EARLY CAPACITIES FOR SPEECH COMMUNICATION

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1. PREFACE

This paper is an extended version of a paper presented at the Second European Conference on Developmental Psychology, held in Rome, Italy, 10th-13th September 1986. The subtitle of the conference was: "Development: European Perspectives" and accordingly the contributors and participants were mainly European.
One of the six scientific themes of the conference was "Development of Language and Communication", under which heading several symposia were organized, including the one entitled "Early Capacities for Speech" (co-conveners: B. de Boysson-Bardies and F.J. Koopmans-van Beinum).
Within this symposium the following five papers were presented:
J. Bertoncini (Paris-France): Early perception units and categorization.
J.M. van der Stelt (Amsterdam-The Netherlands): Early interaction and pragmatic development (see for an extended version her contribution in this Proceedings).
F. Franco and L. D'Odorico (Padua-Italy): The problem of continuity: sound meaning system in infant vocalisations.
B. de Boysson-Bardies (Paris-France): Early production capacities.
F.J. Koopmans-van Beinum (Amsterdam-The Netherlands): Early capacities for speech: general discussion.

2. INTRODUCTION

The main task of a discussant in a symposium is in my opinion not merely summarizing the papers of that symposium and repeating what already has been said, but rather putting those papers in a theoretical framework, trying to relate them, showing what seems to be clear and resolved, and indicating where gaps in this framework show up yet. So first I shall try to sketch a tentative, theoretical framework of the early capacities for speech communication.
Next several parts of this framework will be filled up by means of what we know from literature and from the presented papers. Doing so we shall come up with some general problems and with a few specific questions related to specific parts of the framework.
Finally I will discuss some gaps in the framework and accordingly do a few suggestions for further research.

3. THEORETICAL FRAMEWORK

For the purpose of the present discussion on the infant's early capacities for speech communication, we tried to schematize what is going on in the first year of life especially. In the tentative, theoretical scheme given in Fig. 1 two separate child capacity columns are indicated: one representing the development of infant speech perception and the other one representing the development of infant speech production.

