Research protocol for the Atlantic Bottlenose Dolphin (Tursiops truncatus): Mirage Click Collection Study

Adrienne M. Cardwell
University of Nevada Las Vegas

Follow this and additional works at: http://digitalscholarship.unlv.edu/thesesdissertations
Part of the Zoology Commons

Repository Citation
Research Protocol for the Atlantic Bottlenose Dolphin (*Tursiops truncatus*): Mirage Click Collection Study.

Adrienne M. Cardwell

May 8, 2002

**Content Advisors** - Dan E. Blasko, Curator Mirage Dolphin Habitat, 791-7588

&

Dorian S. Houser, Ph.D., Biomimetica Owner/Research Scientist, 619-465-5170

biomimetica@cox.net

**Class Advisor** - Dr. Helen R. Neill, Chair, Associate Professor of Environmental Studies,

neill@ccmail.nevada.edu

**Abstract**

Past research on dolphin echolocation has shown that dolphins can adaptively control the frequency and amplitude of echolocation clicks. The degree to which click production is controlled and the relationship between click variation and echolocation task remains uncertain. This thesis describes a research protocol for studying the adaptive control of dolphin echolocation. The protocol builds on past studies to investigate the manner in which the spectral characteristics of clicks and the overall number of clicks produce for a given task vary in relation to the type of task being performed.
# Table of Contents

I. Introduction ........................................................................................................... 3-6  
   A. Fig. 1  

II. Background of Echolocation ............................................................................... 6-10  

III. Literature Review .............................................................................................. 10-22  
   A. Picture 1  
   B. Picture 2  
   C. Table 1  
   D. Table 2  
   E. Table 3  
   F. Fig. 3  
   G. Fig 4  

IV. Methods and Data .............................................................................................. 22-27  
   A. Setting and environment  
   B. Subjects  
      1. Table 4  
   C. Equipment and positioning  
      1. Table 5  
      2. Picture 3  
      3. Picture 4  
   D. Analysis  

V. Results ................................................................................................................... 27-28  
   A. Trial 1  
      1. Fig. 5  
      2. Picture 5  
   B. Trial 2  
      1. Fig 6  

VI. Discussion .......................................................................................................... 29-32  

VII. Conclusion .......................................................................................................... 32  

VIII. Acknowledgements ........................................................................................... 32  

IX. Appendix .............................................................................................................. 33-39  
   A. Reference list  
   B. Fig 2  
   C. Map 1  

2
Introduction

A sound wave traveling through water can encounter different objects through which much of its energy cannot penetrate. This causes a reflection of the sound which is known as an echo. Sonar is a method of acquiring a sense of the surrounding environment by projecting acoustic signals and processing echoes received from objects in the environment (Au, Popper & Fay, 2000). Research on animal sonar began in the 1770’s by Lazzaro Spallanzani; who observed that bats could fly freely in complete dark while owls could not (Au, 1993). Schevill and Lawrence (1956) later found that a marine mammal, the dolphin, also possessed a biological sonar system. They observed that an Atlantic bottlenose dolphin (Tursiops truncatus) emitted clicks while locating and swimming to a food reward (reinforcement) in murky pond water. In a follow-up experiment, they showed that the dolphin was able to choose between two feeding locations when only one location contained food. The locations were 2.5 M apart, separated by a net, and the test was only administered at night. Schevill and Lawrence (1956) reported that two-thirds of the time the dolphin emitted an “impulsive creaking” sound. It is now known that this “clicking” is a type of biological sonar, or echolocation, which allows the dolphin to survive and utilize the marine environment (Au et al. 2000).
It has been argued that the ability of a dolphin to perceive its surroundings and to perform difficult discrimination tasks depends in part on the characteristics of the emitted echolocation signal.

Dolphin echolocation signals are short acoustic pulses, or clicks, and are emitted in a sequence known as a click train (Au et al. 2000). These sounds can be broadband, exceeding 85 kHz in frequency band width (Houser, Helweg & Moore, 1999). Clicks can be arranged from a few to several hundred per second. The clicks may have peak frequencies between 20 and 130 kHz and average peak to peak click source levels of 220 dB re 1μPa at 1 M (Au, Floyd, Penner & Murchison, 1974). Below is an example of an echolocation signal. It is plotted as a function of time with the corresponding frequency spectra.

**FIG.1 Spectra Reading of Dolphin Echolocation**

Researchers of dolphin echolocation have investigated the transmission of echolocation signals, echo reception and signal processing and its role in decision
making (Au et al. 2000).

