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**FACTORS INFLUENCING THE VARIANCE IN SIGN LEARNING
PERFORMANCE BY FOUR JUVENILE ORANGUTANS (PONGO PYGMAEUS)**

The University of Oklahoma

Ph.D. 1985

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THE UNIVERSITY OF OKLAHOMA

GRADUATE COLLEGE

FACTORS INFLUENCING THE VARIANCE IN SIGN LEARNING
PERFORMANCE BY FOUR JUVENILE ORANGUTANS [Pongo pygmaeus]

A DISSERTATION

SUBMITTED TO THE GRADUATE FACULTY

in partial fulfillment of the requirements for the
degree of

DOCTOR OF PHILOSOPHY

By

GARY LOUIS SHAPIRO

Norman, Oklahoma

1985

FACTORS INFLUENCING THE VARIANCE IN SIGN LEARNING

PERFORMANCE BY FOUR JUVENILE ORANGUTANS

A DISSERTATION

APPROVED FOR THE DEPARTMENT OF ZOOLOGY

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ACKNOWLEDGMENTS

I wish to thank the many people who visited camp and directly assisted in the signing project: the biology students of the Universitas Nasional, Jakarta; the students of Gadjamata University, Yojakarta; Dr. Flora Katz; Ms. Diana Hossman; Ms. Miriam Huaco; and Ms. Carey Yeager. I am also appreciative of the assistance given by the staff of the Orangutan Research and Conservation Project (ORCP) including Mr. Usman Yahya, Mr. Rod Brindamour and Mr. Bohap bin Jalan. I am especially indebted to Dr. Birute Galdikas, Founder and Director of the ORCP. Without her trust, support, and friendship, this project would not have been possible. She helped in both data collection and in providing fruitful discussion during my stay in Tanjung Puting.

Thanks must be given to the many people in North America and Europe who graciously gave me support. I thank Dr. Roger Fouts, and my parents, Mr. Dwight Jenkins and Mrs. Lorraine Jenkins for the opportunity and encouragement to conduct overseas fieldwork. I am appreciative of Mr. Norman Lear's contribution of videotape equipment to the project. Mr. Dan Hough, Ms. Chris O'Sullivan, Dr. Al Schwartzkoff, and Dr. Larry Toothaker were extremely helpful in statistical and computer analysis. I thank them as well as the following individuals who aided me in the behavioral assessment element: Ms. Melanie Bond, Dr. Terry Maple, Ms. Kim Bard, Ms. Diane de Graffenreid, Mr. Douglas Donald, Ms. Lisa Stevens, Ms. Barbara King, Dr. Suzanne Chevalier-Skolnikoff. For

commenting on the manuscript, I thank Drs. Jane Lancaster, Charles Carpenter, H. James Grimshaw III, Roger Møllgren, Douglass Mock, and Bedford Vestal.

Funding for the signing project was provided through grants from the L.S.B. Leakey Foundation, National Geographic Society, Wilkie Brothers Foundation, Jane and Justin Dart Foundation, and the Van Tienhoven Foundation to Dr. Galdikas. Thanks must be given to Mr. and Mrs. Djura Postma for their most timely gifts to the ORCP. Sponsorship in Indonesia was provided by the Indonesian Institute of Sciences (LIPI), the Nature Protection and Wildlife Management Service (PPA), and the Universitas Nasional (UNAS). I must express my gratitude to Mr. Napitapulu (LIPI), Mr. Lukito and Mr. Siallagan (PPA), and Mrs. Nina Sulaiman (UNAS) for giving me the privilege of experiencing the magnificent wildlife of the tropical rain forest. I feel compelled to express my appreciation to those endearing red apes that made this dissertation possible. Finally, I appreciate the kindness given to me by the people of Indonesia which made my stay enjoyable.

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ABSTRACT

Following the methods of Gardner and Gardner [1969] and Fouts [1973], ten signs (American Sign Language) were trained to four juvenile orangutans. None of the subjects acquired all of the signs even after 2400 trials distributed over 15 months. However, all of the subjects acquired some of the signs. An analysis of variance of performance measures indicated that some subjects learned significantly faster than others and that some signs were easier to acquire than others. Two caged animals learned signs significantly faster than did two uncaged ones, though this was probably due to the exceptional scores of one individual. Three falsifiable hypotheses to account for the variance in sign performance were evaluated. Two hypotheses were supported: [1] Motor differences in the gestural aspects of the sign had a significant effect on sign performance and [2] selective attention to the sign's referent had a positive relationship to the performance of the sign. The hypothesis that pre-existing behavior in the species' natural behavioral repertoire would facilitate sign learning was not supported.

CHAPTER I

INTRODUCTION

The Psychobiological Potential of Sign Learning Behavior in Apes:

Ethology may have deemphasized the study of learning during the first half of this century, but it has never denied the role of learning in mediating behavior [Lorenz, 1935, 1937]. While the attention of early ethologists was on the evolutionary relationship of fixed action patterns, imprinting, and other forms of innate behaviors, comparative psychologists and learning theorists were focusing on classical conditioning, instrumental conditioning, habituation, and other learning phenomena. This difference in emphasis, however, has never been absolute, and in recent years behaviorists from both ethology and comparative psychology have come to appreciate the significant interdependence of both innate and learned components in behavior [Eibl-Eibesfeldt, 1975]. Today the line between the two disciplines is blurred as scientists from zoology, psychology, and anthropology explore behavior from evolutionary, ecological, and developmental perspectives.

In this tradition, the study of signing behavior in apes [Gardner & Gardner, 1969] provides the comparative and

developmental psychologist, physical anthropologist, ethologist and neurophysiologist with a methodology that has potential for enabling a comparative perspective of processes and behaviors that appear similar to certain human behaviors. Since great apes and humans are so closely related from a genetic and evolutionary perspective [King & Wilson, 1975], the possibility of homologous neurological processes and behaviors cannot be cursorily dismissed. The rather conservative nature of neuroanatomical evolution among the higher primates, in fact, suggests that certain behaviors and/or mediating neurological processes are likely to be homologous [Dingwall, 1975; Parker & Gibson, 1979].

Originally developed by comparative psychologists to explore the communicative potential between chimpanzee (Pan troglodytes) and human [Gardner & Gardner, 1969, 1971], signing studies have been expanded to other species [Patterson, 1978; Shapiro, 1982] and to noncommunicative contexts [Mellgren, et al., 1973]. One noncommunicative context that has received attention in all ape signing projects has been the acquisition of signs (i.e., learning signs to a criterion of performance). The development of a body of signs has been a prerequisite for examining the communicative potential of apes, for without a vocabulary there can be no expression of potentially communicative or linguistic behavior. Frequently, the vocabulary size of an ape is cited as a measure of its signing ability; however, the qualitative and quantitative features of an ape's sign vocabulary may be a function of both

the achievements of the ape and the training procedures employed [Shapiro, 1982].

An understanding of the psychological processes underlying the learned sign, like other learned behavior, is presently incomplete. It is unclear whether the learned sign is the product of a simple association between a gesture and a referent or of symbolic representation [Savage-Rumbaugh & Rumbaugh, 1978]. Piagetian analysis of signing behavior [Chevalier-Skolnikoff, 1981] and studies of symbol learning in chimpanzees [Savage-Rumbaugh & Rumbaugh, 1978] suggest that the level of cognitive mediation in ape signing may be limited by training protocol. Experimentation is necessary for determining the nature of the representation in the sign learning ape. However, experimental procedures enabling an ape to learn signs can be used to identify biological and ecological factors that not only influence the development of a sign vocabulary in one species but may influence the learning of analogous or homologous behavior in other species. This study was designed to evaluate several biological and ecological factors that might influence sign learning in juvenile orangutans (Pongo pygmaeus), a species whose signing abilities had received little attention.

"Language" Learning Experiments with Apes: A Historical Perspective:

Following scientific acceptance of Darwinian theory, several

attempts were made to verify the great ape's close relationship with humans in terms of mentality [Witmer, 1909; Furness, 1916; Kohler, 1927; Yerkes, 1929; Kohts, 1935]. Since one prominent view of speech is as a window to intelligence and mentality, training in vocal English was given to chimpanzees and an orangutan during the first half of the twentieth century. Witmer [1909] tested and observed a chimpanzee that was trained for stage shows. The juvenile male chimp was given a number of manual problems to solve (e.g., opening boxes and locks, using a hammer to drive nails into a board) which he did successfully. Witmer also observed that the chimp was able to vocalize the word "mama"; however, the articulation of the word was strained and sounded like a hoarse whisper. Witmer concluded that the ease with which the chimp learned to produce the letter "p" (in only a few minutes) suggested that the chimp could learn to articulate most of the elements of speech within six months. He also predicted that comparative experiments with home-reared apes would be conducted within a few years time for purposes of scientific investigation.