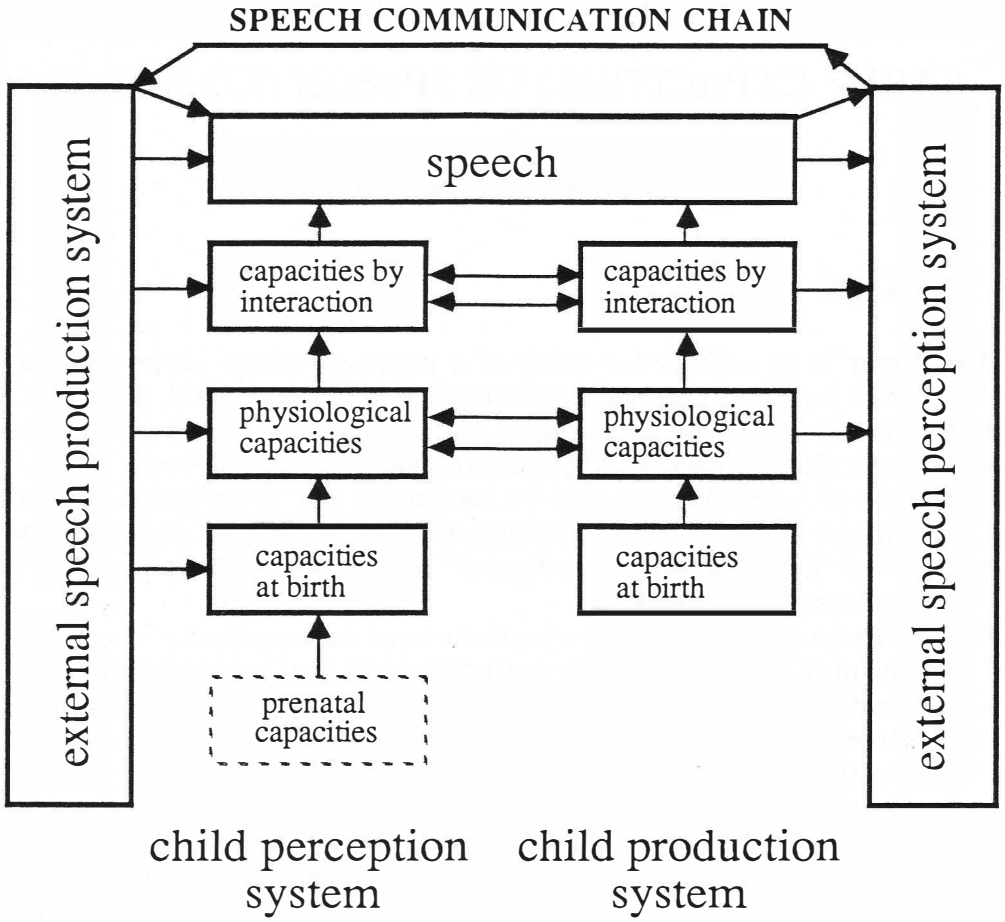

Fig. 1. Tentative scheme representing early infant capacities in the development of speech communication.

Each of the columns has a number of distinct levels, but within the column each level communicates with neighbouring levels. The distances between the distinct levels, however, should not be considered to give any temporal indication about the infant's age. The top level for the infant perception and production columns, concerns understandable speech, which is per definition part of the normal communication chain. Of course this end will normally not be reached in the first year of life yet, but it is nevertheless the final goal. On several levels perception and production are influencing each other, in the scheme indicated by arrows. Besides, the infant has to do normally with at least one external speech production and perception system.

When we look at the two columns in more detail we can see that perception has one more level than production, since it is known that amply before birth the auditory system is already well developed. So it is very plausible that we have to indicate perception capacities before birth, whereas the sound production system only can start its activities from birth on as soon as the respiration system of the infant functions. This difference in starting levels may account for the leading position of speech perception over speech production, at least in the infant's first years of life.

From the moment of his birth onwards the infant belongs to a human society, although most of the times a quite private society at first. From the very beginning the child is confronted with at least one fellow-creature whom he is initially even totally dependent on. A newborn human cub is possibly one of the most dependent mammals in the

world. And especially this dependency is a perfect ground for the development of communication, for getting in touch with other members of the surrounding community, for being partners, sharing the same world of living. Because of his dependency the infant is forced to express his necessaries of life immediately from birth onwards. Fortunately the infant is equipped with neat perception and production mechanisms. A problem, however, is that the child indeed has the instruments for communication at his disposal, he is born quite complete, but that he does not know the adult system to apply these instruments yet. He has to learn the encoding and decoding rules for communication within the group he is born in.
So, apart from the capacities present at birth, a number of capacities have to be acquired during the course of development: part of them mainly by physiological maturation, and part of them mainly by interaction. It is clear that the role of interaction increases according as the physiologically developed capacities provide the possibilities for social and intellectual responsiveness.
All three aspects of the development of early speech communication, perception, production, and interaction, will be discussed in more detail in the following sections.

4. CAPACITIES FOR EARLY SPEECH PERCEPTION

Let us first consider the lower levels of the perception column in our scheme (Fig. 1). As said before the auditory system is already very well developed amply before birth. The auditory apparatus of a five-month fetus is structurally comparable with that of an adult and at that stage the cochlea functions already. The auditory mechanism of a fetus of six months reacts to pure tones, and a seven-month premature responds both autonomically and behaviorally to a number of acoustic parameters (Eisenberg, 1979).
As soon as a child is born, he is able to discern all kind of acoustic features. During the last decade many studies have explored the infant's basic perceptual capacities and it is amazing to establish how well equipped a newborn is for the perception of speech. Without trying to treat these capacities exhaustively we shall discuss a few of them in the next paragraphs.
First there is a group of psycho-acoustic studies concerning the effects of frequency and of sound pressure level on infant perception (Eisenberg, 1979). By studying the electro-physiological responses, significant increase or decrease in the level of ongoing activity can be measured and correlated to the stimulus conditions. Results in this area indicate that e.g. signals with frequencies below 4000 Hz evoke two to three times more reactions than signals above 4000 Hz, whereas it is this very range below 4000 Hz that mainly is used for human speech communication. Moreover, low frequencies are felt as 'pleasant' by the newborn, whereas high frequencies are felt as 'unpleasant', correlating with comparable results in adults. In the same way loudness functions, essential for orientation in space, are in the newborn comparable with the norms in the adult. The mechanisms for processing intensity seem to be fully operational at birth: the infant is quite ready for attentive behaviour.
During the last two decades much research has been done on early basal capacities of speech perception in infants, in studies concerning categorical perception. Pioneering work in this area has been done by Eimas, Siqueland, Jusczyk, and Vigorito (1971). By means of the HAS-procedure (high-amplitude sucking procedure, in which the infant sucks on a pacifier wired to a pressure transducer), perception of differences in voice onset time in pairs of speech-like sounds ('BAH'- or 'PAH'-like) were measured as significant deviations of the base-line rate of sucking. It turned out that one- and four-month old infants did perceive exactly the same category boundaries as the (American) adults did. In subsequent studies comparable results were obtained in category boundaries in the onset frequency of second and third formant (differences in

