BEATRIX GARDNER (1933 - 1995): HER CONTRIBUTIONS TO DEVELOPMENTAL PSYCHOBIOLOGY

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In March of 1995, I arranged a speaking tour in North Carolina that featured Allen and Beatrix (Trixie) Gardner of the University of Nevada, Reno. The tour included well received presentations to groups of faculty and students at the University of North Carolina at Chapel Hill, Duke University, and Fayetteville State University, the institution where I teach. At that time, Trixie Gardner was President-Elect of the Rocky Mountain Psychological Association (RMPA). She asked if I would be interested in participating in the Sixty sixth Annual Convention of the Rocky Mountain Psychological Association scheduled for 1996. "Of course," I said and offered to present a paper entitled *Production tests of categorization with nonhuman subjects: The advantages of a cross-fostering technique.* After a week long visit made even more enjoyable by stimulating discussions about the April convention, at which time Trixie would be the President of RMPA, and about their planned trip to Europe, Allen and Trixie returned to their home in Reno.

On June 6th of 1995, I received a message to call Bill Wallace, a Professor of Psychology and a close personal friend of Allen and Trixie Gardner, at the University of Nevada, Reno. It was then that I heard the tragic news that on June 5th, while in Padua, Italy, on the European lecture tour Trixie Gardner had suddenly died from septicemia. I was stunned. For more than ten years, I had worked with and had grown to respect and

admire Allen and Trixie. Trixie's death was not only a deep personal loss for me and my family but also a profound loss to the scientific community. Her brilliance and insight is evident in her teaching, research, and the students that worked alongside her on the cross-fostering study. Her generosity of spirit was infectious both to students and colleagues. The likes of her will not pass this way again. I would like to address Trixie Gardner's unparalleled contributions to Developmental Psychobiology.

THE EARLY YEARS

Beatrix Gardner, nèe Beatrice Tugendhat, was certainly an international woman. When Trixie was 6 years old, she and her family fled Europe in 1939, just ahead of the Nazi invasion. She spent the following six years in Brazil before the family moved to the United States. Trixie Tugendhat earned her BA at Radcliffe College and a MS from Brown University. Her return to Europe was to England where she earned her D. Phil. in zoology at Oxford University. Trixie studied under the renowned ethologist and Nobel Laureate Nikolaas Tinbergen.

One of the many topics that Tinbergen studied was nesting defense behaviors of the male three-spined sticklebacks (*Gasterosteus aculeatus L.)* against intruding male sticklebacks. A species of fish that was popular among ethologists, in the 1950s, for the study of species specific behaviors. Tinbergen was interested in eliciting stimuli of attack behaviors in sticklebacks . He demonstrated that a model will be attacked if it has certain specific characteristics. Size and shape were relativity unimportant, but a bit of red color, as male sticklebacks normally have on their bellies, was essential. The red had to be on

the ventral side. A vertical orientation of the model, similar to the posture adopted by males when aggressing, also facilitated a strong response.

Trixie, inspired by her mentor, studied the feeding behavior of the three-spined sticklebacks. She identified those responses that are associated with normal feeding and then related them to varying levels of deprivation and satiation. The focus on the role of motivational issues in her study is an example of her American contribution (Trixie was a student of and worked with Carl Pfaffman while at Brown University) to ethological studies. Trixie's research with sticklebacks furthered our understanding of feeding behavior and in the relationship of drive and thwarting to the completion of a behavior sequence.

As we know, the first step in any study is clear, precise, and quantitative description of the behavior of interest. The second is manipulation of subjects (in this case deprivation or satiation) or the environment (conflict electric shock) to see how behaviors change. Her hypothesis was that later stages in a behavior sequence as compared to initial stages, require higher levels of motivation to initiate and maintain (Tugendhat, 1960a; 1960b; 1960c). Trixie tested her hypothesis by exploring the effects of food deprivation and electric shock on the feeding behavior of three-spinded sticklebacks. The sticklebacks were maintained in aquaria divided by a partition into a food area and living area. A portion of the partition was removed to permit one hour of access to the food at 1-, 2-, or 3-day intervals (three levels of deprivation). In *conflict sessions*, the fish received electric shock at three increasing intensities of shock, through a pair of electrodes immersed in the

water. The first two entries into the food area or the 10th and 20th grasp at food were the occasions for administering shock (Tugendhat, 1960c).