This research shows that dolphins have adaptive control over their echolocation, but the degree of control exhibited by dolphins requires further investigation. Information about the differences in click production between individuals performing different tasks will provide the research community with a broader understanding of the variable control of dolphin echolocation. Houser et al. (1999) classified dolphin echolocation clicks based upon their energy and frequency distributions, producing a classification scheme usable for the evaluation of dolphin click. This project will examine the Houser et al. (1999) research in an effort to create a research protocol for collecting and analyzing echolocation clicks collected at the Mirage Dolphin Habitat. The hypothesis is that the available literature will provide guidance for a scientific research design.

The remainder of this paper will be organized in the following manner. What is known of echolocation production and control will be reviewed. Relevant literature will be reviewed and an analysis of the Houser et al. (1999) study will be conducted. From the literature an experimental design will be created for the Mirage click collection project. The methods session will be broken down into four areas: setting/environment, subjects, equipment/design layout and analysis. This thesis will end with a discussion of the
methodological design and the reasoning behind its choosing.

**Background of Echolocation**

It is presumed that all odontocetes (toothed whales) produce acoustic pulses or clicks for use in echolocation (Au, et al. 2000). Most studies on echolocation are on captive dolphins, customarily *Tursiops truncatus*, although other experiments have shed light on click production in *Delphinapterus leucas* (beluga), *Phocoena phocoena* (Harbor Porpoise), *Phocoenoides dalli* (dall’s porpoise), *Inda geoffrensis* (boutu) and many more species of cetaceans (Nachtigall & Moore, 1988).

The origin of the click has been the subject of a long-standing debate: Does the click come from the nasal plug or the larynx? The laryngeal phonation hypothesis was largely based on the anatomical analyses of Purver (1966), Blevins & Parkins (1973) and Purves & Pilleri (1973). They reasoned that the larynx was the most parsimonious choice for the source of echolocation in odontocetes based on the fact that most mammals use laryngeal phonation for sound. The other side of the debate was posed by Norris and Harvey’s work (1972) with a sperm whale. They published a description of the anatomy of the sperm whale and hypothesized that the purpose of the nasal plug was as a sound generator. Later, Ellis (1983) reported he was able to feel pulsed sounds from the anterior surface of the forehead of the sperm whale. This supported Norris and Harvey’s
ideas. The debate has subsided since the 1980's due to a number of papers collectively supporting the nasal phenomenon hypothesis. These studies included electromyography and pressure event recordings during sound generation in a single species (Ridgeway, Carder, Green, Gaunt & Gaunt, 1980), ultrasound imaging (Mackay and Liaw, 1981) and direct observations of the sound generation process (Au et al. 2000; Cranford, Van Boon, Chaplin, Carr, Kamdnick & et al. 1997).

Within the nasal plug the sonar signal is generated by pushing air past a pair of phonic lips (monkey -lipped dorsal bursae). The lips vibrate in a movement called "relaxation oscillation" (Au, 1993). Adjacent tissue composed of translucent lipids and oil then vibrates allowing the channeling of clicks into the water (Au, 1993). A click occurs within one oscillation cycle of the lips. The cycle begins when the lips part, a burst of air and fluid come over the gap between the lips followed by the closure of the lips. It has been hypothesized that T. truncatus can produce the click from both phonic lips or from different sites along the lips, therefore providing at least two sonar signal generators (Cranford et al. 1997).

The inter-click interval is the time that exists between the sound pressure peaks of two subsequent clicks. The number of clicks produced and the inter-click intervals can change as a function of what the dolphin is asked to do, be it detect an object or
discriminate between objects. Interclick interval allows the dolphin to measure how far away the target is located. The interval consists of the time from when the click is emitted to when it is received as an echo (before the dolphin emits the next click) (Au, 1993). Dolphins can also vary their amplitude of echolocation clicks; amplitudes have been recorded from 150 μPa to 230 μPa (Au, 1980). The variation in amplitude is a measure of how much the source level can change across multiple clicks. Dolphins scan targets while echolocating by moving their head in both a lateral and in a circular motion. Scanning allows the outward flare of the jaw bone (pan bone) to receive sounds from multiple angles (Au et al. 2000). All of these physical characteristic aid the dolphin in their sonar abilities (Au et al. 2000).

