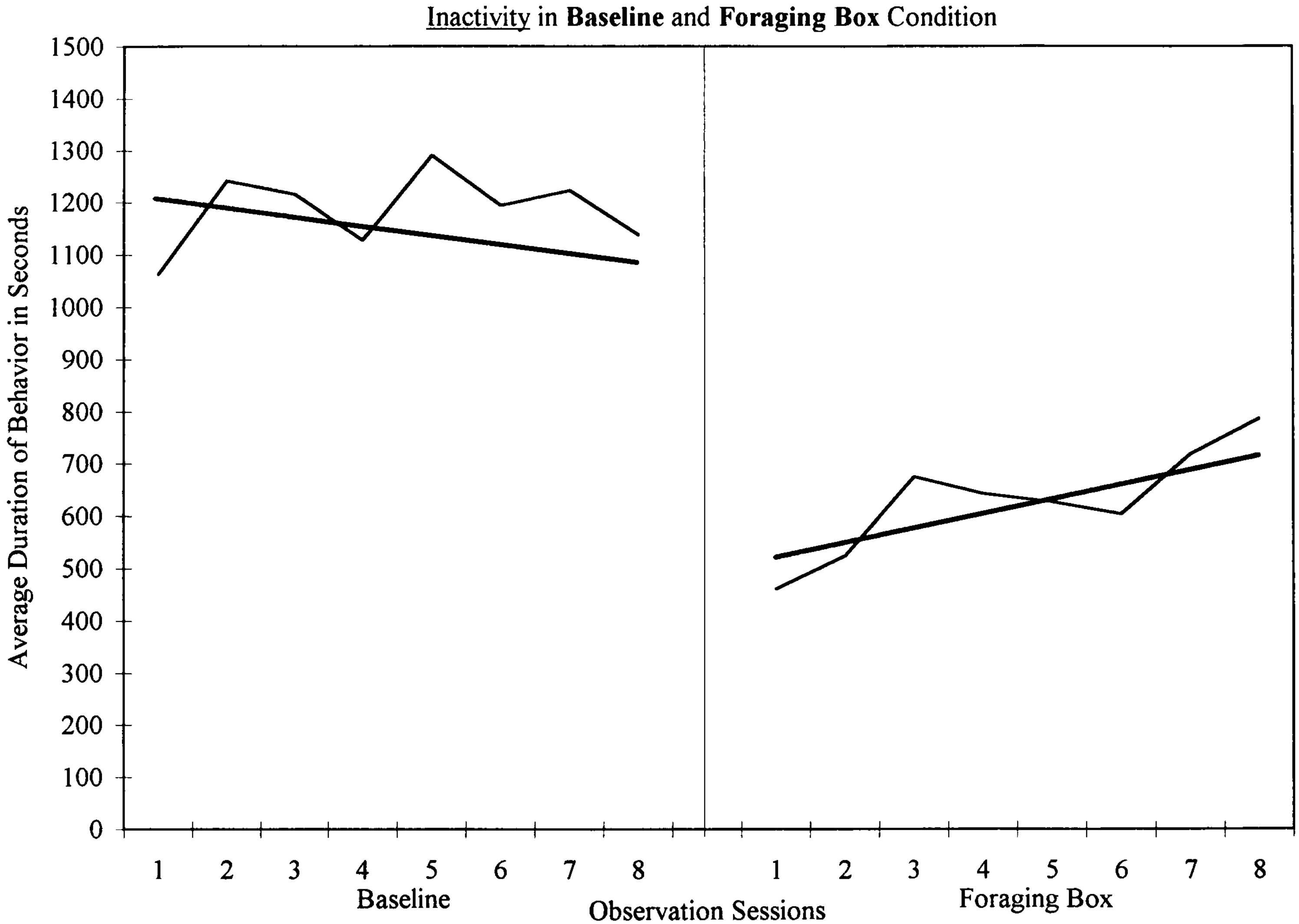

Figure 3.3. Duration averages (in seconds) of Inactivity in **Baseline** and **Foraging Box** condition.

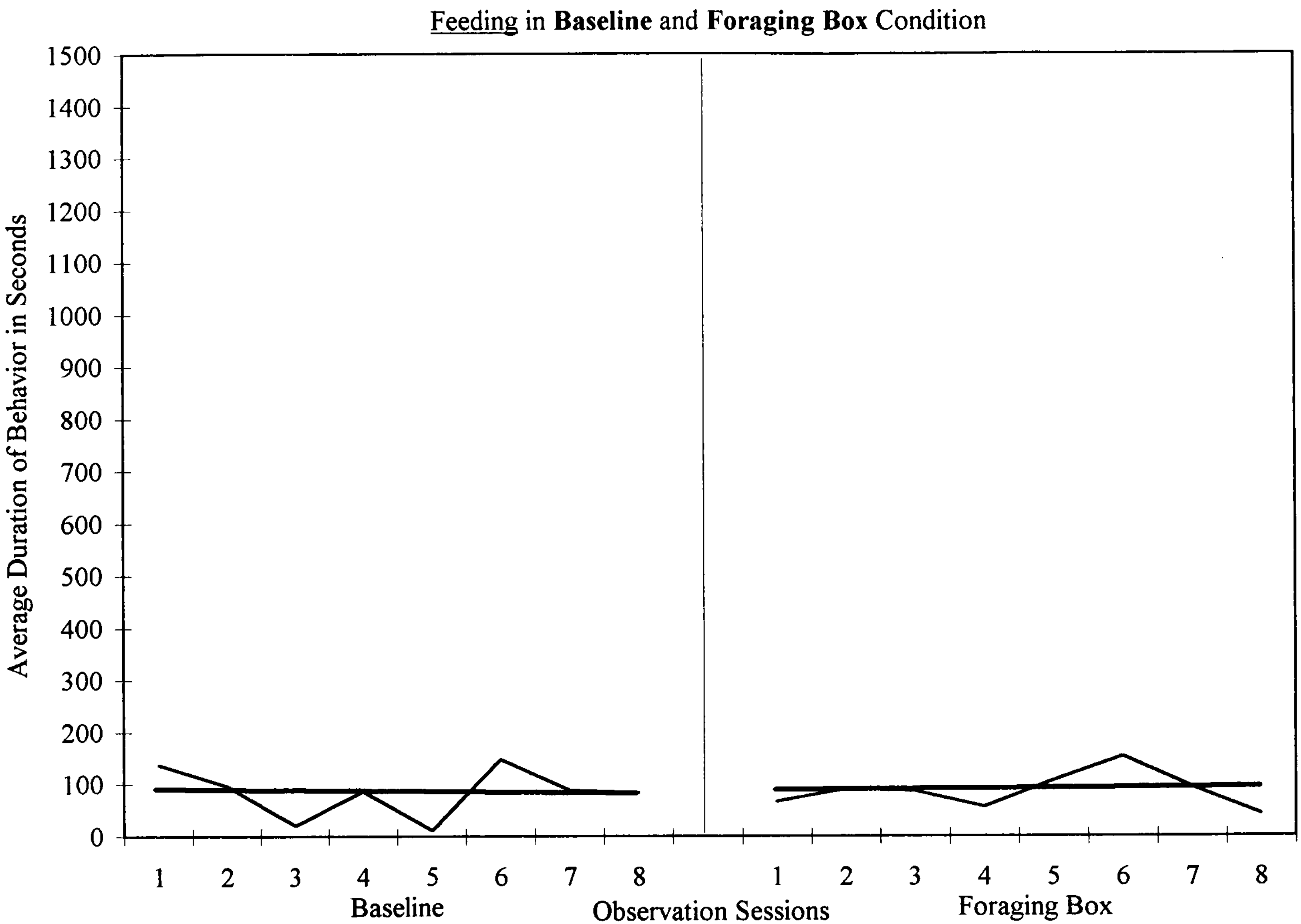

Figure 3.4. Duration averages (in seconds) of Feeding in **Baseline** and **Foraging Box** condition.

The foraging box was unique in that it was the only device that provided a food reward. The ethogram distinguished Feeding as to either eating normal food or treats retrieved from the box. Frequency of eating treat items is shown in Table 3.1. This frequency did not include multiple instances of partially eating the same treat. Subject 001 was the most proficient at retrieving and eating treats with a total of 30 retrievals. As a group, the subjects reached their highest proficiency in session five, eating 24 treats. The average number of treats eaten per session ranged from 1.0 to 1.71.

Ropes

Although the average duration of Locomotion on all substrates declined from 132.42 seconds in the **Baseline** to 115.41 seconds in the **Ropes** condition (Figure 3.5), this was not a significant difference, (F(VR treatments) = 1.4292, $p = .2344$). Only three subjects, 001, 002, and 010, spent any appreciable amount of time Locomoting on the ropes (Table 3.2). All subjects combined spent 553 seconds on the ropes, with subjects 001, 002, and 010 representing 455 seconds. Figure 3.6 illustrates subject 001's use of the ropes with her highest peak on day five.

Nature Sounds

Inactivity showed a significant increase, (F(VR treatments) = 5.6438, $p = .0192$). It rose from an average of 1302.54 seconds to 1363.29 seconds. The regression lines in Figure 3.7 illustrate the difference in Inactivity levels between **Baseline** and the **Nature Sounds** condition. Of the four conditions, **Nature Sounds**

Table 3.1. Number of separate treat items retrieved from the foraging boxes.