Trixie, then, identified the components of the sequence of feeding behavior. Sticklebacks feeding on their ground-living prey swim near the floor of the tank and occasionally tilt their bodies to remain poised over the worms which are half-embedded in the sand. The eye movements during fixation on the prey are quite distinctive. Fixations followed by grasping the prey were scored as *complete feeding responses*. Behavior such as attacks, returns to the living area, swimming up and down the walls of the food area, and so forth, has been grouped together as a bout of *nonfeeding behavior*. Such activities would appear in the absence of food and their frequency and duration could be changed by varying conditions other than deprivation. Then, *total time spent feeding* measured the predominance of feeding behavior in the one hour session. The *ratio of initiations to completions* measured the predominance of one element in the feeding behavior pattern. In a bout of feeding, it is possible that few completions are performed because the *duration* of feeding responses is very long (Tugendhat, 1960a; 1960b).

The findings showed that increase deprivation time resulted in a greater number of completed feeding-responses, and a decrease in the ratio of initiated to completed feeding responses. But neither the number of initiations nor the total time spent feeding were reliably increased by deprivation. Hunger shows its effects on the predominance of completions over initiations, not on the predominance of feeding behavior over nonfeeding behavior.

In the conflict sessions the total time spent feeding is below normal values, and more markedly so for increasing shock intensities. But the ratio of initiations to completions is lower than normal, and the duration of feeding responses is below normal. These latter two effects are not changed by increasing shock intensities.

Nonfeeding behavior has become more predominant in the conflict session, but when feeding behavior is shown it is like that of very hungry fish. As a result, over half the fish performed more completed feeding responses than normally under conditions of low shock, with some fish scoring as much as 40 percent over normal values.

As the feeding session progresses, the usual satiation changes occur and deviations from normal feeding scores are less marked. The initiated to completed response ratio is below normal throughout the session, but reliably below normal only for session as a whole or for the first 15 minutes of the session.

From these results Trixie (Tugendhat, 1960a; 1960b) concluded that when the conditions that favor the occurrence of two different and incompatible behavior patterns are simultaneously presented, interactions between the patterns are observed. These interactions are more than an observable alternation between the two patterns. In the shock and feeding conflict, the intensity of feeding was increased by the interaction. This was manifest in feeding response totals that were higher than for normal feeding sessions, but, more generally, in the higher deprivation level characteristics of each bout of feeding activity. These changes, which were positively correlated with the reduction in total time spent feeding that was produced by shock, might not be sufficient to make up for the more

drastic reductions in time spent feeding. But for the lesser reductions in this measure, the increased intensity of feeding behavior was more than compensatory and overeating would occur. It seems very plausible that organisms are continuously in a situation that evokes several incompatible behavior patterns. An animal could not behave at all if mutual suppression of the behavior patterns resulted; it could not behave very efficiently unless pattern predominant at a given time actually increased in strength in the presence of irrelevant behavior tendencies.

Her hypothesis that later stages in a behavior sequence as compared to initial stages, would require higher levels of motivation to initiate and maintain was supported by her results (Tugendhat, 1960a; 1960b; 1960c). This training in ethology would remain as a significant influence on Trixie's thinking throughout her professional career.

WELLESLEY COLLEGE

After completion of the D. Phil., Trixie Tugendhat assumed a position in the Department of Psychology at Wellesley College. Trixie infused the ethological approach into her work in Developmental Psychobiology. In partnership with Lise Wallach, she explored the head shape of a baby verses that of an adult. This study clearly adhered to the ethological approach of Tinbergen. In this study (Gardner & Wallach, 1966), silhouettes of adult males and those of infants less than one year of age were systematically distorted. The differences in shape between a profile view of the head of the infant and that of the adult were used to derive a formula that yields a family of

shapes, that range from extremely exaggerated adult heads to extremely exaggerated baby heads.

These figures were shown in pairs on a projection screen to subjects (146 women and 46 men) who were instructed to judge which silhouette as most suggestive of a baby or "babyish." The pattern of judgements obtained for the heads in the series, together with the judgements of control heads indicates that a continuous transformation in shape (which could be described as a change from a tall, narrow head with large features and a large chin, to a short, wide head with small features and a chin) was an effective determinant of judged babyishness (Gardner & Wallach, 1966). This study illustrates an effective use and blend of approaches from both ethology and Developmental Psychobiology.

While at Wellesley College, it was arranged for Trixie Tugendhat and Allen Gardner to attend a lecture given by Professor Harry Harlow on the effects of contact comfort . This event marked the beginning of what would be a life long bond and a vital professional collaboration. This was a marriage made in psychology heaven: Allen Gardner, a student of Benton J. Underwood marrying Beatrix Tugendhat, a student of Niko Tinbergen in 1961. In 1963, Allen and Trixie Gardner accepted positions in the Department of Psychology at the University of Nevada, Reno (UNR) where they would lead remarkable careers.