Furness [1916] reported that his efforts to teach a young orangutan vocal English were relatively unsuccessful. After extended training in a home-type environment, the orangutan was only able to vocalize two hoarsely emitted and strained words, "papa" and "cup."

Kohts [1935] raised and observed a young (1.5 to 4 years old)

male chimpanzee in her Moscow home. The notes she collected on the chimp's behavior were later compared with those from her own child twelve years later. She concluded that the mental capabilities of the chimpanzee were qualitatively different from that of the human child. However, the failure of the chimpanzee to acquire any vocal vocabulary was reportedly because she did not attempt to provide special language training.

During the 1930's, W.N. and L.A. Kellogg [1933] concurrently home-reared an infant son and an infant female chimpanzee. For nine months the Kelloggs observed both human and chimp vocal development, but unlike Koht's observational technique, the Kelloggs attempted to teach the word "pa-pa" to the chimp. Through manual manipulation of the lips, the chimp made occasional lip reactions. However, she failed to produce any modulated sound. Likewise, efforts to train words to the experimenter's own son was at the same period unsuccessful, although the child was making babbling and gurgling sounds.

The most extensive attempt to teach a chimpanzee vocal language was made by Keith and Catherine Hayes during the late 1940's. In conjunction with Yerkes Laboratories of Primate Biology in Florida, the Hayes obtained a female chimpanzee and home-reared her beginning only a few days after birth [Hayes, 1951]. Maintained within an environment closely resembling that of a human infant, the chimpanzee, Viki, was trained for six years. By employing the most sophisticated teaching techniques

of the time, the Hayes attempted to determine if Viki could be trained to develop a more extensive vocabulary of spoken words than the apes in the studies discussed above. The infant chimp was given as many environmentally enriched opportunities as possible. Despite the enriched environment and length of training, Viki was only able to produce the four words: "mama," "papa," "cup," and "up." Although they were produced in both appropriate and inappropriate contexts (e.g., "mama" was uttered to Mrs. Hayes but some items were not correctly identified), the vocal productions were apparently difficult for Viki. Facial and manual gesticulations frequently accompanied the production of a word. Additionally, the vocal productions were frequently inaudible or hoarsely whispered.

In a recent study, Laidler [1978] trained an infant male orangutan to produce vocalizations in association with object and action referents. After nine months of training using operant conditioning methods modified after those successfully employed with autistic children, the young animal could only produce four sounds, "kub," "puh," "fuh," and "thuh," though they were used appropriately in a variety of contexts. For example, "kub" was vocalized as a response to drinks in containers while "puh" was produced as a request for contact and comfort.

In conclusion, the various attempts to teach anthropoid apes vocal language have proven unsuccessful. It has been argued that the results of these experiments confirmed the long held

philosophical belief that humans are unique by virtue of their unique linguistic abilities [Chomsky, 1968]. This, of course, assumes that vocal speech is equivalent to linguistic competence. It can be argued similarly that the negative results of the experiments do not mean the ape have no competence for language per se, but only that vocal language or speech is apparently not within the animals' neurobiological capacity. Certainly, the possibility of establishing other forms of interspecific communication cannot rule out a linguistic interpretation a priori.

Prior to the 1960's, little if any factual information was known about great ape natural behavior or functional neurology. Fieldwork done on the chimpanzee since the pioneering work of van Lawick-Goodall [1968] has confirmed that chimpanzee vocalizations occur in emotive contexts with environmental stimuli seemingly eliciting the wide range of chimpanzee sounds. Neuroanatomical studies with other primates suggest that primate vocalizations are mediated primarily by noncortical regions of the limbic system [Dingwall, 1975]. Additionally, studies of comparative laryngeal anatomy between ape and humans have recently confirmed that articulated speech is an unsuitable medium of communication for apes [Liebermann, 1968]. Finally, there is a growing body of evidence in many learning studies suggesting that animals are biologically constrained to the type of stimuli and responses that can be conditionally paired [Bolles, 1970; Breland &

Breland, 1961]. Gardner & Gardner [1971] proposed that certain portions of an animal's behavioral repertoire may not only be difficult to modify but completely resistant to modification. Great ape vocalizations may be such behaviors.

It was not until 1966, when Gardner & Gardner [1969,1971] showed that Washoe, an infant female chimpanzee, could be taught to use American Sign Language (Ameslan) that the visual-gestural and not the auditory-vocal mode was found to function as an effective medium of two-way propositional communication. Used by the deaf in North America, Ameslan gestures correspond to words and phrases [Stokoe, et al., 1965]. The Gardners suspected that a chimpanzee could utilize this medium as gesturing had been observed within chimpanzee communities in the wild [van Lawick-Goodall, 1968]. In fact, while watching a film of Viki attempting to speak, they found they could better understand the intent of the gesticulating chimp when the sound track was eliminated.

Washoe was judged to be between 8 and 14 months old when training began. She was housed in a trailer in the continual presence of human care-givers who exclusively used Ameslan to communicate among themselves as well as with Washoe. Ameslan signs became a part of Washoe's vocabulary in response to (1) subject-directed activities and (2) trainer-directed activities.

(1) Subject-directed activities: Manual babbling, analogous

to vocal babbling in human infants, was observed infrequently during the early part of the project. The frequency of manual babbling increased until the end of the second year of the project, after which it apparently was replaced by increased signing activity. Observational learning of signs by Washoe represented a second type of subject-directed activity within the sign learning context. Such learning was inferred inasmuch as Washoe began generating signs that were not intentionally taught (e.g., "sweet" and "toothbrush"). Because Washoe was totally immersed in a social environment where signing between humans was commonplace, opportunities for sign acquisition by observational learning were available. Furthermore, because wild young chimpanzees are known to learn many manual skills (e.g., termite fishing) by observing older and more experienced chimpanzees [van Lawick-Goodall, 1968; Parker and Gibson, 1979], chimpanzees may be predisposed to learn coordinated hand movements by watching care-takers. Observational learning of signs became increasingly effective as Washoe matured.

(2) Trainer-directed activity: A number of techniques were employed actively to train Washoe. Shaping was one method that involved rewarding Washoe when she made an approximation of a sign. Over time several signs (e.g., "open") were acquired as successive approximations were rewarded. Another successful technique was guidance or molding, in which Washoe's hands were physically manipulated into the proper configuration by the

trainer. Simultaneously, Washoe was presented with a referent (e.g., an object or activity) so as to demonstrate the association between the sign and the sign's referent. Fouts [1972] discovered that molding was the most effective method of teaching signs to Washoe and later used molding exclusively to train signs to other chimpanzees [Fouts, 1973]. The last trainer-directed method of sign learning used by the Gardners was imitation. By providing the subject with an active model of the sign within a social setting, the trainer increases the probability of the subject learning the sign through observational learning. As Washoe matured, imitation became an increasingly more effective method of sign training.

By the time Project Washoe terminated in 1970, the chimpanzee had learned to produce 130 signs in the proper context and in combinations that seemed appropriate to the social context. Gardner & Gardner [1971, 1973, 1975], Brown [1973], Bronowski & Bellugi [1975] and others have analyzed the manual utterances of Washoe and other signing chimpanzees in relationship to children's early vocal utterances. Many of the utterances seemed analogous to the early verbal sentences of children and even early linguistic competence was inferred from the signing behavior [Brown, 1973].

Several ape "language" research projects were developed in the 1970s which employed artificial visual systems [Premack, 1971; Shapiro, 1975; Rumbaugh, 1977] or gestural systems [Fouts,

1973, Patterson, 1978; Terrace, 1979; Miles, 1983]. The artificial visual systems permitted more complete and systematic data collection than permitted in signing projects. Premack [1971] taught a chimpanzee a plastic chip system in which variously colored and shaped plastic pieces could be placed on a magnetic board by either experimenter or chimpanzee as a medium of communication. Premack used the system not only to investigate "language" abilities of the chimpanzee but to evaluate the basic components of chimpanzee intelligence. Following Premack, Shapiro [1975] examined a juvenile orangutan's ability to produce and comprehend sequences of colored plastic pieces using a conditional discrimination technique. Rumbaugh [1977] taught a chimpanzee to operate a computer-based lexigram system as a means of examining chimpanzee communicative and linguistic skills. By pressing keys on a panel array, a sequence of lexigrams was projected on a screen and the computer evaluated and recorded the production. If the sequence was correct, according to the preprogrammed set of rules that defined the grammar of the system, the computer activated machines that dispensed foods or drinks or provided activities (e.g., open a window for outside viewing). The chimpanzees in both Premack's [1971] and Rumbaugh's [1977] studies and the orangutan of Shapiro [1975] demonstrated both the abilities to comprehend and to produce messages of various lengths within the constraints of the systems.