Subject / Day	001	002	010	017	027	033	034	035	Total	Average
1	2	1	3	2	1	0	0	0	9	1.13
2	3	2	0	6	0	1	0	0	12	1.5
3	3	0	1	0	0	0	2	2	8	1
4	6	0	1	0	0	7	1	1	16	2
5	1	2	0	6	2	9	3	1	24	3
6	1	2	1	5	2	0	3	2	16	2
7	3	1	1	0	1	3	1	2	12	1.5
8	11	0	0	0	1		0	0	12	1.71
Total	30	8	7	19	7	20	10	8	109	
Average	3.75	1	0.88	2.38	0.88	2.86	1.25	1	1.73	

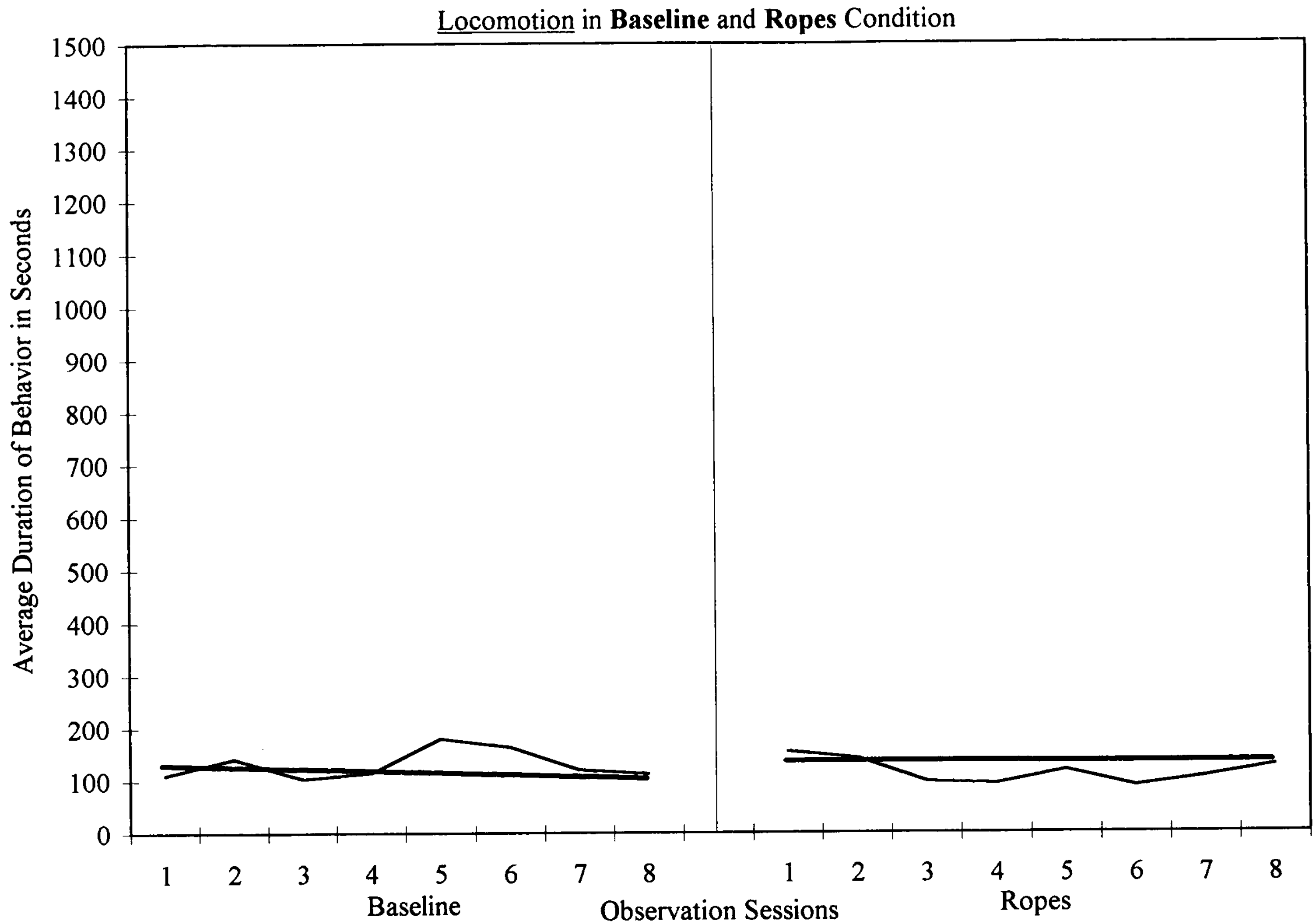

Figure 3.5. Duration averages (in seconds) of Locomotion in **Baseline** and **Ropes** condition.

Table 3.2 Time (in seconds) spent Locomoting on the ropes.

Subject / Day	001	002	010	017	027	033	034	035	Total	Average
1	25	42	17	0	0	0	2	12	98	12.25
2	12	36	16	4	0	0	0	23	91	11.38
3	11	2	2	0	1	0	0	16	32	4.0
4	25	26	5	0	11	0	0	0	67	9.57
5	54	19	1	3	0	0	0	0	77	9.63
6	18	0	22	10	0	0	1	0	51	6.38
7	13	37	35	0	0	0	0	6	91	11.38
8	14	6	17		2	7	0		46	7.67
Total	172	168	115	17	14	7	3	57	553	
Average	21.5	21.0	14.38	2.43	1.75	0.88	0.375	8.14	8.92	

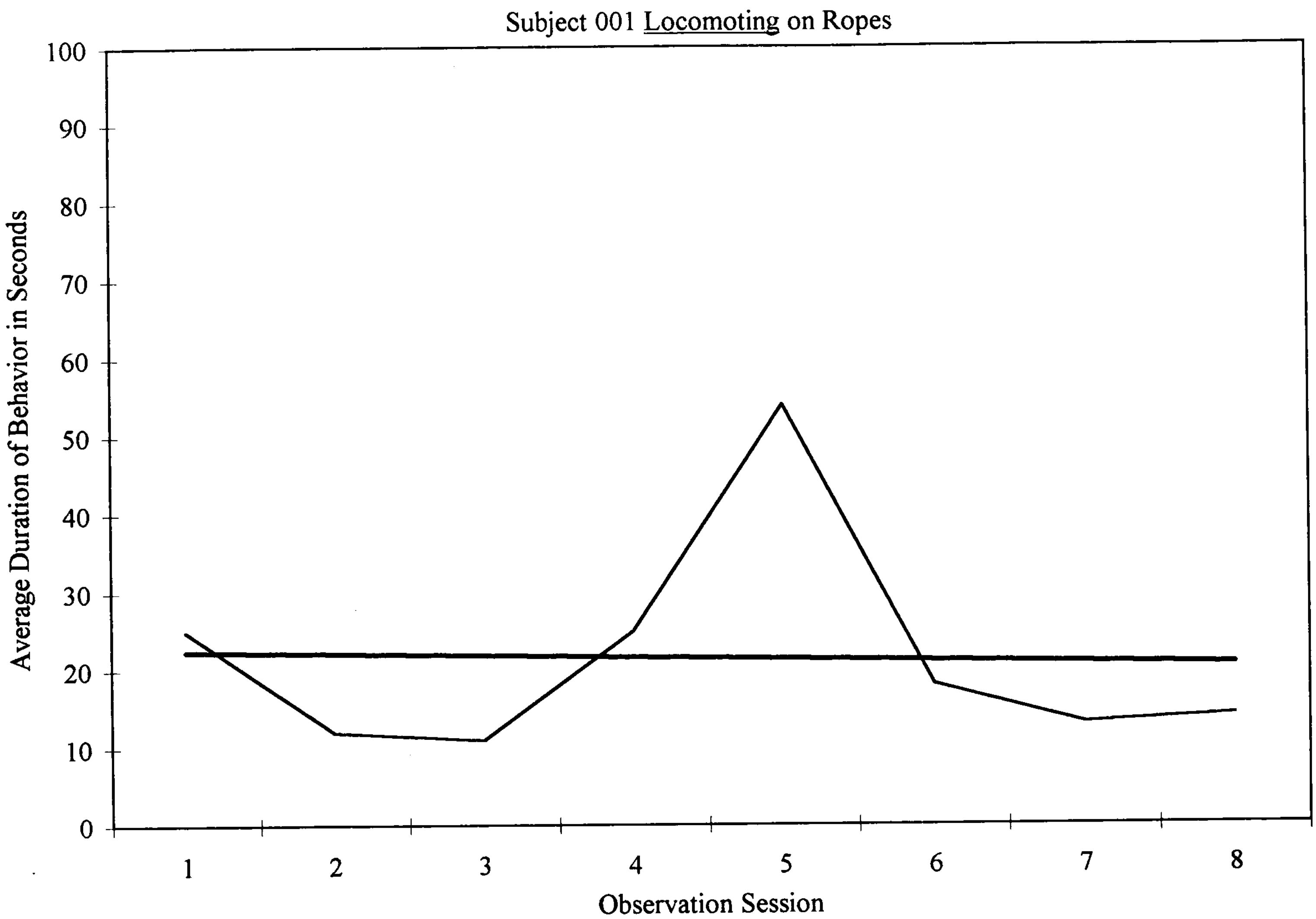

Figure 3.6. Time spent by Subject 001 Locomoting on the ropes in the **Ropes** condition.

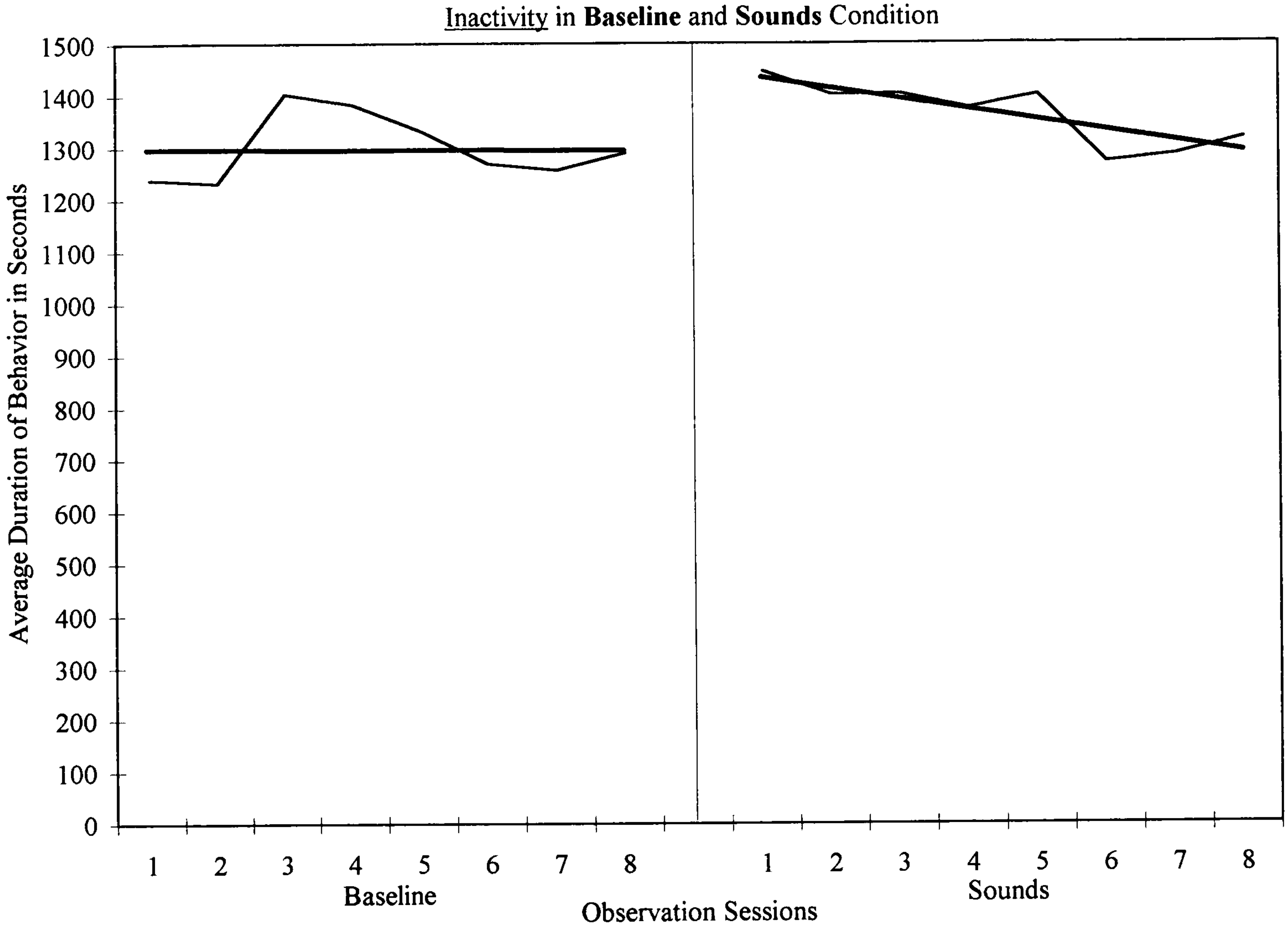

Figure 3.7. Duration averages (in seconds) of Inactivity in **Baseline** and **Sounds** condition.

caused the largest increase in Inactivity. However, it declined in the latter sessions to approximately the same level as **Baseline.** The other behaviors show a corresponding overall decrease in duration. Locomotion, for example, declined from 96.89 seconds to 56.75 seconds. Behaviors such as Investigation or Manipulation were irrelevant with respect to this condition.