Norris (1968) hypothesized that cetaceans have an "acoustic window" consisting of fatty tissues and a thin bone on the lateral sides of the lower jaw. Norris noted that the mandible had a large cavity housing a fatty cylinder and an ovoid of thin bone, called the pan bone, which had fat overlaying it. Norris noted that the fat resembled fat found in the melon suggesting that the lower jaw acted as an acoustical channel, much like the melon acts as an acoustic lens (Norris, 1968). More recent magnetic resonance imaging (MRI) work by Ketten (1994) has revealed that multiple lobes of fatty tissue exist within the jaw. The fat bodies project postero-laterally as a defined connection to the tympanic
bone of the middle ear. Ketten's work suggests that the multilobed structure could function as "segmented" sound conduction channels with specific tuning properties. The anterior channel could be specialized for capturing echolocation signals, while the interior/lateral channels may be tuned for communication signals (Ketten, 1998). As the acoustic energy passes through the lower jawbone, it enters the mandibular fat body, which directs the signal to the thinnest area on the tympanoperiotic bone. This structure houses the middle and inner ears (Norris, 1968). The sound energy is then passed to the inner ear where it is translated by the nervous system.

To investigate the "jaw - hearing" theory, Brill and Harding (1991) designed an experiment where a dolphin was conditioned to wear a rubber hood covering its lower jaw while performing an acoustic discrimination exercise. A discrimination exercise requires the dolphin to learn acoustic distinctions between targets that are similar, but not exactly alike, based upon echoes off of the targets. The experimental hood was made of closed-cell neoprene, which is a good reflector of sound. Their results demonstrated that the dolphins' ability to echolocate was impaired while wearing the neoprene hood, thus supporting the theory that echoes from insonified objects are received through the lower jaw (Brill & Harder, 1991).

Cetaceans have evolved biological sonar that permits them to survive in an
aquatic environment. Although we have a relatively basic understanding of echolocation; theories and debates still exist over the control and utility of echolocation, suggesting that more research will come. The limits and control of click production by dolphins is an issue that needs attention. Research into this issue could provide ways to study dolphin echolocation from the point of click production which will help to further the understanding and function of the sonar systems of dolphins. The click collection study for which the methods are developed in this thesis will delve into the question of the degree of control that dolphins have over their clicks. This is the main focus of the Mirage click collection project.

**Literature Review**

Classification of dolphin echolocation clicks has been performed by Houser et al. (1999). They collected approximately 54,000 clicks with the goal of investigating the adaptive control over click production in bottlenose dolphins. For my literature review, I will explore this study in detail and tie in other studies which have ideas that may assist the development of a click collection project to be performed at the Mirage.

The Houser et al. study used two Atlantic bottlenose dolphins, one fourteen year old female (Tt751F) and a thirty three year old male (Tt018M). They were trained to perform an object detection exercise. The object detection task was set on a standard of
“go/no go” response paradigm. A “go/no go” paradigm is a psychophysical method where the subject can indicate its decision regarding the presence of a target by making a response. To give the response as in the Houser et al. study, the subject would go and touch a paddle if the target was present and would not go if the target was absent. (Au et al. 2001). These tasks were run in the San Diego Bay.

A third dolphin, an 18 year old male (Tt598M) performed a two interval three-alternative Match-to-Sample (MTS) task. The task consisted of two intervals. In the first interval the dolphin would inspect a sample target through echolocation (echo-inspection). The second interval involved echo-inspection of a set of comparison targets. The comparison targets consisted of one target, which was the same as the target inspected in the first interval, and two other targets of a different type. After the second interval the dolphin would attempt to match the sample target from the first interval to the correct comparison target in the second interval (Houser et al. 1999). All targets were set in a random presentation series to guard against the subject figuring out a biased pattern of presentation resulting from human decisions about presentation order (Houser et al. 1999). The MTS task was performed in Kaneohe Bay, Hawaii.

Sample targets were placed 4.65 M in front of the subject during the inspection portion of the MTS task. Comparison targets were placed 3.65 M in front of subject and 1.6 M to
the left and right of center. To collect emitted clicks during echo-inspection, a Bruel and Kjar 8103 hydrophone (B&K) was mounted 2 M from the subject and 1 M underwater. The B&K had a flat frequency response (± 3dB) up to 150 kHz, and a sensitivity of -211dB at 100 kHz. A click was detected when the sound energy at the hydrophone exceeded a threshold of 150 dB re: 1 Pa, triggering the computer to store the clicks after a 2 second delay. The clicks were amplified 20 dB (Hewlett-Packard 465A), digitized at 500kHz with 12-bit resolution using an RC Electronics ICS-16 computer scope A/D board, and 256 points per waveform were stored to a PC.