UNR: JUMPING SPIDERS

Upon arriving at the University of Nevada, Reno, Trixie continued research with behavior chains and motivation. This time she was interested in predatory behaviors of jumping spider (*Salticidae*) (B. T. Gardner, 1964; 1966). Jumping spiders were chosen because of the long and clear distinct sequence of predatory behavior. The sequence of behaviors consisted of orientation, pursuit, crouching, attachment, and jumping. These behaviors can be elicited by a mechanical model of the prey consisting of a black dot moving on a white background (B. T. Gardner & Gardner, 1967). The studies with jumping spiders demonstrated that different stages in the predatory chain were sensitive to different visual characteristics of the prey and that the initial predatory responses of orientation and pursuit as compared with the latter predatory behavior sequence response required a lower drive level. Drive level was manipulated through food deprivation. These findings are supportive of her earlier work with sticklebacks.

CROSS-FOSTERING STUDIES

In 1966, Trixie along with her husband Allen began their greatest adventure in empiricism, one that yielded both acclaim and controversy within the scientific community. But even their most ardent critics must acknowledge that the Gardners' research in the cross-fostering study was soundly based on the ethological approach of Niko Tinbergen and the experimental approach of Benton J. Underwood and therefore scientifically rigorous. The Gardners reasoned that many animals have to learn to identify with their own species and have to learn species-specific behavior, for example, many

birds have to learn their mating songs. Even complex sequenced behavior such as migration or overwintering in the same place are profoundly influenced by species-typical rearing conditions.

In cross-fostering, the young of one species are reared by foster parents of another species (R. A. Gardner, Van Cantfort & Gardner, 1992). It is through the manipulation of this procedure that we may better understand the role that rearing conditions play in intellectual development and in language acquisition. According to the Gardners, chimpanzees are good candidates for cross-fostering because, like human beings, they mature gradually and over relatively long period of time. Infant chimpanzees are quite helpless; warmth, bodily care, and food must be provided. Under favorable conditions, their behavioral repertoire continues to expand and develop throughout their long childhood on into maturity. Captive chimpanzees can remain vigorously and intelligently alive for more than 50 years (Maple & Cone, 1981).

The Gardner raised from approximately 10 months-of-age, Washoe, a chimpanzee in a two and one-half room, eight by twenty-four foot house trailer that contained most of the usual items of a human dwelling, such as a general living and cooking area, a sleeping area, and a bathroom. It was equipped with typical human furnishings such as a bed with sheets and blankets, a couch, drawers and cupboards for storage, a stove, and a refrigerator. Washoe had access to and used personal items such as clothing and grooming aids to include combs, brushes, lotions and toothbrushes. Toys and picture books were freely available. Thus, the living areas were similar to those commonly

available in a child's home. Regular routines such as meals and grooming sessions, household chores, outdoor play at the research station, and car rides to interesting areas provided many opportunities for the use of sign language. American Sign Language (ASL) was the means of two-way communication between Washoe and her foster family. Four other chimpanzees, Moja, Pili, Tatu and Dar were raised under similar conditions in a second project.

VOCABULARY STUDY

Early in Project Washoe, the Gardners developed procedures to determine when a sign first entered the vocabulary and when it became a reliable item (B. T. Gardner & Gardner, 1971). After three separate and independent reports of well-formed, unprompted, and appropriate observations of a new sign by three different observers, they placed the new sign on the list of candidates for reliability. A sign remained on this list until there was at least one report of a well-formed, unprompted, and appropriate observation on each of fifteen consecutive days. The same procedures were used on the second project.

With the use of the findings on establishment of signs in the vocabulary of Washoe, Moja, Pili, Tatu, and Dar, I would like to highlight the results of the cross-fostering studies. One of the first things to note is the development of vocabulary over time. Vocabulary grew robustly throughout the 60 month period (see figure 1). For cross-fostered chimpanzees, as for human children, specificity of category and generalization across item type within categories occur. Golden Delicious and Rome Beauties are apples, apples are

food, and foods are objects as distinguished from actions or attributes (B. T. Gardner & Gardner, 1994). As is seen in children, the cross-fostered chimpanzees also used broader, functional categories in forming their early phrases. Table 1 groups the signs in their vocabularies into these functional semantic categories. The Gardners have field records of appropriate usage (B. T. Gardner & Gardner, 1975) and experimental evidence from the Wh-question tests (Van Cantfort, Gardner & Gardner, 1989). Wh-questions are *Who*, *What*, *Where*, *When*, and *Why* questions. When replies to Wh-questions were incorrect Tatu and Dar usually replied with a sign from the semantic category specified by the question showing that the semantic categories controlled errors as well as correct replies (R. A. Gardner, Van Cantfort & Gardner, 1992)