Whiffle Ball

The **Whiffle ball** condition had only slight effects on overall behavior patterns. For example there was a only a small increase in levels of Inactivity between **Baseline** and the **Whiffle ball**, 1174.69 to 1186.13 seconds. This was not a significant change, (F(VR treatments) = 0.0694, p = .7927).

The Handling of the whiffle balls is of interest when assessing the subjects' curiosity in and/or use of the device (Table 3.3). Cagemates 034 and 001 showed the highest levels of interest with duration totals of 621 seconds and 593 seconds respectively (Figure 3.8). Conversely, cagemates 002 and 010 (Figure 3.9) have the lowest duration levels with 115 seconds and 105 seconds respectively.

The average of Handling, across subjects by day, showed a decline over the course of the **Whiffle ball** condition (Figure 3.10). This trend starts at a high of 86.88 seconds on day one and reaches its low on day eight at only 18.71 seconds.

Table 3.3. Time (in seconds) spent Handling the whiffle balls.

Subject Day	001	002	010	017	027	033	034	035	Total	Average
1	360	16	0	42	42	53	182	0	695	86.88
2	0	68	73	26	46	13	123	69	418	52.25
3	79	0	1	116	26	130	167	14	533	66.63
4	86	5	11	28	39	37	31	17	254	31.75
5	36	0	5	72	11	0	28	36	188	23.5
6	0	26	6	39	18	104	24	0	217	27.13
7	0	0	9	21	22	66	49	20	187	23.38
8	32	0	0	4	41	37	17		131	18.71
Total	593	115	105	348	245	440	621	156	2623	
Average	74.13	14.38	13.13	43.5	30.63	55	77.63	22.29	327.88	

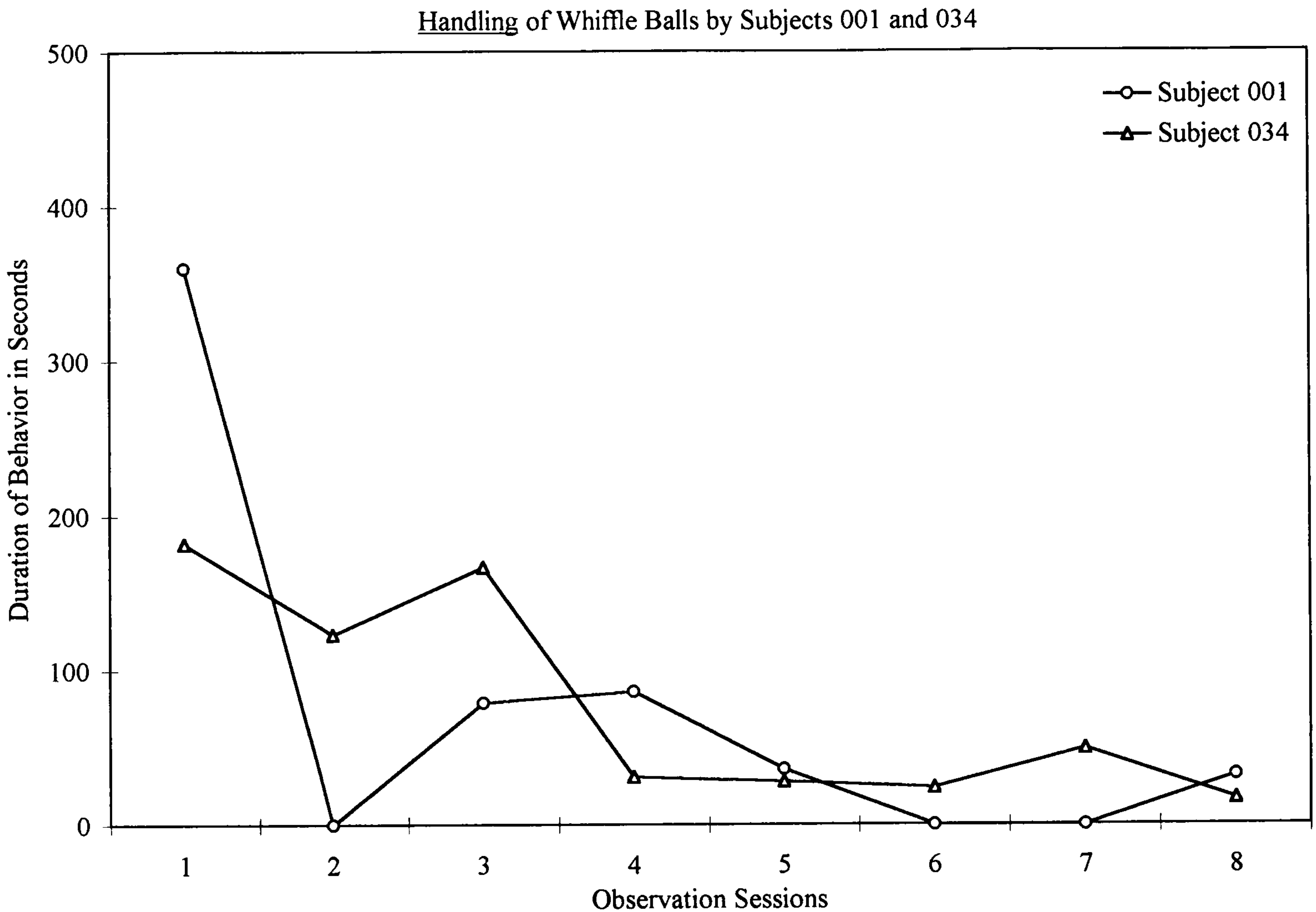

Figure 3.8. Time spent by cagemates 001 and 034 Handling the whiffle balls in the **Whiffle Ball** condition.

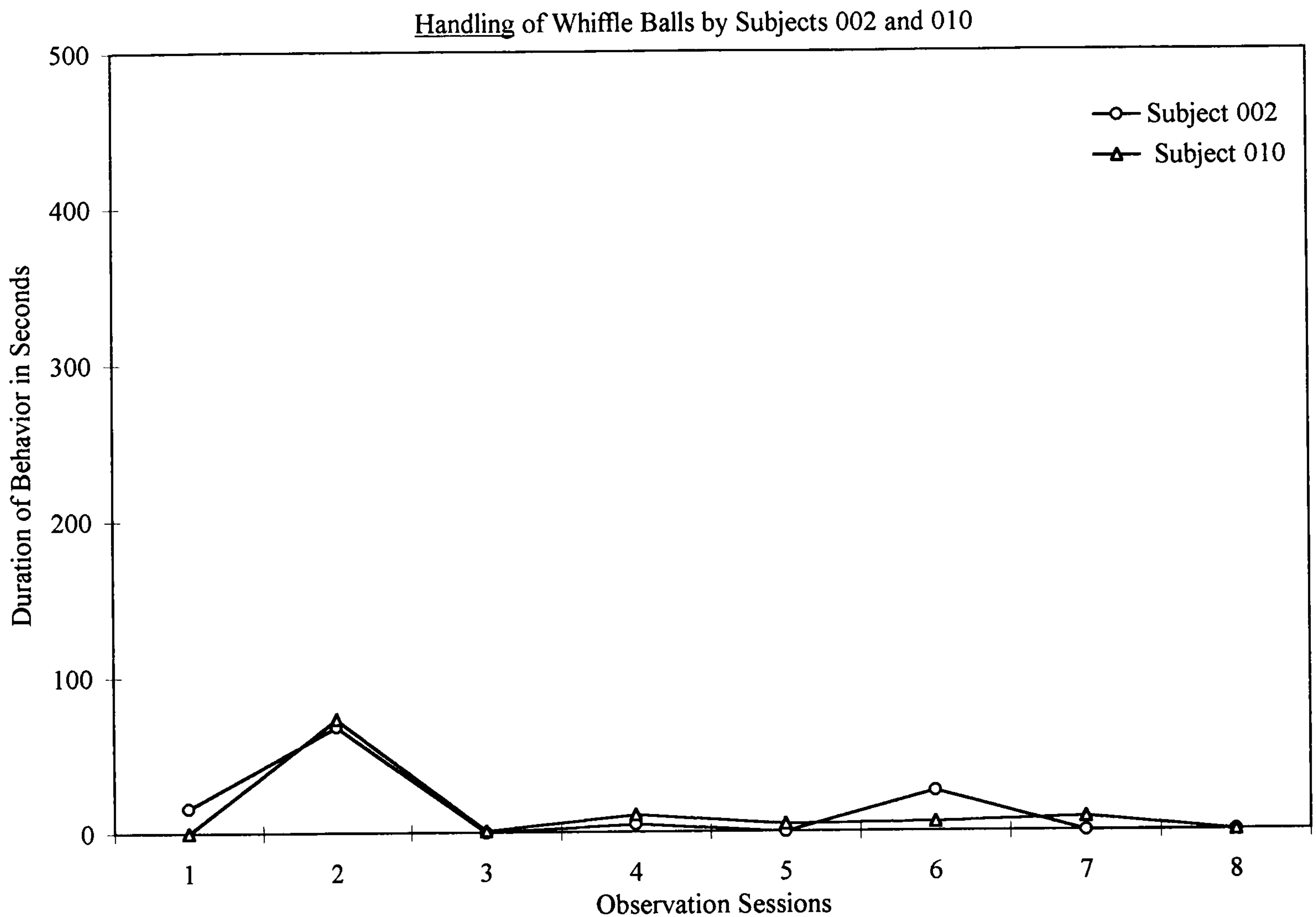

Figure 3.9. Time spent by cagemates 002 and 010 Handling the whiffle balls in the **Whiffle Ball** condition.