For the object detection task the targets and subjects were separated by 10 m. Targets were lowered to a depth of 1 m by a monofilament line during target present trials. Dolphins echo-inspected the targets through a “window”, a circular aperture placed with the center at 1 m of depth. The “window” insures that the animal centers itself on axis with the target. Other studies, like Brill and Harder, (1991), used the same methodology, while others, like Au and Moore (1983), used bite plates to station the dolphin. Bite plates are made out of a polystyrene plastic material and are fitted with contoured rubber inserts made from a dental impression of the animal’s jaw. The bite plate maintains the animal’s head and jaw in a fixed position (Au and Moore, 1983).
An aluminum sheet, placed between the subject and target, was used to block the subject’s attempts to echolocate on targets before a trial was started. A pulley system was used to lower and raise the shield at the beginning and end of trials.

The hydrophone used in the object detection task was the same type of hydrophone (B&K) used in the MTS task; it had a flat frequency response (± 3dB) up to 150 kHz, with a sensitivity of -211dB at 100 KHz. The same trigger threshold was used in the object detection task as was used in the MTS task. The clicks were amplified 60dB (Stanford Research System Model SR560) and were digitized at 500 kHz with 12-bit resolution using an RC electronics ICS – 16 computer scope A/D board and a 256-point waveform was stored to a PC.

After a visual inspection of the Tt598M clicks the researchers formed
seven categories. Each of these categories was based upon a set of Boolean characters that described the form of the click spectrum (Houser et al. 1999). Boolean rules, or “yes” and “no” decisions, were used to classify the clicks based upon their spectral characteristics. The clicks were classified by:

Table 1

1. Peak frequency

2. The number of distinctly bounded regions existing within the 3-dB bandwidth.

3. The secondary peak frequency of a region if one existed within the −3 dB bandwidth.

4. The frequency bandwidth of distinctly bounded regions existing in the −3 dB bandwidth.

5. The −10 dB bandwidth.

6. The number and peak frequency of model regions existing with in the −3 dB and −10 dB bandwidths.

7. The drop in power of distinctly bounded regions existing between the −3 dB and −10 dB boundaries.

(Houser et al. 1999)
TABLE 2 – Categories of click type description and a representative spectrum for each.

The horizontal dotted line signifies -3 dB regions and the vertical dotted line signifies peak frequency.

<table>
<thead>
<tr>
<th>Click Type</th>
<th>Description</th>
<th>Spectrum</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>Unimodel low frequency (&lt;70kHz) spectral distributions</td>
<td>![Diagram A]</td>
</tr>
<tr>
<td>B</td>
<td>Unimodel low frequency clicks with a secondary peak existing at a higher frequency between the -3 dB and -10 dB regions.</td>
<td>![Diagram B]</td>
</tr>
<tr>
<td>C</td>
<td>Contained a distinctly bounded bimodal distribution within the -3dB bandwidth.</td>
<td>![Diagram C]</td>
</tr>
<tr>
<td>D</td>
<td>Unimodel high frequency (&gt;70kHz); secondary low-frequency peak (&lt;70kHz) between the -3 dB and -10 dB down.</td>
<td>![Diagram D]</td>
</tr>
<tr>
<td>E</td>
<td>Unimodel, high frequency (&gt;70kHz).</td>
<td>![Diagram E]</td>
</tr>
<tr>
<td>W</td>
<td>Wide-band clicks and contained a single bounded region of the spectrum within the -3-dB bandwidth with a frequency bandwidth of &gt;85kHz.</td>
<td>![Diagram W]</td>
</tr>
<tr>
<td>M</td>
<td>Three or more distinctly bounded regions within -3dB of the peak frequency.</td>
<td>![Diagram M]</td>
</tr>
</tbody>
</table>

(Houser et al. 1999)
The classification process was implemented as a computer program that applied the Boolean rules to the data. The Boolean rules were a list of rules created by a human expert that defined clicks based upon the characteristics of the frequency spectrum. Use of the rules eliminated the potential for human error during classification. A threshold peak was set at 150 dB for inclusion of clicks within the Boolean classification program (BCP) and the frequency spectrum was restricted to 27 to 150kHz (Houser et al. 1999). A total of 54,283 clicks were collected and classified.