PHRASES

From the time Washoe had eight reliable signs in her vocabulary she began to combine them in meaningful phrases such as, GIMME SWEET (when shown a jar of baby food dessert), COME OPEN (after the bathroom door was locked) and MORE TICKLE (after Naomi, a member of Washoe's foster family, had tickled Washoe). Shortly after the comparative psychology which appeared in the (1968) *Handbook of social psychology*. Hebb put a bracket around the following passage:

> We propose therefore that the minimal criterion of language, as distinct from other purposive communication, is twofold. First, language combines *two or more* representative gestures or noises purposefully, for a single effect; and second, it uses the *same* gestures in different combinations for different

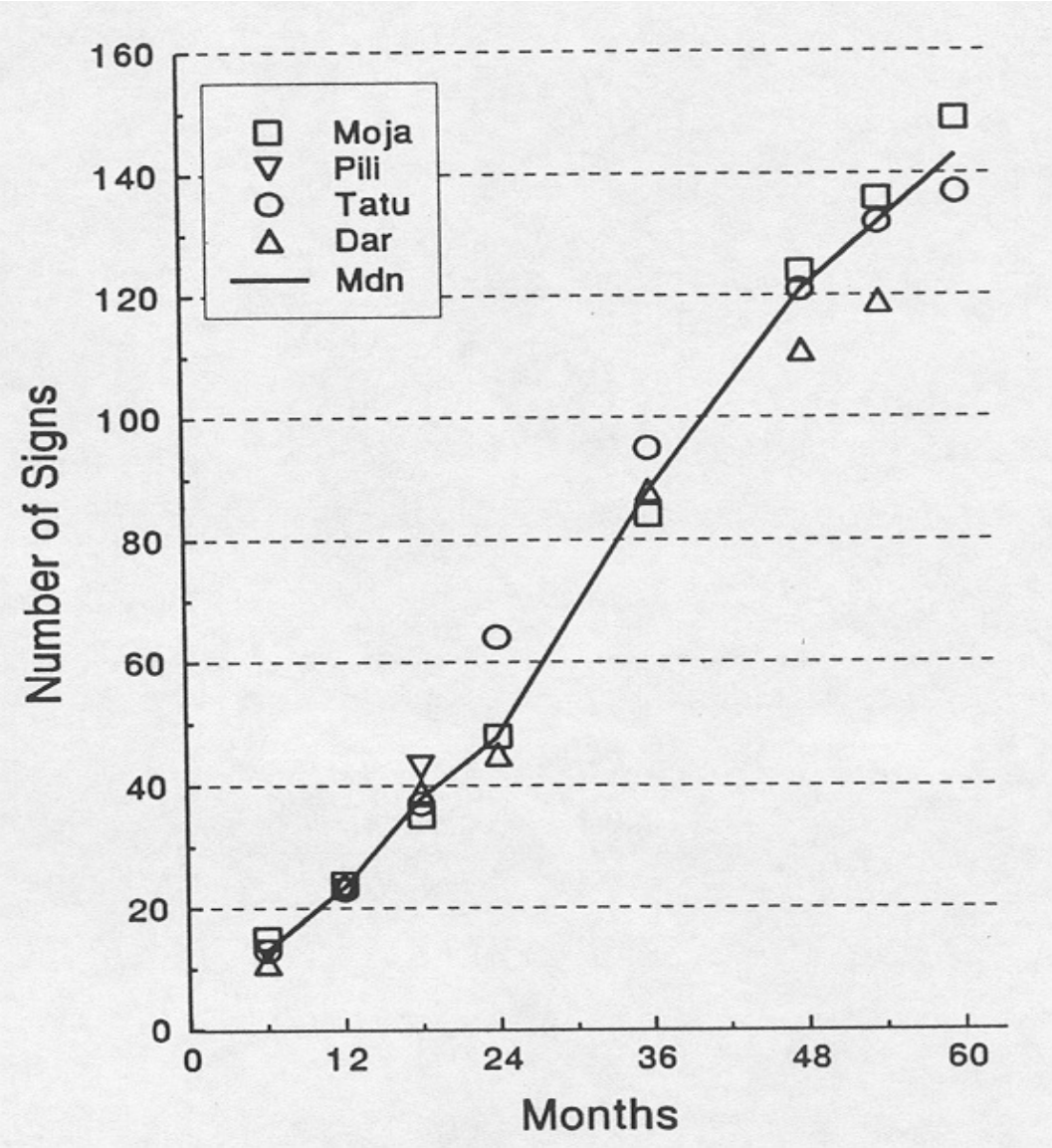

Figure 1. Growth of Vocabulary

From B. T. Gardner & R. A. Gardner, 1994, p. 226

Table 1. Semantic Categories

Category	Description	Examples
person	names of chimpanzees	DAR, TATU
	names of adult familiars	SUSAN, TOM
	generics for persons	BOY, GIRL
	pronouns	ME, YOU
object	animates	BUG, DOG
	inanimates	BALL, TREE
	edibles	APPLE, CEREAL
verb	actions	CHASE, KISS
noun/verb	either noun or verb	BRUSH, DRINK
locative	directions or places	OUT, UP
demonstrative	indicatives	THAT
attribute	colors	BLACK, RED
	possessives	MINE, YOURS
	materials	METAL, WOOD
	numbers	ONE, TWO
	comparatives	BIG, SAME
	sensory quality	HOT, SWEET
trait	personal attribute	GOOD, QUIET
negative	negative markers	CAN'T, FINISH
request	request/emphasis markers	HURRY, MORE

For detailed description see Gardner, Gardner, & Nichols (1989).

From B. T. Gardner & R. A. Gardner, 1994, p. 227