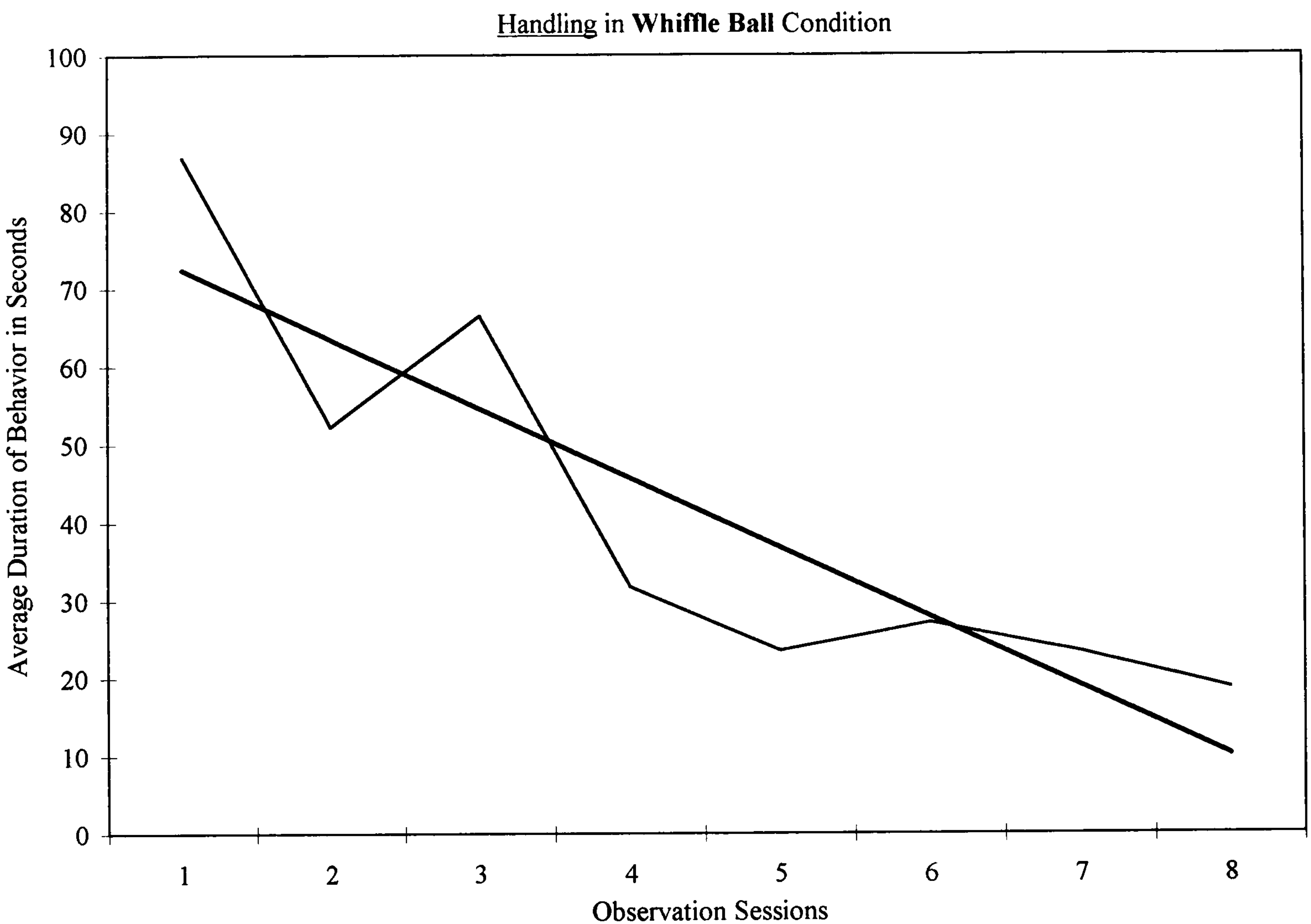

Figure 3.10. Duration averages (in seconds) of Handling across sessions in **Whiffle Ball** condition.

Preferences for Enrichment Devices

Preferences for individual enrichment devices are illustrated in Figures 3.11 and 3.12. These figures show the amount of time the subjects spent in Contact with the devices or Proximal to the devices. The data representing these positions are shown in Tables 3.4 and 3.5. The cumulative averages of all days for all subjects is an important indicator to quickly assess interest. With these data it is evident that the animals spent the most time in Contact with the foraging box, 686.40 seconds, less time with the ropes, 101.04 seconds, and the least amount of time in Contact with the whiffle balls, 43.30 seconds. The animals were Proximal to the ropes the most amount of time at 317.62 seconds. The foraging boxes followed with 217.70 seconds. The subjects were Proximal to the whiffle balls the least amount of time at 124.55 seconds.

The average of all subjects for each day is an indicator of changing interest levels in the devices. The average time spent in Contact with the foraging box was consistently high. It varied between 854.63 seconds and 538.13 seconds. Proximity to the foraging boxes varied from 287 seconds to 160 seconds. The average time spent in Contact with the ropes fluctuated from a high of 147.75 to a low of 68.25. Proximity to the ropes varied between 225 seconds to a high of 440.71 seconds. The whiffle balls drew the most interest in the first and third sessions, 110.63 and 70.75 seconds, but this interest declined to only 20.63 seconds in the eighth session. Proximity, with a range of 159.75 to 88.25 seconds, was higher than time spent in actual Contact with the whiffle balls.

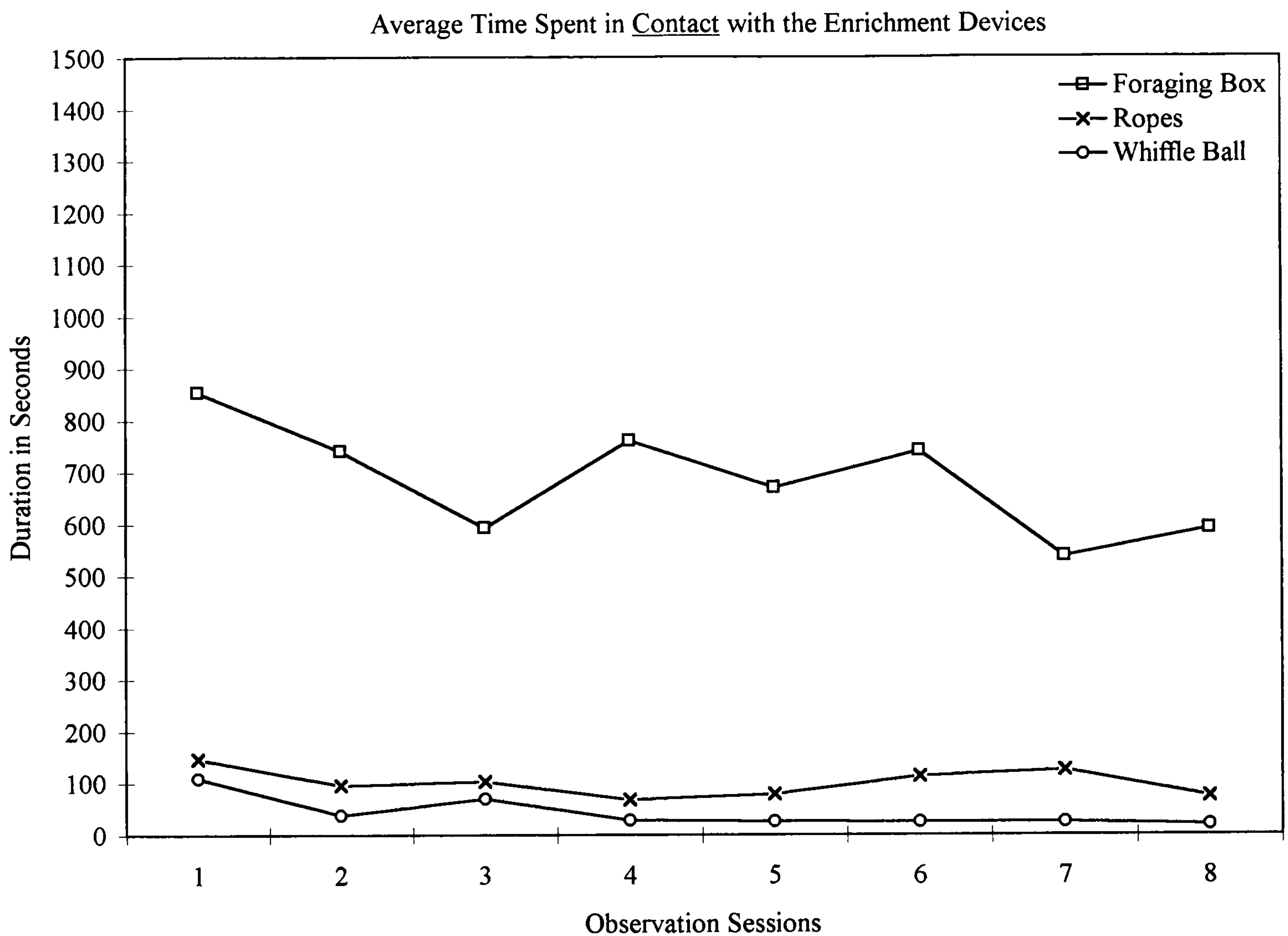

Figure 3.11. Duration averages (in seconds) spent in <u>Contact</u> with devices in each of the conditions.