**TABLE 3** – Dolphin identification, gender, and number of echolocation clicks collected from each.

<table>
<thead>
<tr>
<th>Dolphin</th>
<th>Gender</th>
<th># Of Clicks</th>
<th>Task</th>
</tr>
</thead>
<tbody>
<tr>
<td>Tt751F</td>
<td>Female</td>
<td>13,679</td>
<td>Detection</td>
</tr>
<tr>
<td>Tt018M</td>
<td>Male</td>
<td>11,043</td>
<td>Detection</td>
</tr>
<tr>
<td>Tt598M</td>
<td>Male</td>
<td>29,561</td>
<td>3A MTS</td>
</tr>
</tbody>
</table>

For each trial the clicks were summed and considered an observation for statistical analysis. A Mann-Whitney U-test on rank sums was used to test for the differences in click types (Houser et al. 1999). The echolocation clicks were submitted to an artificial neural network (ANN). The ANN determined if the Boolean rules were
intuitive and if there was overall agreement between click classification in the object
detection tasks and MTS tasks (Houser et al. 1999). ANN’s have also been used in
dolphin bioacoustics to look at echo features during a discrimination task and to classify
targets based upon the echoes they generate when insonified (Au, Andersen, Rasmussen,
Roitblat & Nachigall, 1995)

The ANN test examined the percentage of the classification that was in agreement
with the Boolean rules (Houser et al. 1999). The neural network achieved a 92% success rate with a “generalization set”. (The generalization set is a small portion of the whole
data set used for testing). Agreement across the total dataset ranged from 45.5 to 82.0% agreement.

From FIG. 2 (Appendix) you can see where the clicks where classified (Houser et
al. 1999).

The graph showed that subject Tt018m had the greatest variation in the
classification of clicks while subject Tt751F predominantly was classified by ANN as
emitting type E clicks (unimodal high frequency clicks). Tt598M, on the other hand,
produced predominantly type A clicks. The ANN classified 12,989 clicks in type D but
within the Boolean category rules only 30 of the 54,000 clicks where type D. In
conclusion ANN performed well for small data sets but declined in performance when

17
viewed within the entire data. The decline suggests that ANN learned patterns that were distinctive of the ideal spectral shape for a category, but as the spectral distribution moved from the ideal shape the performance declined (Houser et al. 1999).

Following the results of the ANN classification, results of a statistical analysis of both object detection task and MTS task and the differences between all click categories were discussed. The click types were color coded and positioned within a polar plot diagram for visual representation.

**FIG. 3** – Rolling sum of click types according to position within the click train for Tt598M performing proportional and comparison intervals of two-interval match-to-sample task. Polar plots represent the proportion of click types utilized by position within the click train for the same. Position within the click train is labeled on the periphery of the polar plot. Click types are color coded for identification.
There was a significant difference between Tt751F and Tt018M in click usage. Tt018M produced a number of clicks representative of each category. Most of Tt751F clicks were type E with spectra that had one peak above 70 kHz within the -3-dB bandwidth. Both dolphins produced few type B and D clicks throughout their click trains. For Tt751F, there was a change in click production as the number of clicks in the train increased. Early portions of the click trains commonly consisted of type E clicks, but changed to type A, then to type M when click train length was less than 60 clicks. A few click trains did exceed 60 clicks but had no fixed pattern. In contrast, Tt018M produced no specific click type patterns within a click train, but produced stable proportions of types A, E and M (Houser et al. 1999).

The three alternative MTS performed by Tt598M showed statistical differences
between all click categories except for type D. A substantial number of clicks were
produced in all categories except for types A and D. Numbers of specific types of clicks
appeared to be stable across the click trains, but the click train length could not be
determined because the subject exceeded the capacity of the recording system (< 99
clicks) (Houser et al. 1999).

Houser et al. (1999) concluded that there were “Demonstrated differences
between the type of clicks produced by individual dolphins performing similar tasks and
by a single dolphin within a task”. The researcher’s felt that further comparisons needed
to be made between different dolphins performing the same task and the same dolphin
performing a variety of different tasks. Continued research using this classification
scheme will provide more information on the function of the dolphin sonar system and its
use in specific tasks (Houser et al. 1999).

Special consideration may need to be taken for the category types B and D. Both
of these click types contributed very little to the overall classification, suggesting they
may not be dominant categories. Further comparisons and studies of click production
may determine if type B clicks should be merged with type A clicks and if type D should
be merged with E clicks (Houser et al. 1999).

All three dolphins showed varying degrees of production of specific click types in
regards to their given task. One of the variables which may have influenced this is environmental noise and physiological condition of the animal. For example Tt598M performed its task in Kaneohe Bay, Hawaii which is classified as a noisy environment compared to the quiet waters of San Diego Bay (Au et al. 1985). This may have impacted the frequencies and amplitudes the dolphins used. Houser et al. (1999) showed that Tt598M preferred low -frequency clicks. This is similar to the results Au et al., (1985) obtained in their study at Kaneohe Bay. Physiological conditions may have also affected the frequency and amplitude of produced clicks. Senescence of the auditory system may result in the alteration of the types of clicks produced to accommodate a loss of hearing. For example Tt018M was 33 years old and a recent audiogram study of this animal by Ketten, Moore, Dankiewiez, Brill & Van Bonn, (1997) indicated it had a bilateral decrease in sensitivity above 50 kHz. In other words, the dolphin was deaf above 50 kHz. This may be the reasoning behind the increased production of low frequencies by the males verses the female (Houser et al. 1999). The male would only produce frequencies within this hearing range.