effects, changing readily with circumstances. (p. 739)

In the margin, Hebb wrote "This criterion means Washoe has achieved language." As flattering as is Hebb's comment, the Gardners resisted all such either-or/yes-no criteria. They reasoned that just as in the speech of human children, the first combinations only mark the beginning of a long process of growth and development in the sign language of cross-fostered chimpanzees (B. T. Gardner & Gardner, 1994).

The Gardners found developmental patterns in phrase token (see figure 2), types, and patterns . A phrase token in these analyses were defined as an utterance with two or more different signs within two utterance boundaries. An example of utterance boundary would be when Washoe finished signing and her hands dropped out of the signing space (for a detailed description see B. T. Gardner & Gardner, 1994). To measure the variety of phrases, the Gardners grouped all the tokens into types according to the signs that they contained. For this purpose, all phrases that contained the same signs, as CAN'T POTTY POTTY CAN'T, POTTY CAN'T CAN'T, and CAN'T POTTY CAN'T POTTY CAN'T (recorded for Dar in his 36th month) were counted as different tokens of a single phrase type containing the same two signs CAN'T and POTTY (see figure 3). A phrase pattern is a set of phrase types that are structurally related because they all contain signs that belong to the same semantic categories. Thus, GROOM DAR, YOU TICKLE, and SUSAN CHASE are three distinct phrase types, but each contains one sign that belongs to the, category, *person*, and a second sign that belongs to the category, *verb*, so all three phrase