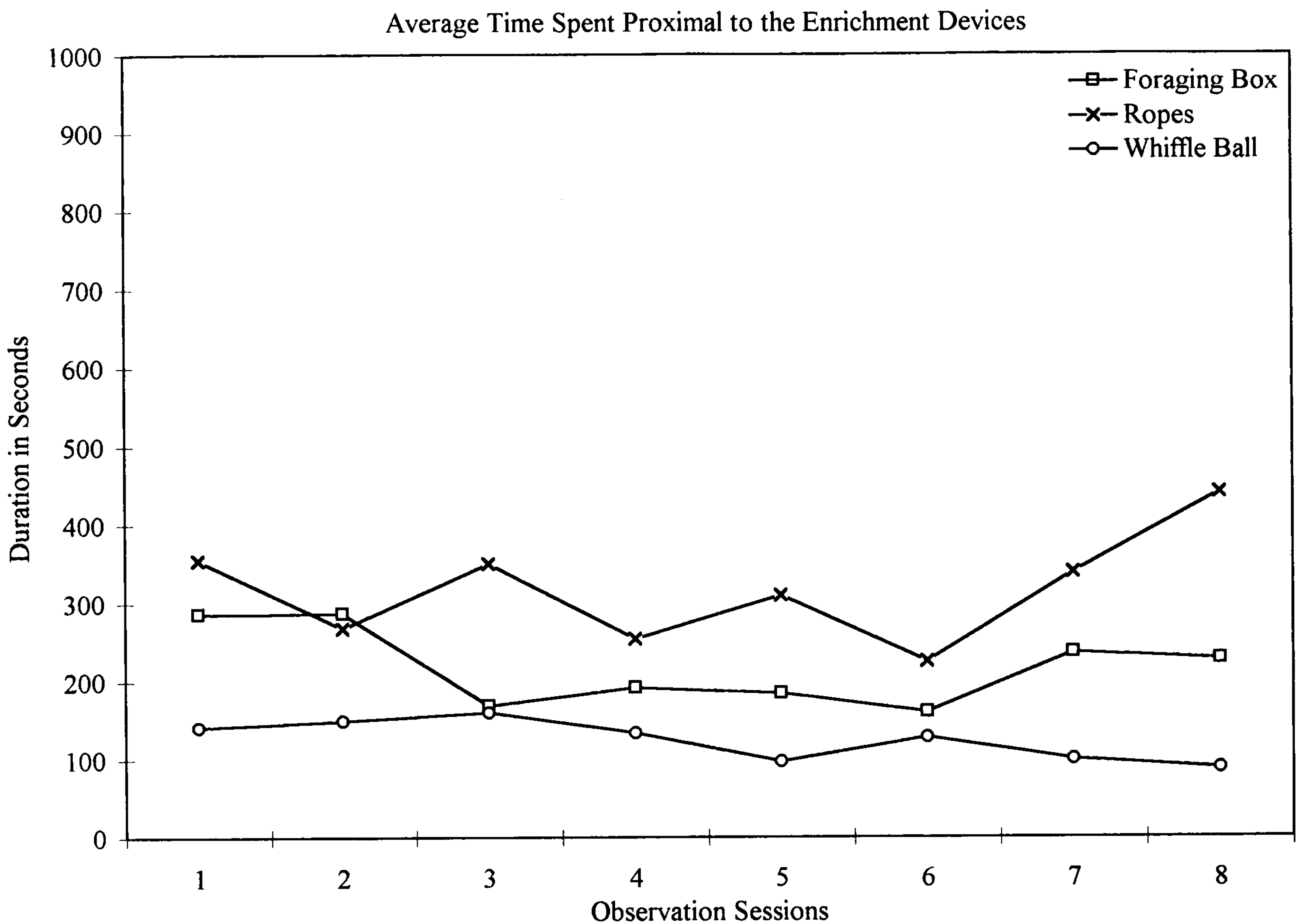

Figure 3.12. Duration averages (in seconds) spent Proximal to devices in each of the conditions.

Table 3.4. Time (in seconds) spent in Contact with enrichment devices.

Day	Foraging Box	Ropes	Whiffle Ball
1	854.63	147.75	110.63
2	740.75	95.88	38.00
3	593.25	103.38	70.75
4	760.88	68.25	29.00
5	670.88	79.13	26.38
6	741.38	113.63	25.88
7	538.13	125.50	25.13
8	591.29	74.86	20.63
Total	5491.16	808.36	346.38
Overall	686.40	101.04	43.30

Table 3.5. Time (in seconds) spent Proximal to enrichment devices.

Day	Foraging Box	Ropes	Whiffle Ball
1	286.50	354.75	141.38
2	287.00	267.88	148.88
3	168.63	350.38	159.75
4	191.13	253.88	133.25
5	183.88	309.63	97.13
6	160.00	225.00	127.88
7	236.50	338.75	99.88
8	228.00	440.71	88.25
Total	1741.63	2541	996.38
Average	217.70	317.62	124.55

Position Comparisons of Females and Males

Foraging Box

The average time spent in Contact with the foraging boxes was 731.5 seconds (Table 3.6) for the females, and 645.7 seconds for the males. The average time spent Proximal to the device was 230.8 seconds for females and 204.7 seconds for males. There were no significant differences between females and males for either Contact with or Proximity to the foraging boxes, (F(VR between groups) = 1.306693, p = .2579 and F(VR between groups) = .9476814, p = .3346). The similarities between the sexes can be seen in Figures 3.13 and 3.14.

Table 3.6. Comparisons of average time (in seconds) spent per session in each positional category for females and males.

Position	Contact		Proximal	
Sex	Females	Males	Females	Males
Foraging Box	731.5	645.7	230.8	204.7
Ropes	153.4	51.16	342.7	289.5
Whiffle Ball	44.97	41.63	129.8	119.3

Ropes

The females spent an average of 153.4 seconds in Contact with the ropes. This was three times the males' average of 51.6 seconds per session. The averages of time spent in Proximity to the ropes were 342.7 seconds for the females and 289.5 seconds for the males. There were significant differences between females and males for Contact with the ropes, (F(VR between groups) = 15.04306, p = .0003). There were not

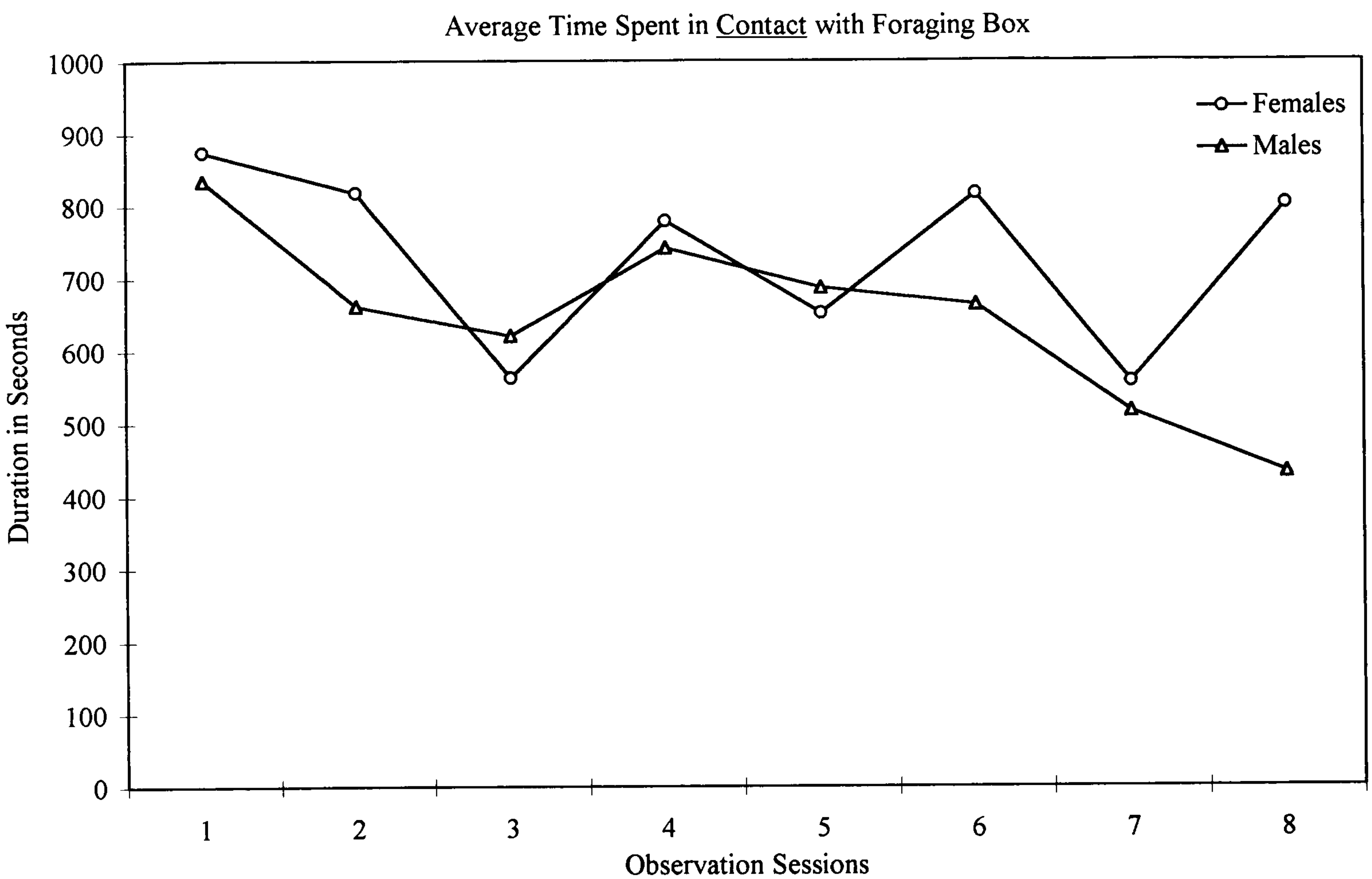

Figure 3.13. Comparison of female and male duration averages (in seconds) of Contact in the **Foraging Box** condition.