consonant articulation) and in differences between nasal and stop consonants, and of stop consonants and semivowels.
Since it is unlikely that during the first weeks of life infants are rapidly trained in discrimination of the features of adult speech, the investigators concluded that a child is born with the perceptual mechanism tuned to the properties of speech (Eimas, 1985). Further research in other language communities revealed that infants all over the world are equipped with the same, and therefore biologically determined, inborn perceptual capacities.
However, does this mean that perception of speech is an inborn human capacity? Are infants indeed innately tuned to discern linguistically significant features? This hypothesis rests on two basic assumptions. Firstly the assumption that categorical perception is reserved to speech sounds only, which seems to be falsified in the meantime by studies on categorical perception of non-speech sounds as well (Cutting and Rosner, 1974). Secondly the assumption that categorical perception of speech properties is reserved for the human race only. And this assumption too has been falsified by e.g. studies of Kuhl and Miller (1975, 1978), Morse and Snowden (1975), Waters and Wilson (1976), and Kuhl and Padden (1983), who demonstrated that non-humans like chinchillas and rhesus monkeys show exactly the same sensitivity for phonetic category boundaries as humans do. So the conclusion presses forward that these capacities are inherent in the auditory system of several kinds of mammals, and that the evolution of speech and language has optimally made use of these properties.
Apart from studies concentrating on discrimination of speech sounds are those on the infant's perception of similarity across variability in speakers, in vowel context, in stressed or in unstressed syllables, or in the position within the syllable (Kuhl, 1986; Jusczyk, 1986). Cross-speaker categorization, however, seems to be a capacity of the auditory system as well, since infants, cats, dogs, and chinchillas display similar results (cf. Studdert-Kennedy, 1986). Moreover Kuhl (1986) found that after some training infants of 5.5 months of age were able to neglect speaker variability in favour of categorization of vowels, even acoustically very confusable ones. On the other hand Mehler (1986) stated that infants of only four days of age displayed greater sensitivity for their mother language than for any other language, even when the languages were spoken by the same speaker. Does this mean that infants are accustomed to the features of that specific languages in only four days,whereas they were sleeping even most of the time? Or are these the results of a perceptual learning process started amply before birth?
What do we actually know about how these early perceptual capacities develop to the level of understanding speech?
In a clear way Bertoncini (1986) showed a developmental trend in the infant's speech processing capacities during the first few weeks of life. Her results from a study in co-operation with Jusczyk (1987) indicated that neonates when exposed to different CV-syllables display sensitivity for changes in vowel categories only, whereas two-month-old infants show sensitivity for changes in consonants as well. At this point, however, many questions arise with respect to the interpretation of these data. Are not the results of these experiments inherent in the nature of the sounds the infants were exposed to, in relation to the capacities of their auditory system ?
For instance, the main frequency areas of vowels are much lower then those of most consonants, whereas the auditory system of newborns is much more sensitive for low frequencies than for high frequencies. Normally the duration for vowels is longer, the intensity level is higher than for consonants. Besides vowels are more static whereas most consonants are more dynamic in nature. So how do we know that the increase of sensitivity for consonants in infants of two months is not the result of a physiological maturation of the auditory and neurological system?