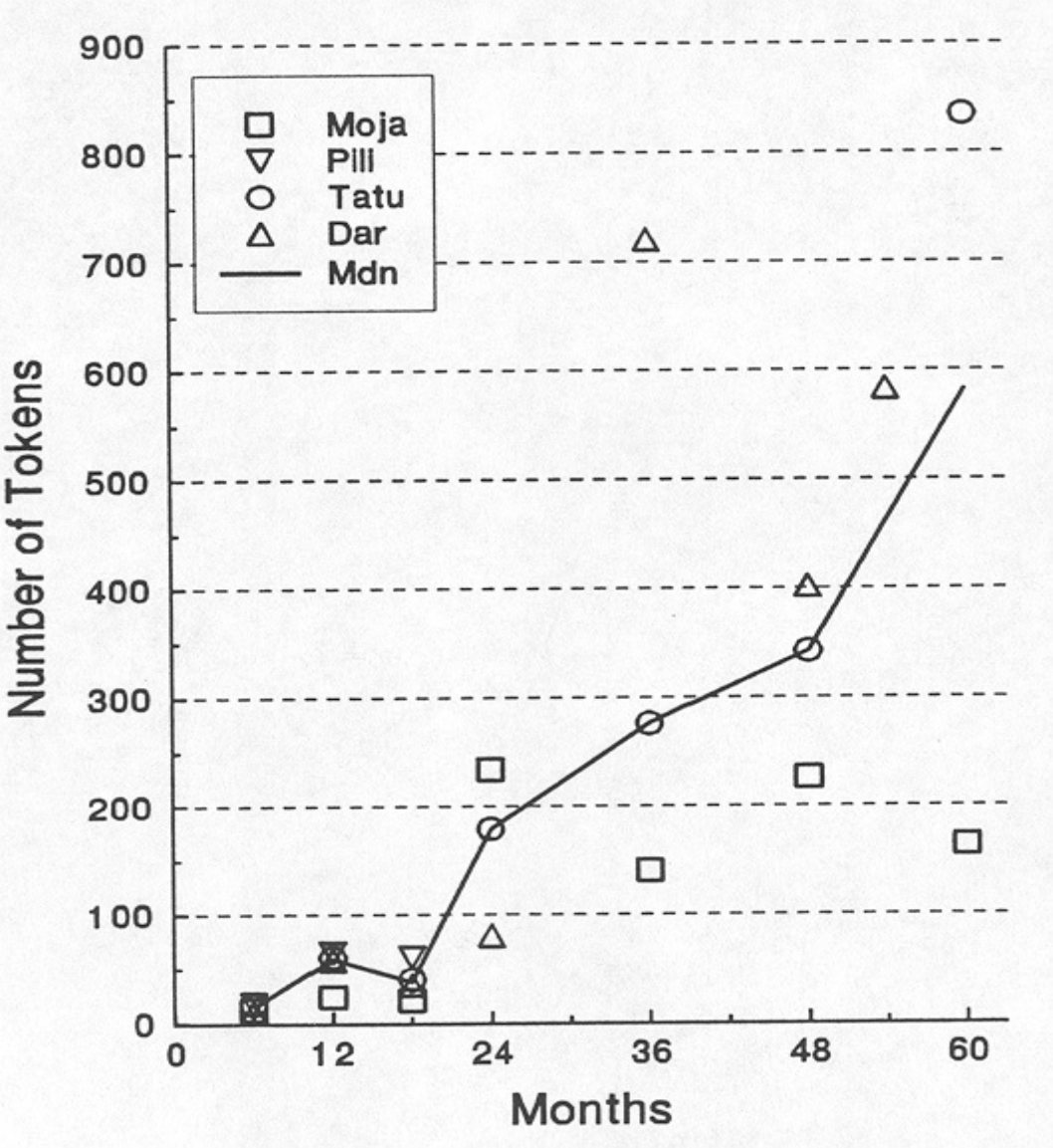

Figure 2. Growth of Phrase Tokens

From B. T. Gardner & R. A. Gardner, 1994, p. 233

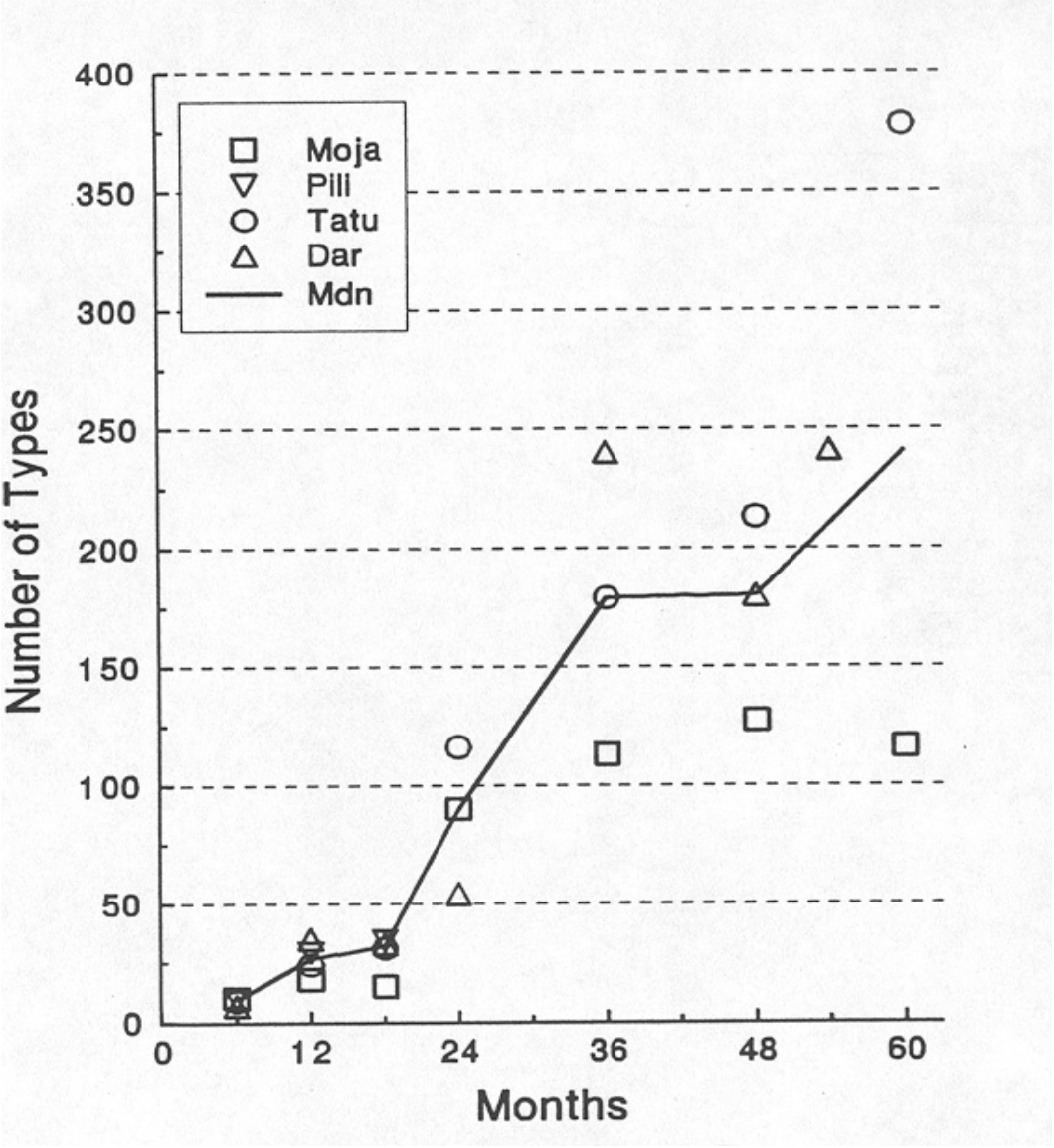

Figure 3. Growth of Phrase Types

From B. T. Gardner & R. A. Gardner, 1994, p. 233

types belong to the structurally related set for this purpose called *person + verb*. Similarly, BLACK HAT, GLASS MIRROR, and YOUR SHOE, are three distinct phrase types, but each contain one sign that belongs to the category, *object*, and a second sign that belong to the category, *attribute*, so all three of these belong to the structurally related set for this purpose called *attribute + object*. Developmental pattern were also found with the cross-fosterling for phrase patterns (see figure 4).

INFLECTION

Among the languages of the world, English is unusual in its heavy reliance on word order; most human languages rely more on inflections. ASL is one of the heavily inflected languages of the world (Klima & Bellugi, 1979). Wilber (1980) argued that:

> the key to understanding ASL syntax, particularly word order, is the recognition that locations in space are used for inflectional purposes. Within the 'signing space' (the allowable area in which signs may be made), signs may be moved from one location to another to indicate differences in subject and object. (p. 19)

We can see this type of inflections with cross-fostered chimpanzees. Videotape records of Dar taken when he was between 40 and 49 months old show that he indicated participants in action with the childish form, touching person, place, or object (Rimpau, Gardner & Gardner, 1989). For example, Dar signed TICKLE (on the side of his head) TICKLE (on the dinosaur toy) ME indicating that Tony was to tickle Dar's head with the toy.