Following the success of the Gardners [1969, 1971], Fouts [1974] taught other chimpanzees Ameslan and encouraged chimp-to-chimp signing and teaching of signs. Patterson [1978] has trained two gorillas (Gorilla gorilla) to use Ameslan. Patterson [1978] has claimed that one individual, Koko, acquired a working vocabulary of several hundred signs and used the signs not only to request items and activities of interest but also to rhyme, joke and insult humans. Some of Patterson's claims have proven to be the most controversial in all of ape-signing studies [Seidenberg & Pettito, 1979]. Terrace [1979] and his students trained a male chimpanzee to communicate with Ameslan. In order to investigate the relationship between the signs produced by the trainers and the chimpanzee, Terrace [1979] employed videotape extensively for data collection and analysis. Shapiro [1982] trained a juvenile female orangutan to acquire 37 signs over 19 months of training and concluded that sign acquisition rates were similar among all the pongids. Miles [1983] trained a young male orangutan to produce signs in a home-reared setting similar to that of the young Washoe. Most of these projects have been discussed in great detail elsewhere, including the controversy of the interpretations of ape "linguistic" behavior [e.g., Seidenberg & Pettito, 1979; Ristau & Robbins, 1982; de Luce & Wilder, 1983] and will not be covered here.

Background for Present Study:

Fouts [1973] reported that the acquisition of signs (i.e.,

performance to an arbitrary criterion) by four young chimpanzees indicated a general chimpanzee ability to learn gestural sign production (from American Sign Language or Ameslan). Fouts's study not only showed that the first chimpanzee given sign training, Washoe [Gardner & Gardner, 1969, 1971], was not unique in her signing skills, but that there were significant differences in the speed with which particular subjects acquired signs and with which particular signs were acquired. This was achieved by using consistent training procedures between different chimpanzees and by analyzing the performance data with an analysis of variance (ANOVA). Although various hypotheses were presented as explanations of the observed variances, none were tested quantitatively.

The purpose of the present study is to: 1) elicit the production of signing responses by four juvenile orangutans, 2) evaluate the effect of variables that could account for the variance in sign performance by the orangutans and 3) test several competing explanatory hypotheses concerning variables which might affect the rate of sign acquisition. Also, some comparisons between the signing abilities of chimpanzee and orangutan are made. The collection and evaluation of such comparative data permits the necessary perspective in the interpretation of the signing vocabulary of great apes.

CHAPTER II

METHODS

Project Site:

These experiments were conducted within the confines of the camp facilities at the Orangutan Research and Conservation Project (ORCP) located within the Tanjung Puting Nature Reserve, Kalimantan Tengah (Indonesian Borneo; 2°48' S, 111° 57' E). The camp is surrounded by abandoned dry rice fields, now covered by elephant grass (Imperata cylindrica) and bands of lowland Dipterocarp forest, incorporating limited areas of tropical heath forest, alternating with shallow peat swamp forests that deepen and interdigitate along the rivers.

The ORCP has been in operation since 1971, during which time project personnel have supervised the reintroduction of formerly captive (rehabilitant) orangutans into the forested areas surrounding camp. Because forest rehabilitation is a slow process, the ORCP had an available group of young orangutans in camp that served as subjects for the signing study.

Subjects:

Four juvenile (3-4.5 years of age) orangutans of unknown origin were selected from a group of rehabilitant orangutans maintained at the ORCP. All four orangutans were quarantined and

appeared healthy prior to training. These four were given sign training based upon three variables: sex, holding condition, and hand preference (Table I). Due to the small number of subjects and number of variables chosen, the experimental design was necessarily incomplete (in that eight individuals would have been needed to represent all combinations of variables). The two "uncaged" subjects (one male, Pola, and one female, Princess) were raised in a human home prior to and during the study (home-reared). During the study the uncaged subjects were also permitted to move freely in the forest surrounding the camp area of the ORCP (free-ranging). The uncaged subjects received additional sign training prior to and during the present study. The two other subjects (one male, Rantai and one female, Hampas) were caged between training sessions until the termination of the study. The caged subjects were given sign training only during the present study.

Prior to training, eight potential subjects were given two different types of manual tasks to determine any degree of hand preference. In one task (peanut selection) the subjects were given the opportunity of using either hand to grasp a peanut that was placed approximately 20 cm from the subject and equidistant from both hands. In a second task (peanut extraction) the subjects were given twenty minutes to extract crushed and packed peanuts from holes in a wooden block. Measures for the peanut selection test were based on 24 trials (six trials per test given

TABLE I. EXPERIMENTAL DESIGN FOR SIGN TRAINING PROGRAM

SUBJECT	PRINCESS	POLA	HAMPAS	RANTAI
SEX	F	M	F	M
CONDITION	U	U	C	C
HAND PREF	LH	RH	RH	LH

SIGN	SIGN TRAINED TO RIGHT OR LEFT HAND			
BIRD	L	L	R	R
BUG	R	R	L	L
GLASSES	R	R	L	L
GRASS	R	R	L	L
HAIR	L	L	R	R
HAT	R	R	L	L
MIRROR	L	L	R	R
NUT	L	L	R	R
SWEET	R	R	L	L
WATCH	L	L	R	R

M, F= MALE, FEMALE
U= UNCAGED (HOME-REARED/FREE-RANGING)
C= CAGED
LH= LEFT HAND PREFERENCE
RH= RIGHT HAND PREFERENCE
L= LEFT HAND TRAINED
R= RIGHT HAND TRAINED

on four occasions) of left or right handed choices. Measures for the peanut extraction test were based on the number of right or left handed finger probes used by a subject to remove the peanuts during two sessions.

Four orangutans that showed a significant ($p < 0.05$, Chi-Square test) preference to use a particular hand for a given task in at least one of the two tests were chosen as experimental subjects. Most orangutans showed hand preference concordance for both tasks. In situations where there was hand preference ambiguity, the results from the peanut extraction test were chosen as the test requiring manipulative skills more similar to those used in signing.

Materials:

Ten signs (standard American Sign Language or Ameslan) were trained to the subjects (Table II). Ameslan signs are composed of subunits called cheremes [Stokoe, et al., 1965]. Minimally, three cheremes define a given sign: hand configuration, hand movement, and location of active hand. Three of the test signs ("hat," "glasses," and "watch") were the same as those taught to Fouts's four chimpanzees [1973]. Other signs were selected because their referents were natural and/or locally available items. All of the signs had small physical items as their referents (objects representing the sign) and all ten signs required the use of only one hand for their production.

TABLE II. SIGNS TRAINED TO FOUR ORANGUTAN INCLUDING
REFERENTS AND MOTOR DESCRIPTIONS OF SIGNS

SIGN	REFERENT(S)	MOTOR DESCRIPTION
1. BIRD	RUBBER BIRD	THUMB AND INDEX FINGER OF COMPACT HAND GRABS AND PULLS PURSED LIPS REPEATEDLY (2-3 TIMES)
2. BUG	PLASTIC INSECT	THUMB OF CURVED HAND CONTACTS NOSE
3. GLASSES	CHILDREN'S PLAY GLASSES	INDEX FINGER EXTENDS FROM COMPACT HAND AND TOUCHES SIDE OF EYE
4. GRASS	A BLADE OF GRASS	INDEX FINGER EXTENDS FROM COMPACT HAND AND SHAKES IN FRONT OF BODY (2-3 TIMES)
5. HAIR	HUMAN HAIR	THUMB AND INDEX FINGER OF HAND GRABS AND PULLS OWN HAIR REPEATEDLY (2-3 TIMES)
6. HAT	CHILDREN'S HAT	PALM OF SLIGHTLY CURVED HAND CONTACTS TOP OF HEAD
7. MIRROR	SMALL HAND MIRROR	FLAT HAND SHAKES IN FRONT OF BODY REPEATEDLY (2-3 TIMES)

TABLE II [Cont.]

SIGNS TRAINED TO FOUR ORANGUTAN
INCLUDING REFERENTS AND SIGN DESCRIPTIONS

SIGN	REFERENT(S)	MOTOR DESCRIPTION
8. NUT	PEANUT	THUMBNAIL OF COMPACT HAND FLICKS AGAINST UPPER INCISORS REPEATEDLY (2-3 TIMES)
9. SWEET	SUGAR CANDY	INDEX FINGER EXTENDS FROM COMPACT HAND AND STROKES LIPS SEVERAL TIMES
10. WATCH	TRAINER'S WATCH	INDEX FINGER EXTENDS FROM COMPACT HAND AND TOUCHES EAR

Assignment of Signs to Subjects:

Table I illustrates the experimental design for the sign training program, including the assignment of the various signs to the subject's hands. There was an a priori reason to suspect that difficulty in executing the gestural configuration of the sign might negatively influence sign performance. Based upon the signing behavior of a chimpanzee [Fouts, 1972], some signs had gestural configurations that were predicted to be motorically difficult for orangutans to produce. These signs were assigned to both left and right hand of a subject to balance any possible effect due to hand assignment. For example, because the signs "grass" and "mirror" are formed by repeatedly shaking the active hand mid-air (the most difficult gestural configuration for chimpanzees), they were assigned to opposite hands. There was a similar a priori reason to suspect that food-related signs might be more motivating for orangutans than nonfood-related signs. Consequently, the signs "nut" and "sweet" were assigned to opposite hands to control for hand assignment effect. Other possible similarities in gestures or referents prompted a balanced hand assignment for sign training: cheremic location ("hat" vs. "hair"), animal ("bird" vs. "bug"), and human implement ("watch" vs. "glasses"). If a given sign were assigned to one hand of the caged subjects, it was assigned to the opposite hand of the uncaged subjects.