Suggestions made by Houser et al.(1999) to achieve a better understanding of dolphin sonar from this study included using dolphins of different ages and sexes, performing identical task with identical targets. The study also suggested using the same
dolphin performing multiple tasks (Houser et al. 1999).

Methods

Using the information presented in my literature review and personal recommendations from Dr. Dorian Houser, I formulated the methods that will be used for the Mirage click collection study. This methods section will be broken down into four areas: A. Setting & Environment, B. Subjects, C. Equipment & Positioning and D. Analysis

A. Setting & Environment

All data will be collected at the Mirage Dolphin Habitat. The habitat is an open-system of four connecting pools made up of 2.5 million gallons of man-made ocean water. The habitat is in a tropical setting and is open daily to the public as an educational and research facility. All nine dolphins, five females and four males, are physically and mentally stimulated throughout the day through human interaction. Interaction consists of conditioning\(^1\), husbandry\(^2\), play, water sessions, desensitization\(^3\) and pre-existing behaviors. The animal care staff, life support staff and veterinarians at the Mirage perform all maintenance and care of both the dolphins and the habitat. All protocols

---

\(^1\) Conditioning – A type of learning process through which a response becomes attached to a conditioned (or previously neutral) stimulus (Malott, Malott, & Trojan, 2000).

\(^2\) Husbandry – Long-term physiological and psychological management ensuring the viability of a species (Malott et al. 2000).
using live animals have been approved by the animal care and use committee at the University of Nevada, Las Vegas. Protocols were also approved by Dan Blasko, curator of dolphins at the Mirage.

B. Subjects

The dolphins were chosen for this project based upon their experience in the MTS\(^4\) project at the Mirage and their experience in using eye-cups\(^5\).

**TABLE 4.** Subjects were given dolphin id numbers for the Mirage study and their ages and sex also logged.

<table>
<thead>
<tr>
<th>Animal ID #</th>
<th>Age</th>
<th>Sex</th>
</tr>
</thead>
<tbody>
<tr>
<td>DU-9003</td>
<td>27</td>
<td>F</td>
</tr>
<tr>
<td>PA-9601</td>
<td>5</td>
<td>M</td>
</tr>
<tr>
<td>SA-9701</td>
<td>5</td>
<td>F</td>
</tr>
<tr>
<td>S-9001</td>
<td>30+</td>
<td>F</td>
</tr>
<tr>
<td>PI-9401</td>
<td>8</td>
<td>F</td>
</tr>
<tr>
<td>SQ-9101</td>
<td>11</td>
<td>M</td>
</tr>
<tr>
<td>HU-0001</td>
<td>2</td>
<td>F</td>
</tr>
</tbody>
</table>

C. Equipment and Positioning

---

\(^3\) Desensitization – To make less sensitive to a particular situation or circumstance.

\(^4\) Match- to – sample (MTS) a study funded by the Mirage to discover if one dolphin can communicate information to another dolphin in order to solve a problem. Data is still being acquired (Blasko, 2001).

\(^5\) Eye cups- a rubber suction cup that can be applied to the dolphin’s skin. Once placed over the eyes of the dolphin the only sense they use to image is sonar.
The subjects will perform an object detection task with five possible conditions, four different target presentations and one target-absent trial. The same four targets will be used for all seven subjects. The targets are named as follows.

**TABLE 6.** Each target has been paired with a number for the Gellerman series.

<table>
<thead>
<tr>
<th>X</th>
<th>I</th>
<th>O</th>
<th>Not present</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
</tr>
</tbody>
</table>

The object detection task will be set to a pseudo-Gellerman series which randomizes the presentation of objects in a balanced manner, preventing the subjects from formulating predictions or patterns within the target presentation series. During each trial one of the targets will either be presented (target present), or no target will be presented (target absent). The object detection task was set on a standard go/no go response paradigm.

The subject responds by touching a paddle if the target is present and remains stationed if the target is absent.

**Picture 3 Targets**

**Picture 4 Cradle**
The subject will be positioned in a stationing cradle 1.8 meters from the wall and positioned at a 27.5 degree angle heading toward the center of the habitat. The cradle sits .9 meters under the water.