The same kind of criticism holds for conclusions on syllables or phonemes as the basic representational units for infant speech perception (Bertoncini and Mehler, 1981; Jusczyk, 1986, 1987). But does it make sense to speak here of any linguistic representations, as if to be innate in the infant predestined to be born in a language speaking world full of linguistic rules? It is in our opinion essential to differentiate between auditory capacities on the one hand and the use that is made of them or has to be learned to made on the other hand. And infants indeed are perfect learners, from their very first day of life onwards being fully involved in interactive learning programs within the small society they have to communicate with.
Results from several studies on early perception illustrate this capability. Eilers, Gavin, and Oller (1982) found that infants of 6-8 months of age from different linguistic backgrounds apparently used their early linguistic experience in discriminating language specific contrasts. Werker (1982, as mentioned by Studdert-Kennedy, 1986) showed that children between six and twelve months of age when learning the sound system of their specific language, gradually lost their capacity to discriminate contrasts that are not used in their language environment. It is clear that under the influence of physiological maturation and of interaction, the codes and rules for the perception of the mother tongue are acquired and organized for communication.
In Fig. 2 the various child perception levels of Fig. 1 have been elaborated schematically on the basis of the data described up here.

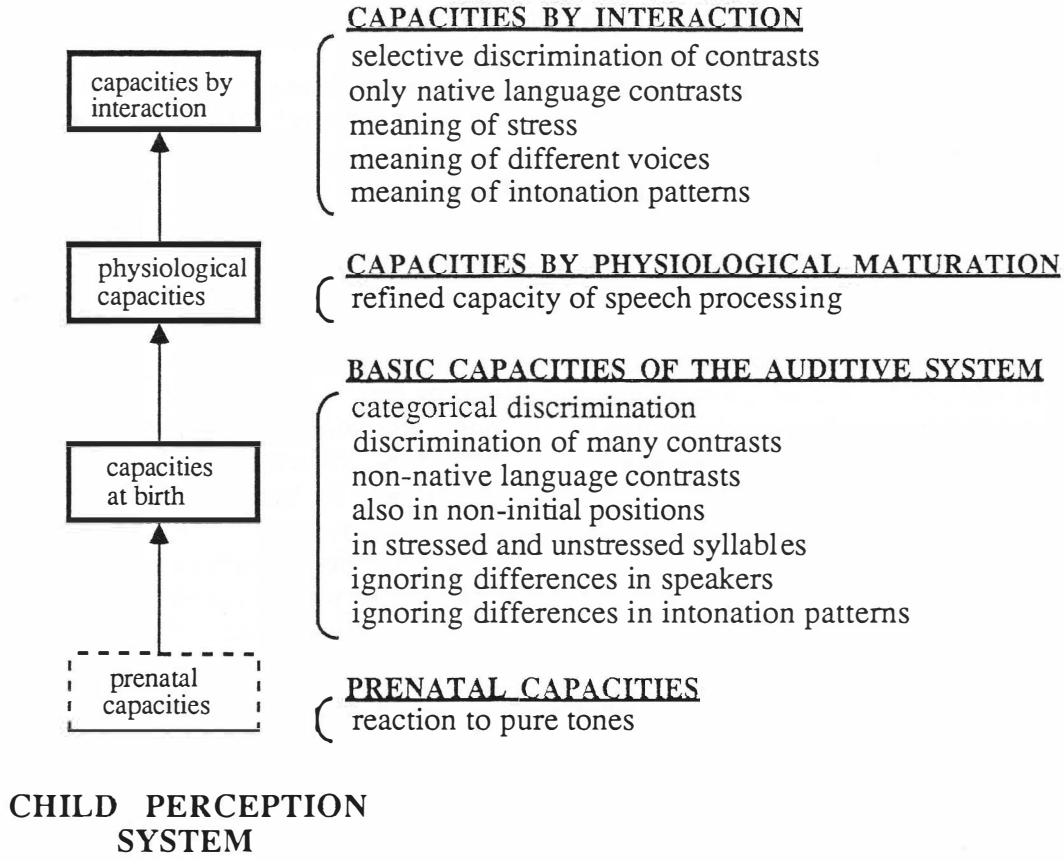

Fig 2. Various levels of infant perception capacities in detail.