Training Procedures:

During a training session, pairs of subjects (either both caged or both uncaged) received simultaneous training from two trainers (usually an assistant and me). Each subject received standard training using the molding or guidance technique [Fouts, 1972, 1973], whereby the subject's hand(s) was manually positioned into the sign's proper configuration by the trainer and moved through the sign's specific range of motion. But instead of training each sign continuously to a criterion (as done by Fouts [1973]), the orangutan subjects received only ten training trials for a given sign during the course of each session. By distributing the training (fewer trials over longer periods of time), subject interest (easily lost with repeated presentations) was maintained. The trial was chosen as the best unit for measuring training effort and subject performance throughout training. Each session's training trials (10 signs X 10 trials/sign) were presented during two subsessions. During the first subsession, the subject received five consecutive training trials for each of the ten signs (e.g., five trials for "bird" were given, then five trials for "bug" were given, etc.). When all the signs had been covered, the two trainers exchanged subjects and data books. The second subsession was then executed like the first. The presentation order of the signs was varied (pseudorandomized) after several sessions to minimize order effects.

The following illustrates the procedure for a typical training trial: (1) a physical referent for the sign was presented to the subject (e.g., a hat was held up for the subject to see). (2) The trainer then asked in Ameslan and vocal Indonesian, "what (is) this?." (3) The trainer waited approximately five seconds for a response. (4) The trainer provided a small food reward with praise or molding, contingent upon the response. If the subject signed correctly (i.e., referent properly identified and in good form), it received the reward. If the subject failed to sign, signed incorrectly, or signed poorly (i.e., producing two of the three gestural components of the sign), the subject's hand was molded. Molding was always followed by a small food reward. The response (including errors) and molding effort were recorded after each trial.

When a subject's correct performance for a sign reached at least 90% over 15 consecutive sessions (10 trials each), the sign was said to be acquired or formally learned. The high acquisition criterion proved to be a reasonable choice for formally assessing subject performance. The number of acquired signs only increased by one when the criterion was dropped to 75%. Immediately following acquisition, the sign was tested for two sessions (20 unreinforced trials) to evaluate performance in the absence of reward.

Training sessions lasted approximately one hour. No more

than one session was given daily to individual subjects, and on some days no training was given. Training continued for over 240 sessions and was terminated after 14 months.

Statistical Treatment of Data:

Statistical tests were performed to evaluate subject- and sign-related effects. It was possible to perform a priori and a posteriori tests to determine any significant effects of sex, holding condition, hand (e.g., handedness, hand assignment), and sign-related effects by using a variety of statistical procedures on the acquisition data. Standard ANOVA and ANOVA with repeated-measures were used to test for significant differences between and among groups. A variety of t-tests (e.g., pair-wise, Wilcoxon two-sample) and correlations were used to evaluate differences between means and relationships between variables.

"Slope Performance Measure" as a Means of Performance Assessment:

Because so few signs were acquired to criterion, the common learning measure (accumulated trials to acquisition) could not be used for ANOVA. Three subject-sign learning curves (Figure 1a-c) illustrate how signs were correctly performed over the course of training. The first curve (1a, Rantai's performance of "bat") depicts typical acquisition. Although not fully acquired, some signs (e.g., Fig. 1b) were definitely performed. Finally, a few signs were never correctly performed during training (e.g.,

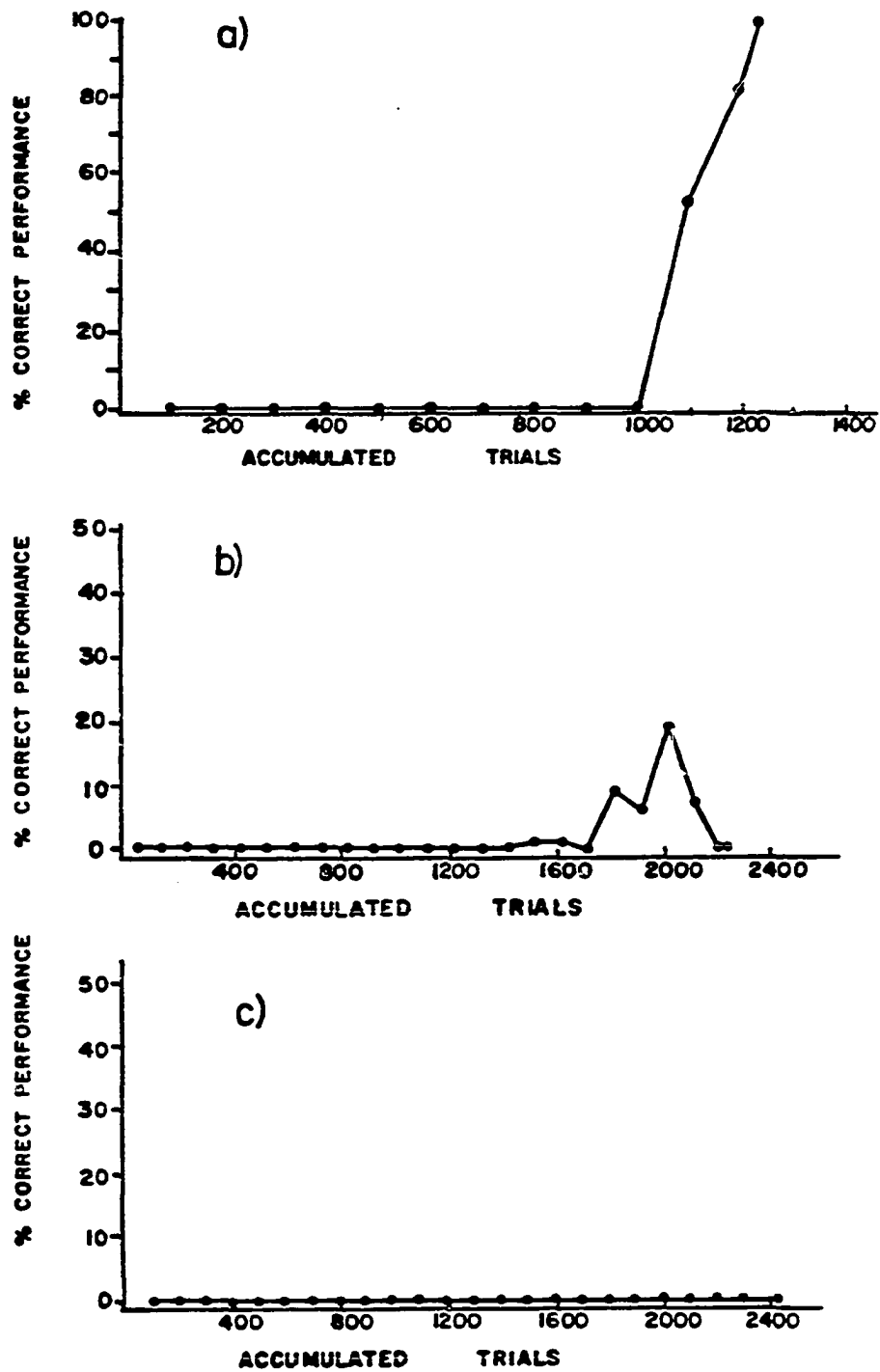


Figure 1. Representative performance curves.
 a) Rantai's performance of "hat."
 b) Princess's performance of "bug."
 c) Pola's performance of "bird."

Figure 1c). In order to analyze data on partially learned signs with the ANOVA, the data were transformed to yield a measure that could represent both acquired (to criterion) and nonacquired signing performances. The transformed value ("slope performance measure" or SPM) represents the average change in performance (% correct) for an average training trial (i.e., "slope"=output/input). For those signs that were acquired, SPM was calculated by dividing the criterion performance value (90% or slightly above) by the number of accumulated trials required to reach or just exceed 90% criterion (see Appendix A). The actual learning curve for an acquired sign is typically a negatively accelerating, monotonically increasing curve with an exponential slope immediately prior to asymptotic performance (e.g., Fig 1a). Thus SPM does not refer to the literal slope of a learning curve, but an overall slope from start to criterion. For those signs that were not acquired, SPM was calculated by dividing the maximum performance value (in percent correct) by the number of accumulated trials to that point. This yielded values that typically were less than SPMs for acquired signs.