The dolphins will be conditioned to station their pectoral fins within the cradle so that no obstructions block the melon. Any obstruction around the melon can potentially interfere with the emitted clicks. A 2.13 meter pole will be placed 45 cm from the cradle. From this pole a 9cm by 9cm aluminum frame is suspended. The frame holds a 6 inch rubber mat that is covered with a closed cell neoprene which acts as an acoustic shield. The material does not allow acoustic signals to pass through it. The pole is hinged to the wall so the shield can be raised and lowered. From the acoustical shield, 45cm away, is a pole 2.44 meter long from which hangs a Reson Model TC4013 hydrophone. The hydrophone hangs .9 m under the water by a monofilament line. The Reson Model TC4013 has a flat frequency response at (± 3dB) up to 150 kHz with a sensitivity of -211dB at 100 kHz. The clicks will be amplified using a Stanford Research Systems Low-noise Preamplifier, Model SR560. The clicks will be digitized using a high-speed digitization board (R.C. Electronics). The distance from the cradle to the last pole, from which the symbol is suspended, is 4.5 meters. This pole is 4.3 meters long and has a .9 meter by .9 meter aluminum frame which is hung from the end. One of the four target objects can be attached to the square and hung .9 meter below the water level.
MAP 1 – Positioning of the equipment for the Mirage project. (See Appendix)

The subjects will position themselves in the cradle. The acoustical shield will be down and a target situated using a pseudo-Gellerman presentation series. At this time the go command will be given and the acoustic shield pulled up and out of the water. The computer used for collecting echolocation clicks will have a two second delay buffer. The recording of this buffer will be triggered when a sound pressure threshold of 150 dB re: 1 Pa is exceeded by the dolphin-emitted clicks. The computer will record the changes in pressure over time. The measure of how fast the pressure changes is called the frequency while the magnitude of the change is referred to as the amplitude. This information will be represented in a spectrum that is produced by running the signal through a Fast Fourier Transform (FFT). Following the same design, all subjects and targets will be tested until we have a subtotal click sample of 120,000 or more.

Analysis

The classification scheme used by Houser et al. (1999) will be used as a guideline in the Mirage click collection. The categories of classification will not be determined until a visual inspection of the results (clicks) is done. Each of the categories will be based upon a set of Boolean rules that are formed upon characteristics of the click spectrum. Once a trial is completed the entire click collection will be summed and
statistically analyzed. The Mann-Whitney U test of sums will be used to test the differences in click type by individual subject. This data will then be recorded in a polar plot diagram (Houser et al. 1999).

Results

To determine whether our methods were suitable for the Mirage click collection study, a few trials were run with subject SQ9101 and target #2.

A. Trial 1

Our first trial was run February 27, 2002. At that time the subject was not desensitized to the cradle and other equipment; the conditioning process had just started at this time. Therefore, we held SQ9101 in a dorsal hold, a type of station where the trainer asks the dolphin to place its' dorsal fin in his/her hand. The trainer can hold the dolphin relatively close to the wall of the habitat and the surface of the water. A total of three collections were taken and a total of 183 clicks were recorded.

FIG. 5 Spectra Reading

![Graph of Spectra Reading](image)
B. Trial 2

After the desensitization process on March 25, 2002 we ran a second trial using the methods reported in this thesis. At this time the object detection task was not conditioned. A total of one collection was taken and 99+ clicks were recorded.

FIG. 6 Spectra Reading

Discussion of Trails 1 & 2

The first trial had a lot of problems. The subject was too close to the wall and the surface of the habitat pool, which caused sound reflections to interfere with the recording. The slight ripples in the later part of the spectra reading are caused by returning echoes.
from the surface and wall. SQ9101 was very close to saturating the computer system with clicks, (96, 89, & 98 clicks) during the trials. This trials where run to test the functionality of the equipment, which had recently been transported from California. Furthermore, it provided an opportunity for the researchers involved to learn how to use the equipment.

The second trial used the methods discussed in the paper. The reading is clean and very clear, unlike trial 1. This suggests that our methods are appropriate for the collection of clicks. The location of the dolphin verses the origination of the acoustic shield, hydrophone and targets is important to the spectral reading. The second trial consisted of the same methods that will be used for the study: the subject is in a straight line with the equipment moving away from the wall at a 27.5 degree angle and 0.9m depth from the surface of the water. This is a very important feature in the design since it allows the collection of clear clicks for the target. Once again SQ9101 was producing a large number of clicks that could exceed the collection capacity of the computer (<99). It’s my suggestion to modify the computer program to collect a maximum of 200 clicks, which would allow for added collection of the subjects that produce a larger number of clicks. It will also aid in determining the length of the click train. In the Houser et al. (1999) study the click train length could not be determined on Tt598M, leaving it uncertain as to which types of clicks were produced in later parts of the click train.
There was no analysis of the clicks from trial one or two because the click categories will only be decided upon after the collection is complete.