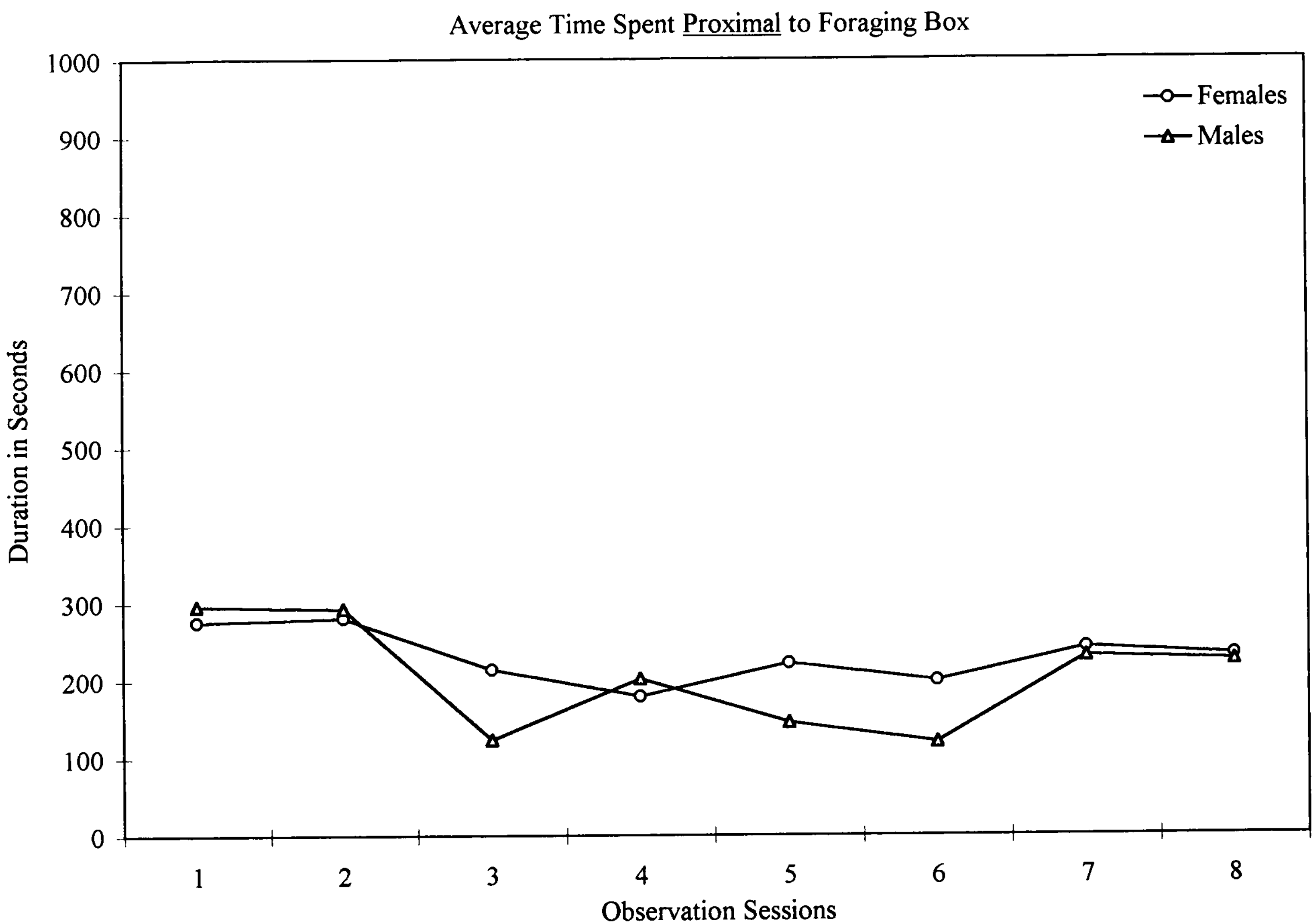

Figure 3.14. Comparison of female and male duration averages (in seconds) of Proximal in **Foraging Box** condition.

significant differences between females and males for Proximity to the ropes, (F(VR between groups) = 0.9624745, p = .3309), (Figures 3.15 and 3.16).

Whiffle Ball

The average time spent in Contact with the balls was essentially the same with 44.97 seconds for the females and 41.63 seconds for the males. Time spent Proximal was 129.8 seconds for the females and 119.3 seconds for the males. There were no significant differences between females and males for either Contact with or Proximity to the whiffle balls. The results were F(VR between groups) = 0.0463465, p = .8303 and F(VR between groups) = 9.348258E-02, p = .7609). Figures 3.17 and 3.18 illustrate the similarities in the sexes.

Stereotypical Behaviors of Subject 027

Subject 027 was the only subject in this study to exhibit a Stereotypy. The erratic patterns of these behaviors are illustrated in Figure 3.19 with the average for that **Baseline** or condition. Each condition showed a decrease in comparison with the **Baseline** (Table 3.7). Yet, no differences in population means were found when analyzing the data with an unpaired t-test; **Foraging Box**, p=.4224, **Whiffle Ball**, p = .3929, **Ropes**, p = .0596. **Nature Sounds** was the only condition where these behaviors were completely ameliorated. Due to the variances between the baseline and the condition, this comparison was analyzed using a Mann-Whitney U test. It was not significant either, p = .0769. This condition had a confounding factor, the reintroduction of subject 033.

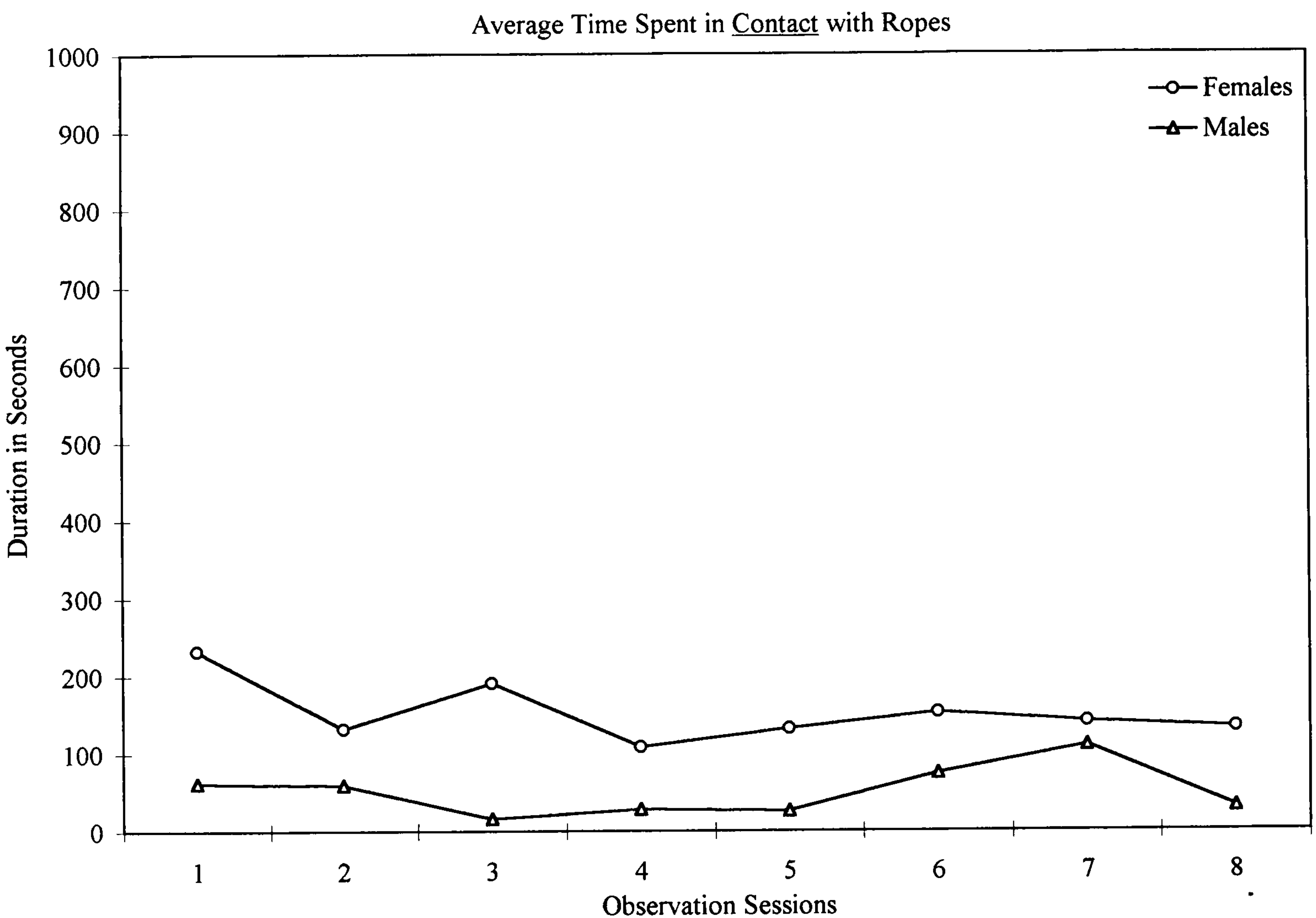

Figure 3.15. Comparison of female and male duration averages (in seconds) of <u>Contact</u> in **Ropes** condition.

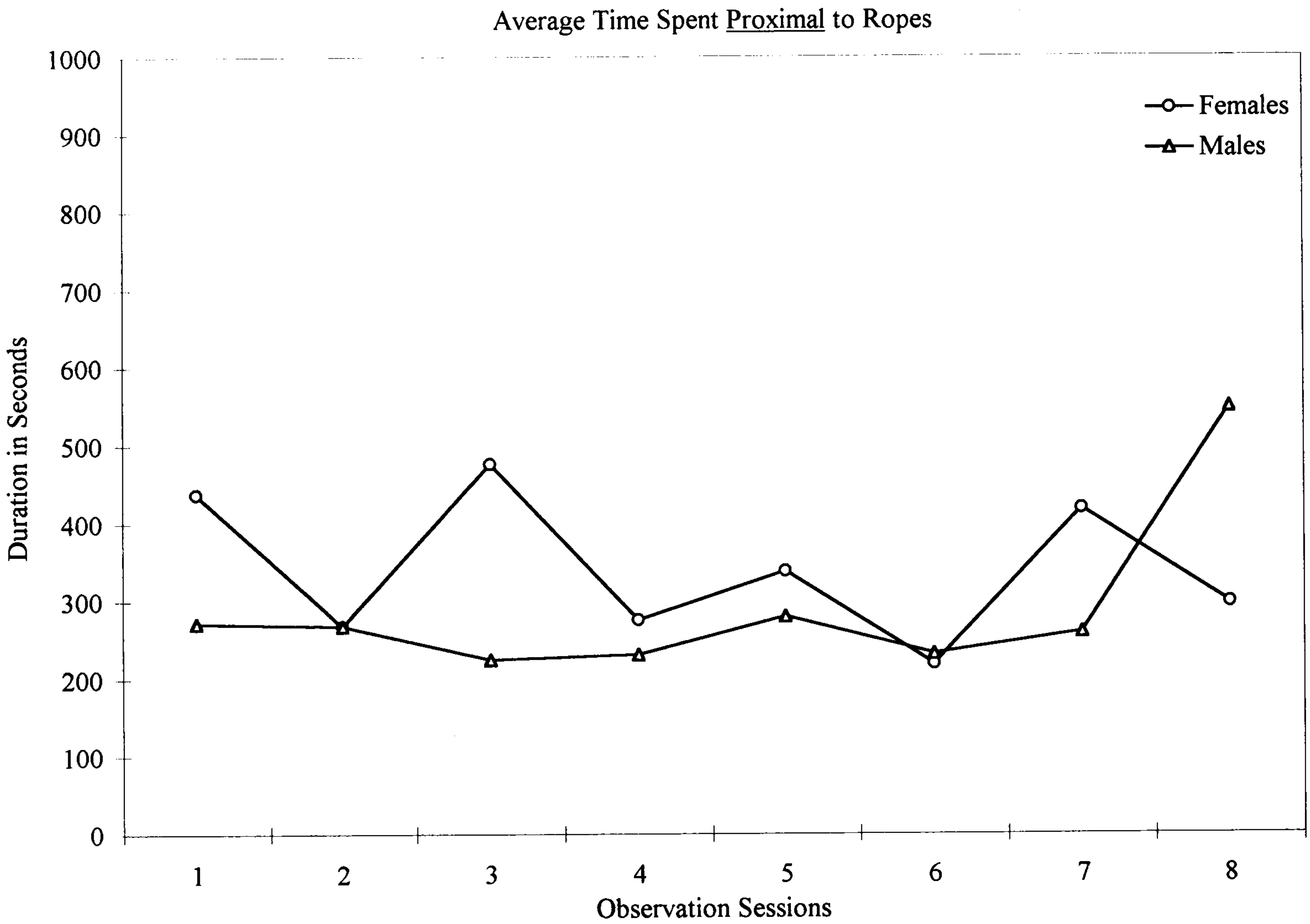

Figure 3.16. Comparison of female and male duration averages (in seconds) of <u>Proximal</u> in **Ropes** condition.