ANOVA on SPMs:

The 40 SPMs were placed in a 4 X 10 design (subjects X signs) and subjected to a standard ANOVA (Statistical Analysis System, SAS Institute, Cary, N.C). Subjects and signs were assumed to be independent of each other and randomly drawn from a large population. Although not normally required, the standard ANOVA

produces an error term that permits the testing of a subject effect. In experiments with large sample sizes, subject variability is assumed to exist and attempts are made to minimize its effect on the dependent variable of interest. However, in designs with small numbers of subjects, the extent of subject variability may be of interest, and the error term in the ANOVA is sufficiently conservative to insure a real subject effect if the F-test is significant.

CHAPTER III

RESULTS

Acquisition as a Means of Performance Assessment:

Many signs were never acquired, even after 2400 trials. Indeed, of the 40 subject-signs (4 subjects X 10 signs), only 17 were acquired at the 90% criterion level (Table III), an average of only 4.25 signs per subject. However, test performance of acquired signs remained high (above 80%) immediately following training. Despite the low number of fully acquired signs, the average subject correctly performed multiple signs (mean= 8.25 signs) during at least one training session.

Table IV contains the "slope performance measure" or SPM values for the subjects and their signs. The results of the ANOVA on SPM data are presented in Table V. There were both significant subject and sign effects.

Subject-Related Effects:

The only subject-related factor that had a significant effect was holding condition. Overall, caged subjects out-performed uncaged subjects ($p < 0.0206$; ANOVA with repeated-measures). There was no significant effect due to the subjects' sex ($p > 0.5209$), and within subjects the group of signs trained to one hand were not performed differently than the group of signs trained to the

TABLE III. SIGNS ACQUIRED BY FOUR ORANGUTANS
AT 90% LEVEL OF CORRECT RESPONSES

SIGN	PRINCESS (F)	POLA (M)	HAMPAS (F)	RANTAI (M)	SUM
BIRD	0	0	0	0	0
BUG	0	1	1	0	2
GLASSES	0	0	0	1	1
GRASS	0	0	0	0	0
HAT	1	1	1	1	4
MIRROR	0	0	0	0	0
NUT	1	1	1	1	4
HAIR	0	0	0	1	1
SWEET	1	0	1	1	3
WATCH	0	1	0	1	2
SUM	3	4	4	6	17

F= Female,
M= Male

1= Sign acquired at 90% level,
0= Sign not acquired at 90% level

TABLE IV. SLOPE PERFORMANCE MEASURES
FOR FOUR ORANGUTANS

SIGN	PRINCESS (F)	POLA (M)	HAMPAS (F)	RANTAI (M)	MEAN
BIRD	.00252	.00000	.00000	.03424	.0092
BUG	.00941	.06557*	.04557*	.08286	.0508
GLASSES	.00050	.00096	.00435	.05529*	.0153
GRASS	.00167	.00000	.00091	.00000	.0006
HAT	.07547*	.06823*	.09434*	.08032*	.0795
MIRROR	.00047	.00299	.00137	.00000	.0012
NUT	.10101*	.10638*	.18056*	.12800*	.1290
HAIR	.01965	.00000	.00000	.04724*	.0167
SWEET	.05493*	.03172	.06019*	.05305*	.0500
WATCH	.00306	.06116*	.02727	.05765*	.0373
MEAN	.0269	.0415	.0337	.0539	.0390

(F)= Female, (M)= Male, *= Signs acquired to 90% criterion.

TABLE V. ANALYSIS OF VARIANCE FOR THE DIFFERENCES
AMONG SIGNS ACROSS ORANGUTANS

SOURCE	MEAN SQUARE	DEGREES OF FREEDOM	F RATIO	P
AMONG ORANGUTANS	0.001341	3	3.45	0.0305
WITHIN ORANGUTANS				
SIGNS	0.006601	9	16.97	0.0001
RESIDUAL	0.000389	27		
TOTAL	0.001896	39		

other hand ($p > 0.9513$). Because caged and uncaged subjects learned the same sign on opposite hands, the nonsignificant results of the ANOVA eliminated any possibility of an interaction effect between handedness and the holding condition variable. There was also no significant hand preference effect ($p > 0.8605$). Individuals showing a right hand preference in manual tasks performed their signs no better than individuals that preferred to use their left hand. Finally, signs trained to a subject's preferred hand were performed no better than signs trained to their opposite hand ($p > 0.9594$).

Sign-Related Effects:

The strongest statistical effect revealed by ANOVA (Table V) was the differences in the rate at which the various signs were acquired ($p < 0.0001$). When the SPM values were subjected to the more appropriate repeated-measures ANOVA (random subject), the significant sign effect was maintained ($p < 0.0001$). Table VI lists the results of all possible pair-wise t-tests and indicates the significantly different SPM values between signs.

TABLE VI. PAIRED COMPARISONS OF PROTECTED T-TESTS OF
SLOPE PERFORMANCE MEASURES OF THE DIFFERENT
SIGNS TRAINED TO FOUR ORANGUTANS

SIGNS										
BI	BU	GL	GR	HA	MI	NU	HR	SW	WA	
/	*	NS	NS	***	NS	**	NS	**	NS	BI
	(BU)			(HA)		(NU)		(SW)		
	/	NS	NS	NS	NS	*	NS	NS	NS	BU
						(NU)				
		/	NS	*	NS	**	NS	NS	NS	GL
				(HA)		(NU)				
			/	***	NS	**	NS	**	NS	GR
				(HA)		(NU)		(SW)		S
				/	***	NS	**	**	NS	HA
					(HA)		(HA)	(HA)		I
					/	**	NS	**	NS	MI
						(NU)		(SW)		
						/	**	*	**	NU
							(NU)	(NU)	(NU)	
							/	NS	NS	HR
								/	NS	SW
									/	WA

*- P<.05; **-P<.01; ***-P<.001; NS- NO SIGNIFICANT
()-BETTER PERFORMED SIGN DIFFERENCE

BI-BIRD; BU-BUG; GL-GLASSES; GR-GRASS; HA-HAT;
MI-MIRROR; NU-NUT; HR-HAIR; SW-SWEET; WA-WATCH

CHAPTER IV

DISCUSSION

The data presented demonstrate that orangutans, the least social of the apes, can learn to produce gestural signs when given extensive training. Statistical evaluation of the performance data indicates that orangutan sign learning ability seems to vary among individuals and among the signs they are given to learn.

With chimpanzees, Fouts [1973] also found these types of subject and sign effects, the former of which he attributed to differences in individual attentiveness, learning ability, and/or behavior during training. Some chimpanzee subjects responded more to food rewards; others more to threats. There appeared to be similar behavioral variations among the four orangutans. Hampas, the caged female, rarely cooperated with the trainers. She was continually hyperactive throughout the sessions and did not respond well to handling. Pola, the uncaged male, was relatively attentive and cooperative with food rewards present, although, he had to be frequently captured for the training sessions. Princess, the predominantly home-reared uncaged female, was rarely attentive during the sessions while Rantai, the caged male, appeared most attentive and cooperative during the formal training session. The significant subject and holding

condition effects were probably the result of the caged male's overall superior performance relative to the uncaged male and female (Table VII). Thus, individual differences in behavior and attentiveness to the training situation, as noted in chimpanzees [Fouts, 1973], probably influence overall signing performance by orangutans.

Fouts [1973] also found a highly significant sign effect with chimpanzees. As with the orangutans, certain signs appeared to be more easily learned by chimpanzees than others. The signs "watch," "drink," and "shoe" were the first three signs acquired by the chimpanzees whereas "nut," "hat," and "sweet" were the signs learned most rapidly by the orangutans. Although differences in training methods make comparisons between Fouts' and the present study only tentative, the three signs that were common in both studies ("watch," "glasses," and "hat") were acquired in differing orders and suggests the possibility of species-specific preferences in sign learning.

A Posteriori Hypothesis Testing to Evaluate Sign-Related Effects:

Because sign-related effects were statistically strongest, the remainder of this paper evaluates three possible explanations for differences in the acquisition of the trained signs: (1) the Motor Difference hypothesis, (2) the Pre-existing Behavior

TABLE VII. PAIRED COMPARISON T-TESTS OF
SUBJECT SPM VALUES ILLUSTRATING DIFFERENCES
BETWEEN SUBJECTS IN SIGNING PERFORMANCE

PRINCESS	POLA	SUBJECTS HAMPAS	RANTAI	
-	.4624, (.77)	.1297, (1.67)	.0118, (3.15)	PRINCESS
	-	.4299, (.83)	.0116, (3.16)	POLA
		-	.2645, (1.19)	HAMPAS
			-	RANTAI

Values in matrix: $P < |T|$, (T score)

hypothesis, and (3) the Selective Attention hypothesis.