5. CAPACITIES FOR EARLY SPEECH PRODUCTION

As said before speech production presents us with totally different problems than speech perception, since the starting point for sound production coincides with birth. From an evolutionary point of view the sound production mechanism is by no means primary intended for speech communication, but for two vital functions: an alimentory and a respiratory one. Moreover, the vital function of the larynx is protection, not sound production. It might be possible that laryngeal and respiratory muscles have been activated before birth already, but in premature children paradoxal respiration is frequent (Wind, 1970). In the neonate breathing is controlled in a rather reflexive way by the respiration centre in the brainstem. For the production of speech, however, the infant has to regulate the airflow, providing natural limits of his sound productions. In the same way movements in the oral and pharyngeal cavaties may be prenatal, thumb-sucking and swallowing in uterus is quite frequent. But after birth, apart from these activities, the child has to learn to reorganize elements of motion into new movements that are adapted to speech production. Form and structure of the oral cavity of a newborn is different from the adult's, the velum in rest position is lowered, the tongue is relatively massive and limited in motion. Only gradually function and shape are changing, the velum is raised, the tongue develops into an organ capable of many variable movements, and lip functions become more complex (Van der Stelt and Koopmans-van Beinum, 1981). So we have to conclude, when considering figure 1 again, not only that sound production starts in a later stage than sound perception, but also that the physiological development and maturation of the sound production mechanism play a much more important role in the first months of life than those of the sound perception mechanism.

Therefore it is in our opinion sensible to access the developing capacities for sound production primarily from a sensorimotor point of view, relating them to other aspects of gross motor development in the infant (Van der Stelt and Koopmans-van Beinum, 1986). This approach avoids linguistic problems of unclassifiable sounds (Kent and Murray, 1982), or of labeling the infant sounds by means of adult linguistic labels, based on one specific language (Stark, Talkin, Heinz, and Bond, 1982). Only after mapping the sensomotoric development of the sound producing mechanism in well defined stages, it will make sense to describe the acoustic aspects of early sound productions and to trace the first evidence of linguistic influence.

In our own research (Koopmans-van Beinum and Van der Stelt, 1979, 1986) we therefore described the development of sound productions in the first year of life by means of phonation aspects and of movements of the articulation instrument.

Hereby we based ourselves on the source-filter model for speech production, using one respiration cycle (one breath group) as a segmentation unit. The source consists in lungs and larynx, together responsible for the phonation, which can be continuous or interrupted. The vocal tract functions as a filter by the movements of the organs within it, and in the various combinations with phonation yields syllabic effects, essential for speech and being, as Oller (1986) claims, "the minimal rhythmic unit of natural languages" (p.24). In principle this model is identical and valuable for infants as well as for adults, since these simple materials for phonation and articulation provide us with the basic elements for the description of both adult speech events and early, developing infant sound productions (see Fig. 3).

Thus describing the early sound productions of two infants during their first year of life, we arrived at an identical developmental pattern for both (Fig. 4), later on confirmed by data on other infants in our own research and in others' (Koopmans-van Beinum and Van der Stelt, 1979, 1986; Holmgren, Lindblom, Aurelius, Jalling, and Zetterström, 1986).