Discussion of Methods

Unlike the Houser et al. (1999) study, the Mirage will utilize seven dolphins for the collection. This decision was based on suggestions from Houser at al. (1999) to focus on dolphins of different ages and sexes. This will allow physiological influences and individual biases to be explored.

The object detection task is part of the conditioning process that needs to be done. At a later time we can make a transition into a three alternative MTS click collection.

The reason for utilizing the cradle over other methods, like the hoop or bite plate, was due to design practicality. The hoop allowed the dolphins to take the responsibility for centering themselves within the middle of the hoop. There was a chance of the dolphin being off center or too far inside the hoop. For these reasons the hoop was not chosen. The bite plate is another way of positioning the dolphin but each bite plate would have to be formed for each subject’s mouth. The bite plates also need to be reformed as the dolphins’ mouth grows. The bite plate was ruled out due to the number of subjects and their ages. The development of the cradle was an invention by Dan Blasko that allowed for easier desensitization, no movement and no changing of biteplates. The desensitization process was made easier due to the neoprene fabric on the
cradle which aided in the direction of where we would like the dolphin to stage. The dolphin will rest on the cradle at their pectoral fins. The way the dolphin is positioned in the cradle prevents the subject from moving forward of their pectoral fins. The stationing area is bolted into the habitat foundation for extra support.

The design for the acoustical screen, hydrophone and targets was very well thought out. The Mirage does not have overhead beams to allow us to drop and raise equipment in and out of the water; therefore we had to be creative. Our innovation was a design based on a hinge system. The acoustical screen and targets are on hinges that can be pulled in and out of the water by one person. One of the four target choices will be placed in the water first then the same person will pull the acoustical shield. The acoustical screen is set like a picture frame: the PVC sheet is surrounded by an aluminum frame then covered in a closed cell neoprene. The shield is a little heavy therefore we added the extra support by bolting it into the habitat foundation like we did on the cradle. The hydrophone does not need to move therefore no hinge was needed on the pole. The hydrophone was also very lightweight and only needs a sandbag to hold it in place.

These trials allowed us to check our pre-amplifiers and filter settings. All of the equipment that is used to collect the click was suggested by Dr. Dorian Houser and Patrick Moore from the SPAWAR Systems Center. Both trials one and two proved that our equipment was set up and working as stated in the methods session. From the test
with SQ9101, the delay proved to be calculated correctly to allow the right amount of
time for the person to raise the shield and the dolphin to start echolocating. The trigger
level was exceeded in both of the trials proving it to be set at an adequate level.

The collection of clicks should take approximately a year based on an average
collection of 17,000 clicks per dolphin. This year will also include the desensitization
process for all of the subjects, as the dolphins must be comfortable with the equipment to
insure completion of the project.

Conclusion

The protocol for the Mirage click collection study will withstand peer-review
within the dolphin biosonar field. Over the next few years, the click classification project
at the Mirage will provide information on the types of clicks produced by dolphins and
their differences in adaptive control over echolocation. This is a new avenue of research
for the Mirage, as we hope to make our mark within the dolphin biosonar community.

Acknowledgments

I would like to acknowledge the overwhelming support from my co-workers at
the animal care department at the Mirage. Their support has aided in the success of the
click collection project. A special acknowledgement goes to Dr. Dorian Houser, Dan
Blasko and Dr. Helen Neill for their guidance and direction in the achievement of my
goals. Lastly I would like to thank my family (Matthew, Mom and Dad) for their loving support.

Appendix

A. Reference list


*Journal of the Acoustical Society of America*, 102, 3123.


FIG. 2 Distribution of clicks as categorized by the counterpropagation neural network.

Clicks are distributed against the Boolean classification scheme and the overall agreement between the neural network and the classification program is given for each animal.

Animal ID (% Agreement Between Classification Schemes)

<table>
<thead>
<tr>
<th>Animal ID</th>
<th>Agreement Between Classification Schemes</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>Tt598M (52.8%)</td>
</tr>
<tr>
<td>B</td>
<td>Tt018M (45.5%)</td>
</tr>
<tr>
<td>C</td>
<td>Tt751F (82.0%)</td>
</tr>
</tbody>
</table>

(Houser et al. 1999).
B. Map of Equipment Position

SYMBOLS

CLICKS

HYDROPHONE

ACOUSTICAL BARRIER

CRADLE

WALL

4.5 M

2.44 M

2.13 M

1.8 M

9.3 M

.9 M

27.5°