(1) The Motor Difference Hypothesis

Fouts [1972] suggested that manual requirements for signs may influence the relative speeds with which those signs can be acquired. He found that signs whose active hand touched a part of the body ("touch" signs) were acquired more rapidly than signs whose active hand did not touch the body ("nontouch" signs). Gestural requirements for "nontouch" signs appeared to make sign performance difficult for a young chimpanzee. Patterson [1978] reported the same phenomenon for a young gorilla. To test the hypothesis that motor factors can influence sign performance in orangutans, SPM values for the two "nontouch" signs ("mirror" and "grass") were combined and compared to the combined SPM values for "touch signs" in a Wilcoxon two-sample t-test. Performances for "touch" signs were significantly superior ($p < 0.003$) to that of "nontouch" signs, thereby supporting this effect as a general motor phenomenon in sign learning pongids.

The "nontouch" signs' dual requirements of hand location (nontouch) and action seemed to make sign performance difficult for the orangutans. Performance curves for poor signing (two of the three cheremes performed correctly) revealed that the orangutans could identify the referents (as their performance curves for poor responses mirrored the performance curves for acquired signs) although they could not correctly perform the

complete sign (Figure 2). Those orangutans that finally performed the "nontouch" signs learned to execute the proper hand configuration and hand position prior to integrating the proper hand action. Had the sign's motor description been changed to require the subject only to present the configured hand in front of the body, the "nontouch" signs would have been acquired by all the subjects prior to the acquisition of some "touch" signs.

Repeated action (as seen in the "nontouch" signs) by itself, however, was not a motor factor that influenced sign performance. When SPM values for the "touch" signs with repeated actions following contact ("sweet," "nut," "bird," and "hair") were pooled and compared to the pooled SPM values of nonrepeating "touch" signs ("glasses," "watch," "hat," and "bug"), there was no significant difference ($p < 0.5883$, Wilcoxon two-sample t-test). Perhaps the combination of a "nontouch" hand location and repeated hand actions made the "nontouch" signs harder for the orangutans. The influence of combinations of various motor factors on sign acquisition suggests that the relative ability to perform more integrated manual behaviors might be a significant factor in signing performance. This ability has been shown to be affected by neurological maturation and experience [Chevalier-Skolnikoff, 1976].

(2) The Pre-existing Behavior Hypothesis

Fouts [1973] proposed that certain signs were acquired more

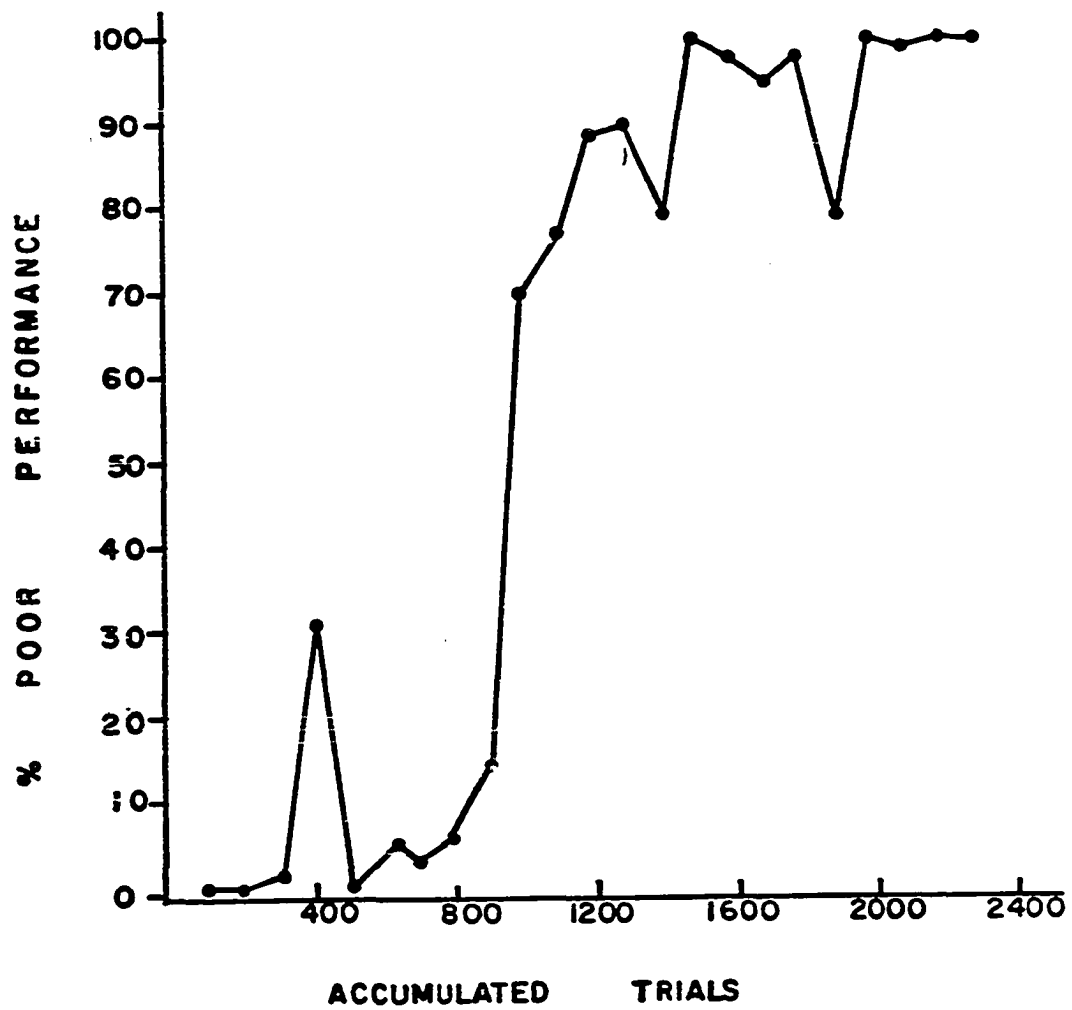


Figure 2. Learning curve for Hampas's poor performance (two of three cheremes present) of the sign "grass"

rapidly than others because the signs were "similar to pre-experimental behaviors in the chimpanzee's repertoire" [Fouts, 1973]. This explanation suggests a behavioral reason as to why certain gestures were more difficult to perform than others (i.e., the motor difference hypothesis). To illustrate his pre-existing behavior hypothesis, he referred to the sign "drink" (overall, the second most rapidly learned sign). The sign is formed by touching the thumb of the closed hand to the mouth, and since some chimpanzees suck their thumbs (the pre-existing behavior), Fouts argued that the sign might be rapidly acquired for this reason. Conversely, to illustrate how the performance of a slowly acquired sign ("look"- Fouts's term for glasses) was consistent with this hypothesis, Fouts suggested that pointing the index finger near the eye (the motor pattern for the sign) might be aversive and therefore less likely to be acquired as a sign. The use of such examples to strengthen a hypothesis can be criticized as post hoc and selective in choosing the motor pattern to fit the signing data. Had "look" been rapidly acquired, one could argue that this would be consistent with the pre-existing behavior hypothesis as some chimpanzees groom near their eyes with their extended index finger.

Similar explanations can be devised from the orangutan data to illustrate how their learning rates are consistent with the pre-existing behavior hypothesis. For example, the sign "hat" is

formed by touching the palm of the flat or slightly curved hand to the top of the head. This gesture is identical to a natural behavior performed by wild, rehabilitant, and captive orangutans, and in the post hoc fashion described above, could be constructed to account for the rapid learning rate for the sign "hat." However, rather than presenting such examples of orangutan behavior that match the signing data, the pre-existing behavior hypothesis was tested in this study by measuring the relationship between a sign's performance measure (SPM) and the extent to which its gestural component pre-exists in orangutan behavior. This was accomplished by statistically comparing the averaged SPM values for each sign with the relative frequency that their motor pattern descriptions have been observed by other orangutan behaviorists (see acknowledgement section). These behaviorists were asked to rate (based on observational experience) the relative frequency they had observed captive, rehabilitant, or wild orangutans perform each of ten motor patterns. The patterns were described in terms that defined each of the ten signs (e.g., the thumb of the curved hand touches the nose); however, no one was told they were descriptions of signs (and anyone suspecting they were descriptions of signs could not have been aware of the SPM values).

Data from the respondents (n=8) were averaged to minimize individual observer biases. These data were then tested against the averaged SPM values. No significant relationship was found

($r=0.0902$, $p>0.804$). Some signs with gestures observed in the repertoire of the species (e.g., "mirror" and "bird") were produced more slowly than other signs (e.g., "sweet" and "nut") whose motor components were observed to be infrequent in or absent from the natural repertoire. Although the pre-existing behavior hypothesis makes intuitive sense and seems to account for the ease and difficulty in performing certain signs, given the method used to define pre-existing behavior, the hypothesis was definitely not supported by the test.