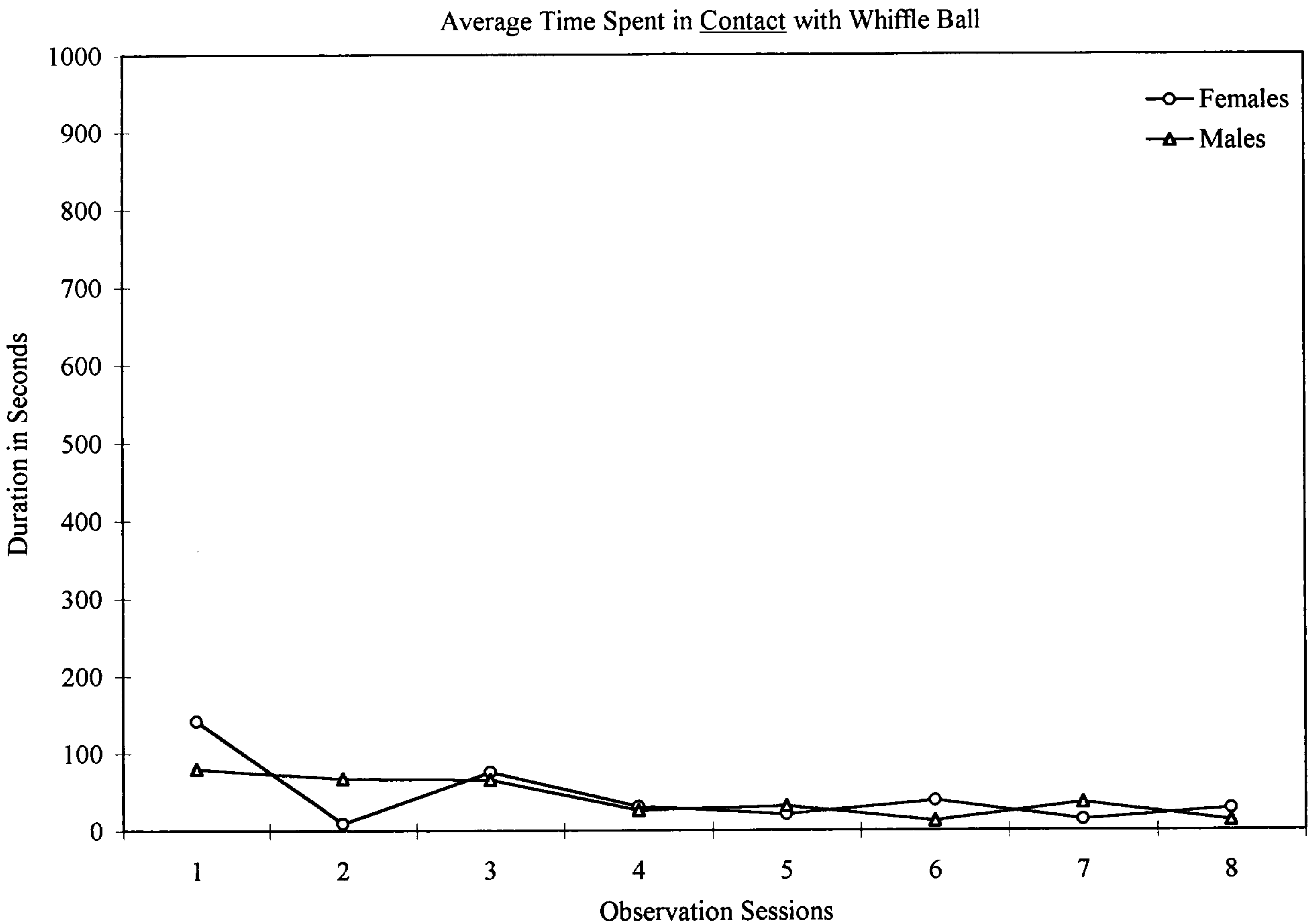

Figure 3.17. Comparison of female and male duration averages (in seconds) of <u>Contact</u> in **Whiffle Ball** condition.

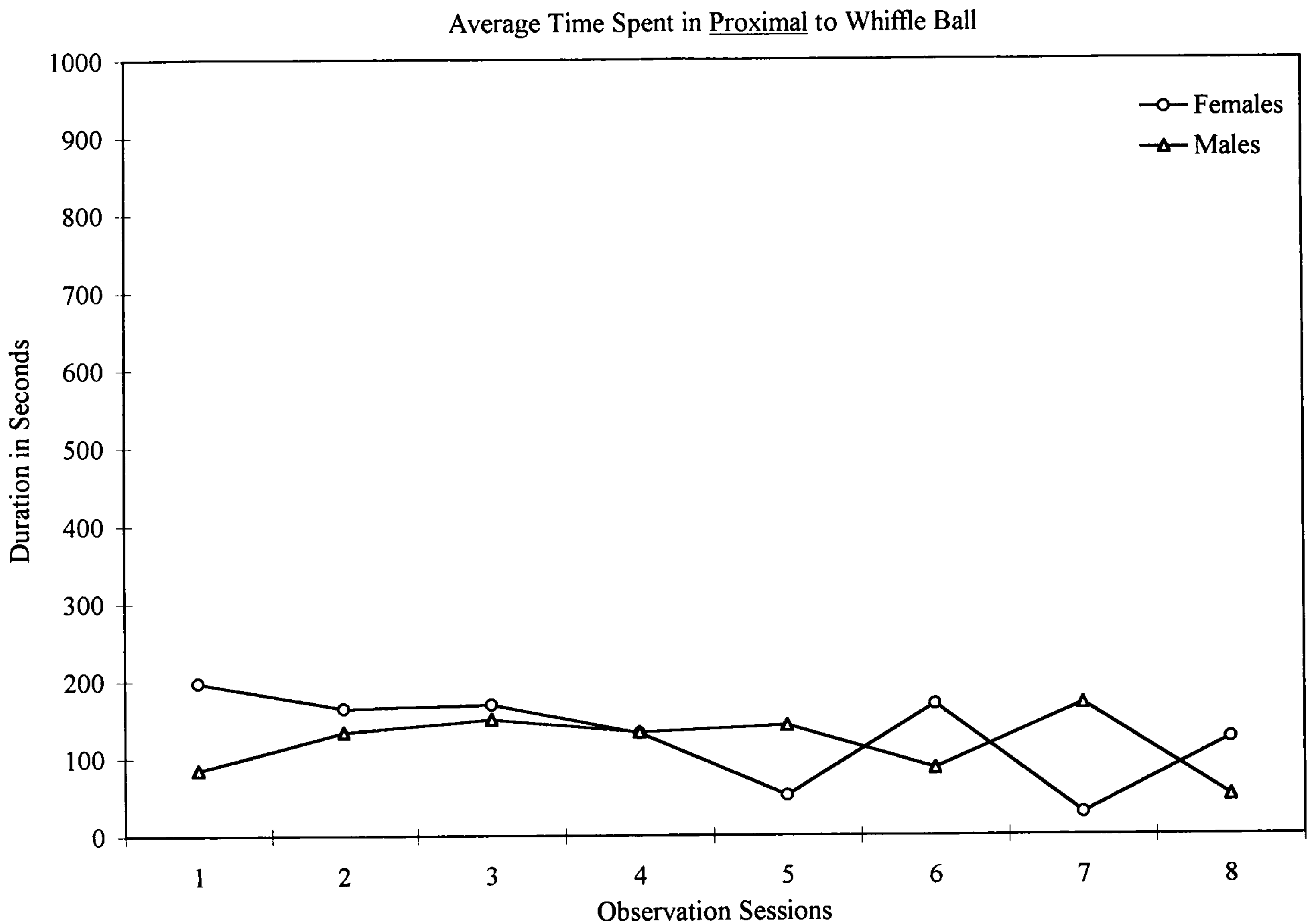

Figure 3.18. Comparison of female and male duration averages (in seconds) of <u>Proximal</u> in **Whiffle Ball** condition.

Table 3.7. Subject 027's stereotypical behavior duration. Baselines and conditions are presented in chronological order.

Day	Baseline 1	Foraging Box	Baseline 2	Whiffle Ball	Baseline 3	Nature Sounds	Baseline 4	Ropes
1	265	0	228	214	47	0	820	29
2	145	294	236	567	0	0	31	0
3	6	15	62	0	57	0	314	151
4	261	139	203	63	0	0	3	193
5	98	194	0	0	0	0	26	38
6	82	119	448	294	0	0	461	487
7	19	35	160	0	237	0	440	38
8	5	0	0	0		0	428	53
Total	881	796	1337	1138	341	0	2523	989
Average	195.78	176.89	297.11	252.89	85.25	0	560.67	219.78