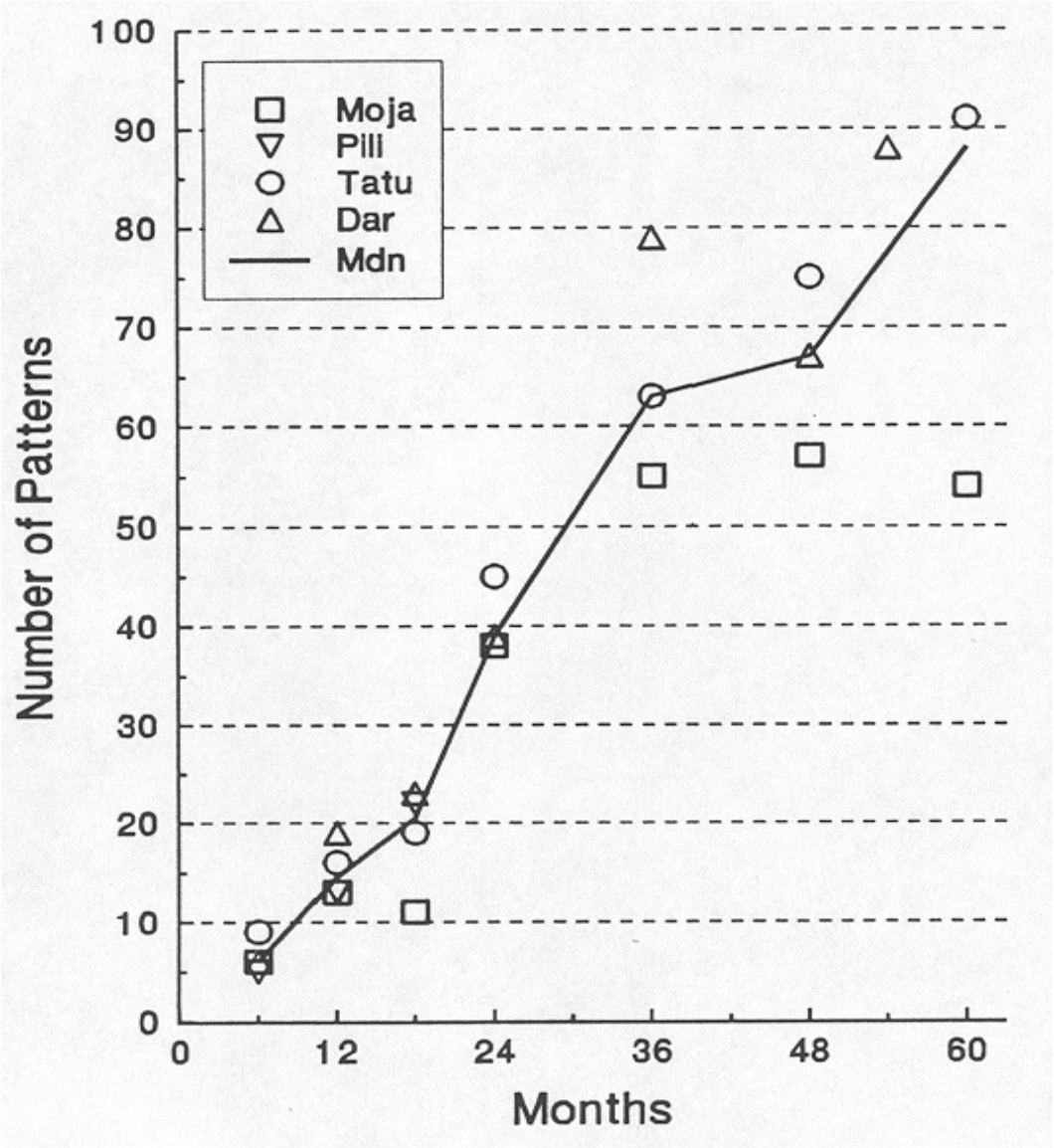

Figure 4. Growth of Phrase Patterns

From B. T. Gardner & R. A. Gardner, 1994, p. 235

CULTURAL TRANSMISSION

On March 24, 1979 Washoe adopted a ten-month old male chimpanzee named Loulis. To show that Loulis could learn signs from chimpanzees, human being did not use ASL signs in his presence (with the exception of seven question signs, WHO, WHAT, WHERE, WHICH, WANT, SIGN and NAME). Instead Fouts and his associates (1989)used vocal English and the rich repertoire of human and chimpanzee nonverbal gestures, postures, and calls to interact with Washoe and Loulis.

While humans refrained from signing to Loulis, the chimpanzees were not bound by this rule. In addition to his adoptive mother Washoe, the other cross-fostered chimpanzees Moja, Tatu, and Dar interacted with Loulis at various stages of the five years. During this five year period Loulis had acquired over 50 signs (Fouts, Fouts & Van Cantfort, 1989). This is the first study to demonstrate the cultural transmissions of ASL signs in chimpanzees.

CONCLUSIONS

The Gardners have always argued that truly discontinuous phenomena must be rare in nature. Historically, the great discontinuities have proved to be conceptual barriers rather than rifts in the fabric of the natural world. It seems unlikely that a phenomenon as rich as language could be based on an isolated, unitary biological trait. It is more reasonable to suppose that language is the result of a complex of interacting traits running through all aspects of human intelligence. Following the same line of reasoning they would argue that, similar to other significant biological phenomena, the

general principles that govern human intelligence are related to the general principles that govern the intelligence of all animals. This search for general biological principles of intelligence led them to sign language studies with cross-fostered chimpanzees (R. A. Gardner, Van Cantfort & Gardner, 1992).

I would like to conclude with the opening line of the Van Cantfort and Rimpau's (1982) paper; "With the beginning of Project Washoe in 1966 a new field of scientific inquiry opened. Sign language studies with chimpanzees provided a new tool for studying linguistic behavior as an expression of intelligence and for understanding the continuity between human and non-human intelligence" (p. 15). It is to Trixie Gardner and her husband Allen that we attribute the genesis of this pioneering body of research.

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