(3) The Selective Attention Hypothesis

During training, I observed that subjects reacted differently to the various referents of the signs. Fouts [1973] mentioned similar differences in attentiveness among chimpanzee subjects. Selective attention towards stimuli has been proposed within theoretical models to account for differences in learning rates [Mackintosh, 1975]. Accordingly, the speed with which a sign is acquired depends on the degree to which the subject perceptually (visually) attends to the sign and its referent (all other things being equal). Theoretically, increased interest in a stimulus item decreases the probability that extraneous factors will interfere with the development of an association between the stimulus item and a particular response. With selective attention toward particular sign-referent combination, one would expect those signs to be learned significantly faster than signs whose referents were less well attended during training.

Conceivably, some of the referents used in sign training were of more interest than others; however, no independent measure of referent interest was made prior to original sign training.

Trainers noticed that the orangutan subjects were more attentive during the training of "food" signs than "nonfood" signs. Specifically, subject eye contact towards the sign's referent appeared to be greater for "food" than "nonfood" referents. This informal suggestion of selective attention within the learning situation gains support from the behavioral ecology of the orangutan. Wild orangutans must spend most of their active time in pursuit of nourishment, apparently because of the scattered spatiotemporal distribution of acceptable foods within the tropical rain forests of Borneo and Sumatra [Galdikas, 1979]. Once habituated to human observers, wild orangutans seemingly ignore the humans and attend to stimuli relevant to food acquisition (e.g., finding the easiest route to the next fruiting tree, looking for the next fruit in the tree).

If a bias of attending towards food or food related items is accepted as plausible for the orangutan, the selective attention hypothesis might predict that "food" signs would be learned faster than "nonfood" signs. This prediction was tested by pooling the SPM values for two "food" signs ("sweet" and "nut") and comparing them statistically to the pooled SPM values for six "nonfood" signs. Only "touch" signs were used in both sets, thereby eliminating the "nontouch" sign interaction effect that

might bias this test. As predicted, the signing performance for "food" signs (\bar{X} = 0.09, SD = 0.053) was significantly superior to the "nonfood, touch" signs (\bar{X} = 0.03, SD = 0.033, $p < 0.016$, Wilcoxon two-sample t-test). Because orangutans occasionally eat insects, "bug" was moved to the "food" sign group and the analysis was repeated. Again, a similar significant effect resulted ($p < 0.013$, Wilcoxon two-sample t-test).

Although the positive results from the statistical tests are consistent with the selective attention hypothesis, two additional issues need to be addressed to help clarify the role of selective attention during sign learning: (1) the possibility of differential attention within the sign learning context and (2) the extent to which a positive relationship exists between selective attention and sign performance.

Differential attention during the sign learning context can be explored with frequency data on eye contact, collected for one subject (Princess) during the training of five new signs ("fungus," "pipe," "pillow," "tuning fork," and "twig") and one old sign ("nut"). Training occurred following the termination of the original study. The observer recorded where the subject looked during the four phases of the trial (referent presentation and questioning, subject's response, molding, and reinforcement). The frequency data were converted into percent occurrence data, which enabled a comparison of the types of visual responses that occurred during each phase of training for

the signs.

Table VIII indicates where and when the orangutan looked during sign training. Such data indicate that during the periods of referent presentation and questioning, response, and molding of a training trial for a new sign, visual attention was diverted from features of the training situation (i.e., referent, trainer's face, subject's hands, and reward) more than half the time. During the reinforcement phase, visual attention was predominantly directed towards the reward. The subject looked at the referents of the new signs less than 30% of the time during referent presentation and response phases and 0% of the time during molding and reinforcement phases. When the "food" sign, "nut," was retrained, visual attention towards the sign's referent was high during the questioning (100%) and response phases (87.5%) of the trial. These data indicate that the subject selectively attended to particular aspects of the sign learning environment and such attention was primarily dictated by referents of interest (e.g., food).

To address the issue of how attentional processes might influence sign performance, the subject (Princess) was given sign retraining, 18 months after the original sign training terminated. Concurrent with sign retraining, the subject was given pair-wise preference tests of the referents used in retraining. Two referents were placed on a test stand and presented to the subject. The referent that the subject first

TABLE VIII. DISTRIBUTION OF VISUAL ATTENTION
BY A JUVENILE ORANGUTAN DURING SIGN TRAINING:

DURING REFERENT PRESENTATION AND QUESTIONING						
EYE CONTACT/ LOCATION	SIGNS:	PILLOW TUNING FORK	PIPE	FUNGUS	TWIG	NUT
NO EYE CONTACT (E.C.)	66.7	63.2	73.3	68.4	54.1	0
E.C. W/ REFERENT	26.7	30.2	21.4	27.7	39.1	100
E.C. W/ TRAINER'S FACE	6.7	6.5	4.0	3.9	4.1	0
E.C. W/ SUBJECT'S HANDS	0	0	1.3	0	2.7	0
DURING SUBJECT'S RESPONSE						
NO E.C.	64.0	54.5	62.7	44.3	35.0	0
E.C. W/ REFERENT	13.3	20.8	12.0	30.4	28.8	87.5
E.C. W/ TRAINER'S FACE	22.7	24.7	20.0	20.3	33.8	12.5
E.C. W/ SUBJECT'S HANDS	0	0	5.3	5.0	2.5	0

- Values are in percentages.

Table continued on next page

TABLE 8. continued

DURING MOLDING (GUIDANCE)						
SEE CONTACT/ SIGNS: PILLOW TUNING PIPE FUNGUS TWIG NUT LOCATION FORK						
NO EYE CONTACT (E.C.)	100	85.7	58.8	81.8	75.6	50.0
E.C. W/ REFERENT	0	0	0	0	0	33.3
E.C. W/ TRAINER'S FACE	0	14.2	2.9	4.5	1.4	16.6
E.C. W/ SUBJECT'S HANDS	0	0	35.3	9.1	21.6	0
E.C. W/ REWARD	0	0	2.9	4.5	1.4	0
DURING REINFORCEMENT						
NO E.C.	8.0	1.3	8.1	2.7	18.7	0
E.C. W/ REFERENT	0	0	0	0	0	33.3
E.C. W/ REWARD	92.0	98.7	91.9	97.3	81.4	66.6

-Values are in percentages.

attempted to grab was scored as the preferred referent for that pair. After each referent was twice paired against every other referent (controlling for position preference), a percent preference score was calculated for each referent, which was used as its relative measure of selective attention.

Sign retraining employed the same methodology as original sign training with the exception that only five trials were given for each sign per session. The correct performance data over the seven retraining sessions were significantly positively correlated with the referent preference data ($r=0.57$, $p<0.05$). When the "nontouch" sign, "mirror," was removed from the analysis to eliminate motor effects, the correlation coefficient and level of significance increased ($r=0.74$, $p<0.01$). The results of these tests support the existence of a relationship between referent preference and signing performance, and further support the selective attention hypothesis.

Selective attention may also influence the early vocabulary development of children [Nelson, 1973]. Some children are inclined to take an interest in learning about social or nonsocial items, and Nelson categorizes such children as either "expressive" or "referential" learners. Because referential learners are more interested in learning about objects than people, selective attention processes may favor the learning of object words during early vocabulary development rather than

words pertaining to themselves and other people. In contrast, expressive learners seem more interested in social items and activities and their vocabulary reflects this bias. The implication of selective attention towards items in particular categories by orangutans and children during early sign and word learning suggests that similar processes may influence the early vocabulary of other primate species as well.

Assessment of Presented Hypotheses:

The three a posteriori hypotheses presented above were falsifiable by the manner in which they were tested statistically. Although the pre-existing behavior hypothesis was rejected, both motor difference and selective attention hypotheses were not. The tests suggest that for orangutans both the relative difficulty in performing a sign's gestural component and the subject's interest in the sign's referent are identifiable factors that can account for much of the variance in ease of sign acquisition. Had the pre-existing behavior hypothesis been supported, an ethological explanation for the difficulty in performing the motor aspect of the sign could have been provided. The supported selective attention hypothesis suggests that biologically relevant stimuli (e.g., food for the orangutan) in an ape's world have influenced the evolution of learning adaptations permitting differential performance for various behaviors.

Another possible explanation for the sign-related effects is presented in Appendix B-- the Pre-concept hypothesis. Because of inadequate data, it was not possible to evaluate this explanation; however, it is offered as an a priori hypothesis for future sign learning experiments with apes. Additionally, an evaluation of the three hypotheses could be improved by developing training protocols that permit a priori testing of those hypotheses. These protocols are briefly discussed in Appendix C for possible evaluation in the future.