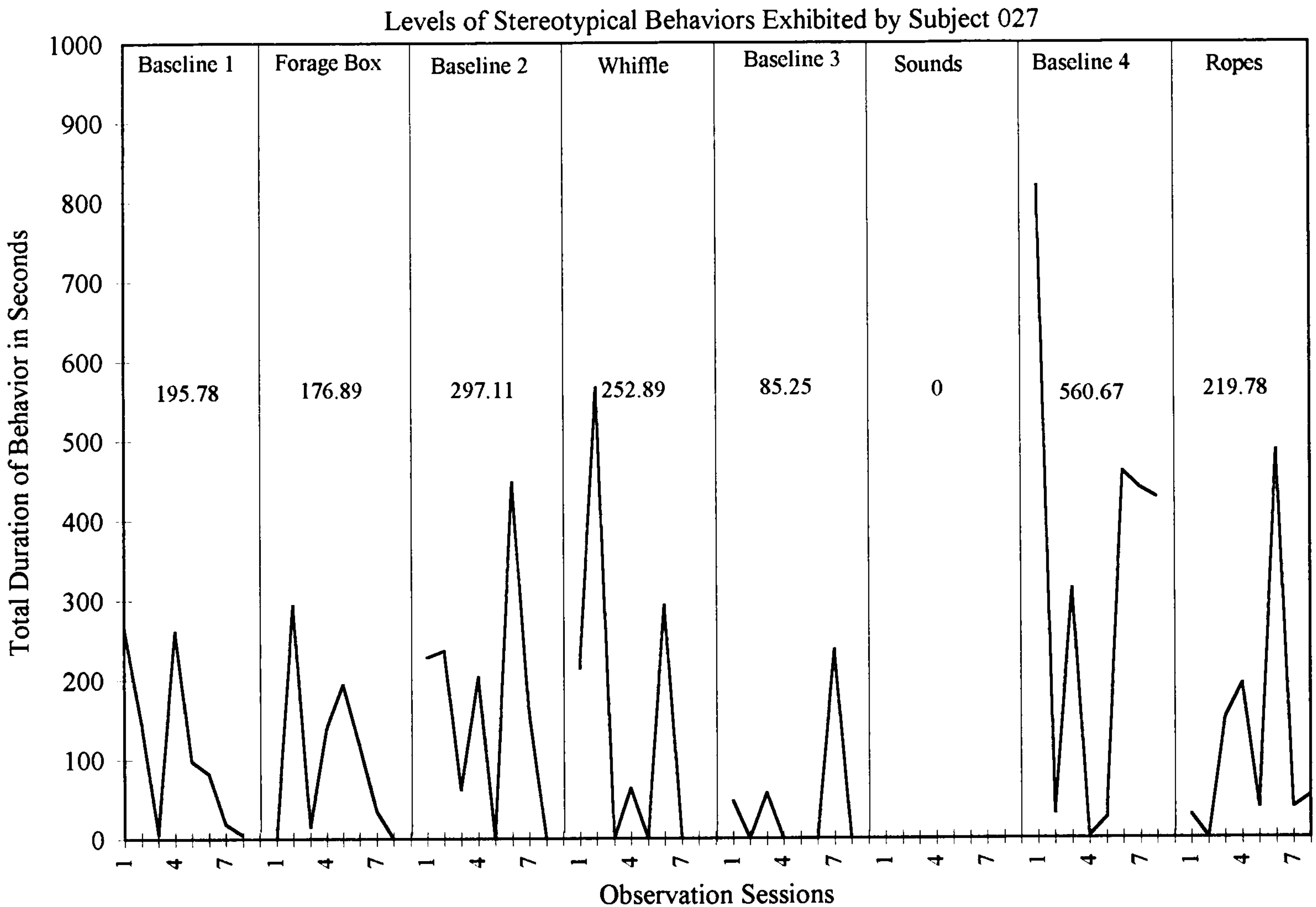

Figure 3.19. Duration (in seconds) of Stereotypy exhibited by Subject 027 across all sessions. Averages for each stage are shown.

CHAPTER FOUR

DISCUSSION

Foraging Box

In comparison to the other four devices, the animals preferred the foraging box the most. It also seemed the most successful because it achieved the original intention of increasing foraging time. The animals spent more time searching for food and extracting it from the boxes than they would have spent foraging for their normal diet. Captive animals usually have food predictably provided for them in an obvious place and at routine times. They have no need to search for food and therefore have excess time for other sometimes non-natural behaviors. Time spent in active labor for food reduces the time that they might be Inactive or involved in behaviors that are not species typical. In this study only acquisition time increased, the marmosets spent an equivalent amount of time actually Feeding.

Females and males showed equally intense interest in the foraging boxes. The possibility of aggression was recognized prior to the study and prompted the use of two boxes in order to decrease fighting between cagemates. The female subjects seemed slightly superior at retrieving the treats. They spent more time slowly and methodically searching through the wood chips. The males, in contrast, sometimes shook and moved the boxes around rather indiscriminately.

In a financial cost evaluation, the **Foraging Box** condition required the highest time investment and in the long term was the most expensive. After the initial fabrication, a modest amount of preparation time was needed to fix the treat items and the wood chips. Clean-up time was the most for this condition as well; wood chips that fell to the floor had to be swept up and the boxes themselves had to be cleaned.

Ropes

The subjects spent more time Proximal to the ropes than the other devices. This is a result of the ropes taking up more space within the cage, essentially making it more difficult for the animals to be Distal to the ropes. Time spent in Contact with the ropes, perching, maneuvering, hanging, or clinging, was highly variable between subjects. Ranging from 002's 1844 seconds to 034's 43 seconds. Subjects 001, 002 and 010 spent more time Locomoting on the ropes individually than the other five subjects spent together.

This disparity between the subjects could have multiple reasons. The subjects could have had different rearing conditions at other facilities prior to this study. After the study, it was realized that the source for 001, 002, and 010 was the same. Prior exposure to ropes or a similar substrate would explain these three subject's willingness to more readily use the ropes. Top ranked subject 001 could be a case of individual difference. The young offspring in the cages with groups C and D seemed to utilize the ropes frequently. The fact that the subjects saw their offspring climbing on the ropes might explain second and third ranked 002 and 010's use. Subjects 035 and 017 ranked fourth and fifth.

Being that average Contact duration was consistent over the observation sessions, eight exposures to the ropes did not effect proficiency on and therefore increase use of the ropes in these adults. Perhaps longer term exposure and exposure to ropes at younger ages would increase use. An excellent situation for a longitudinal enrichment device study would be an investigation of differences between animals with continuous exposure to ropes since birth and those with no experience.

The ropes seemed to be beneficial in the short term for at least some of the subjects. When ropes were furnished the animals were able to utilize more of their cage, effectively increasing their space. Ropes were installed in the cages of other colony animals for long periods of time. These animals seemed as if they used the ropes more often than the test subjects, but no objective data were collected.

From a cost standpoint, the **Ropes** condition required low initial investment. The ropes themselves were inexpensive, but required several minutes to install in a cage. Due to time constraints, metal clasps were used making installation and removal easier and quicker. In non-study cages the rope was run through the mesh and tied off at the ends. In a long term application, there would be minimal time needed for upkeep and replacements.

Nature Sounds

The **Nature Sounds** condition seemed to be the only condition that did not promote a positive enriching environment for the animals. In the initial sessions in which the sounds were played, the animals were alarmed and cautious. They would either stay stationary and look about the cage and room or would hide in the nestbox. The subjects never seemed to be able to locate the source of the sounds. Subject 027 and 033 spent almost all of each of their sessions in the nestbox.

In the wild there are predators, other animals, and situations that might cause the animals to be startled or alarmed. In those situations there is a necessity to be wary, cautious, seek a better vantage point, or perhaps security. One could say that species typical behaviors are being promoted by the **Nature Sounds** condition. By providing stimuli that encourage these behaviors an enriching environment is being promoted even if at first it seems to be a negative one. This situation would not have been continued if it had been determined to be detrimental or harmful to the animals.

Cost-wise, the cassette player and tape made the **Nature Sounds** condition the most expensive due to the relatively high initial investment. It did, however, provide stimuli to a whole room of animals, not just the test subjects. In a long term colony-wide enrichment program, the cassette player could be moved from room to room and those investments would appear minimal.

Whiffle Ball

The **Whiffle Ball** condition seemed to cause the least amount of change in overall behaviors. The devices drew attention in the first few observation sessions with increased <u>Manipulation</u> and <u>Investigation</u>. Interest and the novelty of the balls quickly faded.

Certain individuals might benefit from these devices. Non-study animals that were temporarily pulled from their home cage due to illness or fighting within the group were given balls. These animals showed some sustained interest. This was most likely due to the smaller cage size and restricted social interaction opportunities.

The **Whiffle Ball** condition created the least amount of reaction on the part of the animals, but it would cost the least to carry out in a long term program. There is the initial cost of the balls, but this is very minimal. Making distribution of the balls a normal part of the caretakers' routine would require a small additional time investment. To utilize whiffle balls more effectively as part of an institution's enrichment program, a few balls could be swapped around between different groups. They could be pulled when one group becomes uninterested in them and then given to another group.

Stereotypical Behaviors of 027

Subject 027 was the only animal in this study to exhibit stereotypical behaviors. The first was an autoaggressive behavior where he would roll on the floor of the cage and bite his legs. The second was a self-clutching behavior in which he would place his right arm all the way around his back and sit that way for several minutes.

No definitive conclusions can be made about the effects of these enrichment devices on all individuals performing stereotypical behaviors. Yet, the devices did seem to reduce 027's levels of expression. The only condition that completely ameliorated the behaviors was **Nature Sounds**.

Just prior to the start of this study, 027 had instigated fights and caused injuries to 033. The injuries and concern for 033's health required their separation. The **Nature Sounds** condition began soon after 027 was reintroduced to 033. In this case there was a beneficial side-effect of the sounds. It increased the subjects' proximity to one another. They appeared to be frightened by the sounds and therefore spent the majority of the time in the nestbox together and did not fight with each other. Subject 027 did become aggressive in the following **Baseline** period and required separation once more.

CHAPTER FIVE

CONCLUSION

The term environmental enrichment is used to describe the provision of objects to captive animals to promote the expression of species-typical behaviors, to alleviate boredom, and to reduce the expression of stereotypic behaviors. Environmental enrichment can encompass the use many diverse elements including devices to increase time spent foraging, cage furnishings that promote natural behavior, modes to increase positive stimuli in the surroundings, and toys that increase manipulation. In order to know what items are of actual benefit to a particular species or individual, it is necessary to test them.

In this study four different enrichment devices were tested. These devices were foraging boxes, ropes, nature sounds and whiffle balls. The data clearly show the foraging boxes to be the most successful at effecting behavioral changes. All the subjects had high levels of manipulation and investigation which were sustained over the course of the observation sessions. The second most successful device was the ropes. They were used by three of the eight subjects and by young offspring housed with some of the subjects. The nature sounds ranked third for behavioral impact. It increased the levels of inactivity in all subjects and in a way promoted species-typical behaviors. The animals were alarmed and cautious and either sought security in their nestboxes or perches from which to look for the source of the sounds. This inactivity returned almost to baseline in later observations. The least successful device was the whiffle ball. Because it was novel, it stirred interest in the first few observation sessions. However, the animals quickly habituated to it and their interest declined over the remaining sessions.

A facility holding only a few animals of a certain species might be able to rely on anecdotal reports from caretakers or keepers to subjectively assess an enrichment device's success. However, a facility housing many animals must necessarily objectively evaluate the costs and benefits of an enrichment device with a few animals before instituting a colony-wide enrichment program. This thesis demonstrated a method of assessing the ways different environmental enrichment items effected the behavior of common marmosets. This was a cost effective way to evaluate the animals' responses to and use of enrichment devices. The small N research design utilized here can be used to test enrichment in research facilities or zoos where there is usually little time for extra projects. Institutions that are currently collecting behavioral data could add a few parameters to include enrichment usage. Those not already involved in data collection could start a small program assessing one device at a time with little additional time investment.

With this assessment, a base of components is available upon which a more complex program can be built for the rest of animals in this colony or for any other facility holding common marmosets. Research facilities and zoos most often have different styles of enrichment devices. In a research facility the functional aspects of a device are usually most important. A device must be removable and easily cleaned, looks are usually not a concern. In a zoo, especially in a naturalistic exhibit, aesthetics are a major concern. Function is also important, but, a device must be natural or at least disguised to fit the exhibit surroundings. These two approaches do not have to be at odds, instead they should compliment one another. A research facility or a zoo's off-exhibit holding area might have simple, rudimentary enrichment devices. Whereas an exhibit that the public normally sees might have the same types of devices only more complex or elaborately disguised.

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