A Practical Application of Knowledge Derived from Ape Sign Learning Study:

This paper illustrates that a detailed analysis of sign learning behavior in orangutans can identify of biological and ecological factors that influence the development and performance of sign vocabularies that are potentially communicative in a highly intelligent species. Besides being of value to those interested in animal learning and behavior, the knowledge of such factors has potential applications for humans. Both apes and linguistically handicapped children require significantly more tutelage to develop their language or "language-like" skills than do normal children. To the extent that sign learning by apes is analogous to word learning in linguistically handicapped children, such information may prove useful in developing and refining remedial programs for such children. Language intervention therapy has already benefited from the results of

ape "language" projects which have emphasized communication and methods used to develop communicative relationships and skills [Hollis & Carrier, 1975; Fouts, et al., 1978; Savage-Rumbaugh & Rumbaugh, 1980]. The findings from this study on the analysis of sign learning variables may also be useful in developing improved teaching protocol and evaluating the results of remedial vocabulary training.

CHAPTER V

CONCLUSIONS

1) Following the modified methods of Fouts [1973], four juvenile orangutans each acquired an average of only 4.25 signs (from a possible of 10 signs) after 15 months of training and over 2400 trials; however, an average of 8.25 signs were correctly performed sometime during training.

2) Analysis of variance of a signing performance measure indicated that there were significant differences both among orangutan subjects and among signs. These statistical differences appear to be analogous to those found for chimpanzees [Fouts, 1973].

3) Caged orangutans learned signs better than uncaged (home-reared/ free-ranging) orangutans; however, the superior performance of the caged male probably best accounts for both the significant subject and condition effects.

4) "Touch" signs were performed significantly better by orangutans than "nontouch" signs. A comparative literature survey suggests this may be a general phenomenon in pongids that have been trained to sign.

5) "Food" signs were performed significantly better by orangutans than were "nonfood" signs. Selective attention

towards food referents during training may help account for this difference.

6) Differential attention as measured by direction of gaze during sign training was documented in the one orangutan subject in which it was studied closely.

7) A significant relationship between referent preference and sign performance for one orangutan subject supports the hypothesis of selective attention in accounting for a significant sign effect.

CHAPTER VI

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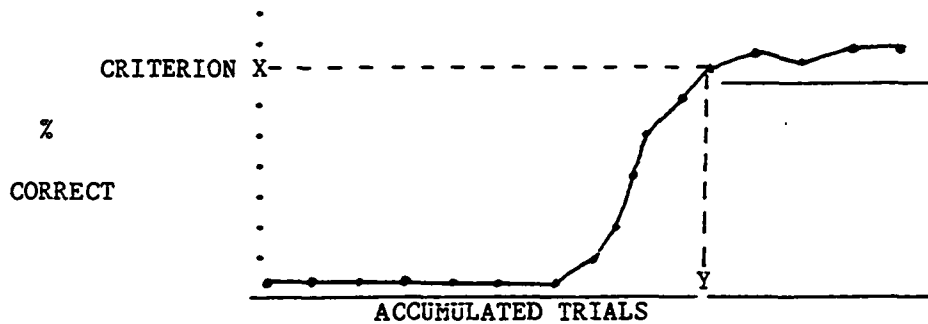
APPENDICES

Appendix A

METHOD FOR TRANSFORMING PERFORMANCE

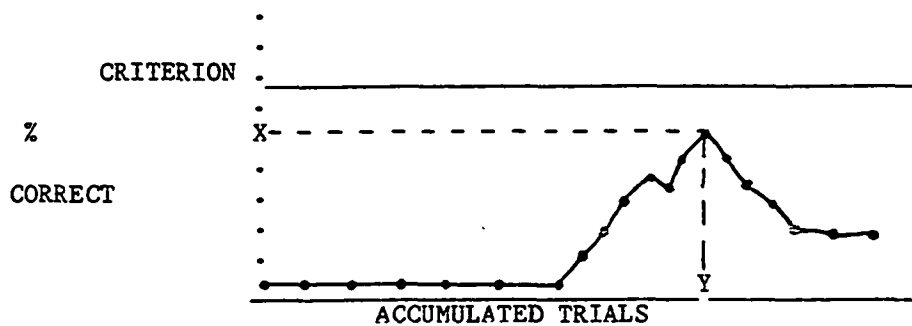
CURVE DATA INTO SLOPE PERFORMANCE MEASURES [SPMs]

FOR SIGNS THAT WERE ACQUIRED



$$\text{SPM} = \frac{X (\% \text{ CORRECT AT CRITERION})}{Y (\# \text{ OF ACCUMULATED TRIALS})}$$

FOR SIGNS THAT WERE NOT ACQUIRED



$$\text{SPM} = \frac{X (\% \text{ CORRECT AT MAXIMUM PERFORMANCE})}{Y (\# \text{ OF ACCUMULATED TRIALS})}$$

Appendix B

An Alternative Hypothesis For Future Evaluation

The three evaluated hypotheses did not constitute all possible hypotheses that can help to explain the variance observed in the ease of sign acquisition by orangutans. Other hypotheses were not assessed because the data necessary to do so were not collected; however, one additional hypothesis, the pre-concept hypothesis, will be discussed as a possible explanation worth evaluating in future signing projects.

Premack [1976] suggested that for an organism to learn a word, the organism must have some concept regarding the word's referent. The concept for the referent develops as the subject experiences the item and learns about the item's function, its relationship to other items, its shape, size and other characteristics. Learning the name for the item is then a matter of tagging an external marker to the concept(s) or mental representation for the item. In this view, concept of referent precedes learning the word for the referent. This hypothesis regarding concept formation and word learning is similar to the Piagetian view of cognitive development in that the child develops, through interaction with his environment, "schemes," or mental representations of the relationship between items, before

being able to express those schemes through linguistic expression [Piaget, 1952].

These interpretations of a cognitive prerequisite for vocabulary development suggests that the variance in sign learning by orangutans may have been due to differences in pre-existing concepts of the sign's referents. Signs rapidly learned may have had referents more familiar to the subject than referents of more slowly learned signs. However, since the background history and prior experience of the various subjects was unknown, a test of a pre-concept hypothesis was not made. A test for such a hypothesis must, therefore, be considered by the experimenter before sign training commences (i.e., a priori).

The pre-concept hypothesis could be tested in future signing projects if the set of trained signs had referents whose length of exposure to the subjects was known. To control for the effects of referent generalization which might bias the test if novel but familiar referents were chosen, the set of unknown referents trained to rehabilitant apes should be recent in origin and novel in function and appearance. If the apes are laboratory born, selection of the appropriate referents would be less difficult.

To control for selective attention which might bias early concept development, pair-wise interest tests like the type mentioned earlier could be conducted such that referents be

placed in high and low interest groups (or other multi-interest groupings) prior to sign training.

A useful variant in the protocol would be to allow the subjects to interact with a subset of the unknown referents for known lengths of time prior to sign training. This would provide the experimenter with three groups of referents with which to test the pre-concept hypothesis: the control group of no prior exposure, an experimental group of known length of exposure, and an experimental group of unknown length of exposure (some familiar items). If the pre-concept hypothesis is valid, signs from the experimental groups should be learned faster than signs from the control group.

Appendix C

Improved Tests of Hypotheses Conducted in This Project

I recommend that future sign training experiments be conducted such that possible sign influencing factors could be tested as a priori rather than a posteriori hypotheses. This would improve the validity of the tests especially in rejecting a particular hypothesis. For example, testing the pre-existing behavior hypothesis could be improved by collecting observations of manual behavior on a number of subjects prior to sign training. A check list of both manual actions of the signs to be trained as well as other signs and activities could be used to effectively assess manual behaviors in the subjects' pretraining repertoire. Analysis of the data might be postponed until after sign training terminated to avoid experimenter bias regarding subject manual tendencies.

A test of the motor difference hypothesis could be improved by controlling for factors other than the gestural component of the sign. By assigning subjects to two groups, the influence of the motor component of a specific sign on sign learning could be evaluated by normally training the sign to one group and by training a modified version of the sign to the other group. The modified sign would consist of the same referent as the normal sign; however, its associated gestural component would be from a

different sign. A comparison of performance for normal and modified sign groups would indicate the influence of the gestural or motor component alone on sign learning.

The selective attention hypothesis test could be improved by conducting referent interest tests prior to and throughout sign training for each of the subjects. In this way the temporal relationship between interest in a referent and the future performance of the referent's sign can be determined. Care in selecting appropriate referents and signs would enable developing a protocol for simultaneously evaluating the selective attention and the pre-concept hypotheses. For example, sets of referents both never seen before and known to have been experienced by the subjects (requiring knowledge of the subjects background history) could be assessed as to the subjects' interest to the referents. This would allow a 2X2 design in which both hypotheses could be evaluated during and after sign training.