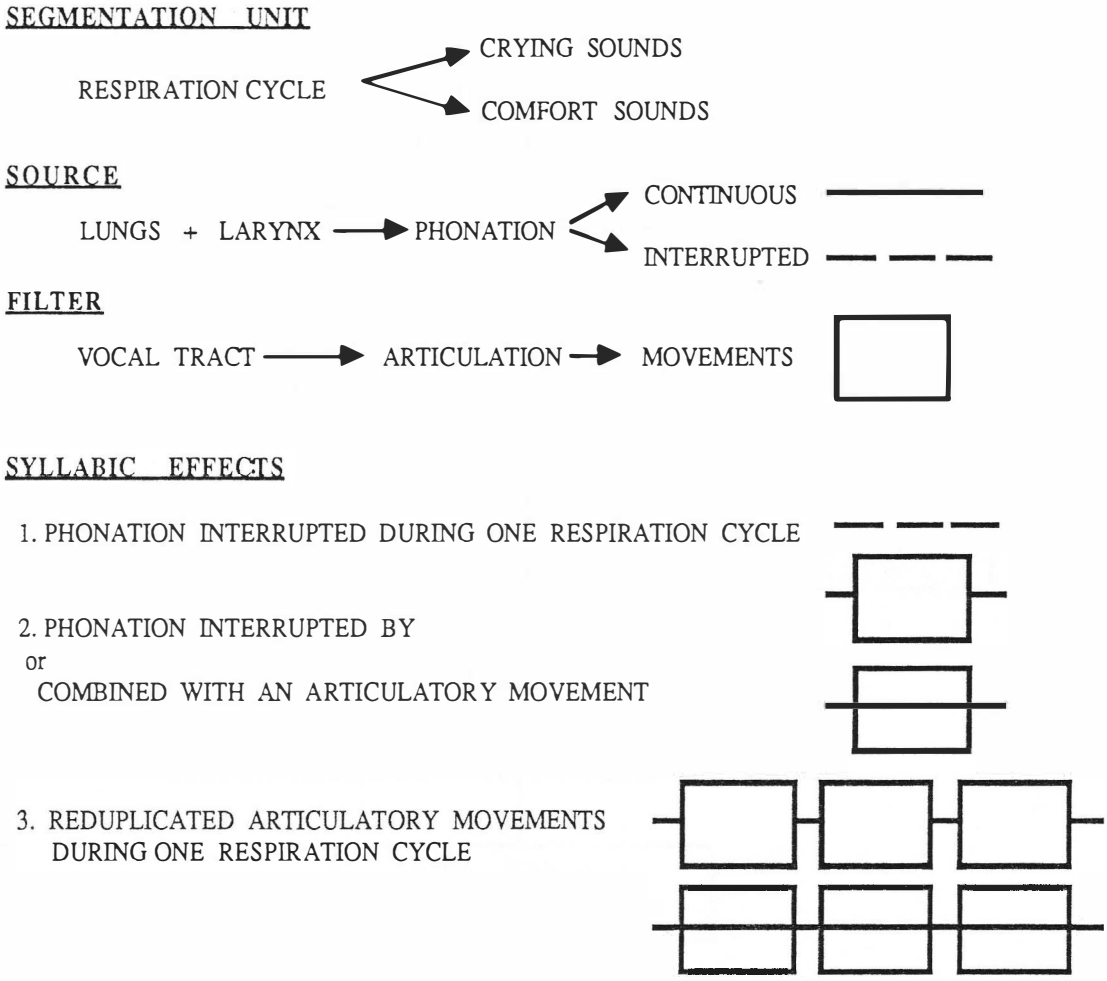

Fig. 3. Elements of infant sound production analysis, based on the source-filter model of speech production. Combinations of these elements provide syllabic effects, essential in infant speech development as well as in adult speech events.

This pattern seems to be defined in a great measure by physiological development, since comparable results have been found in Down's syndrome infants (Smith and Oller, 1981) as well as in deaf children, although the later stages of our scheme (Fig. 4) seem to be retarded here more and more (Oller, 1986; Kent, Osberger, Netsell, and Goldschmidt Hustedde, 1987).

An intriguing question now is at what moment in this pattern of developing sound-production capacities we can trace the influences of the specific language environment for the first time. This question brings us to the top levels of our capacity scheme (Fig.1) and extends from external speech production system to external speech perception system.

The question whether language-specific effects can be established in the sound production of infants within their first year of life has occupied many scholars. Weir (1966) claimed that infants of about six months growing up in a tone language background, for instance Chinese, can be marked off from infants of other linguistic backgrounds on account of their sound productions. However, I always had my doubts about these claims, since it is almost sure that she compared children in different developmental stages (see also Locke, 1983, who shared my doubts). In none of the other cross-linguistic studies discussed by Locke, detection of the linguistic background of the infants, based on their sound productions, is overt before one year of age.

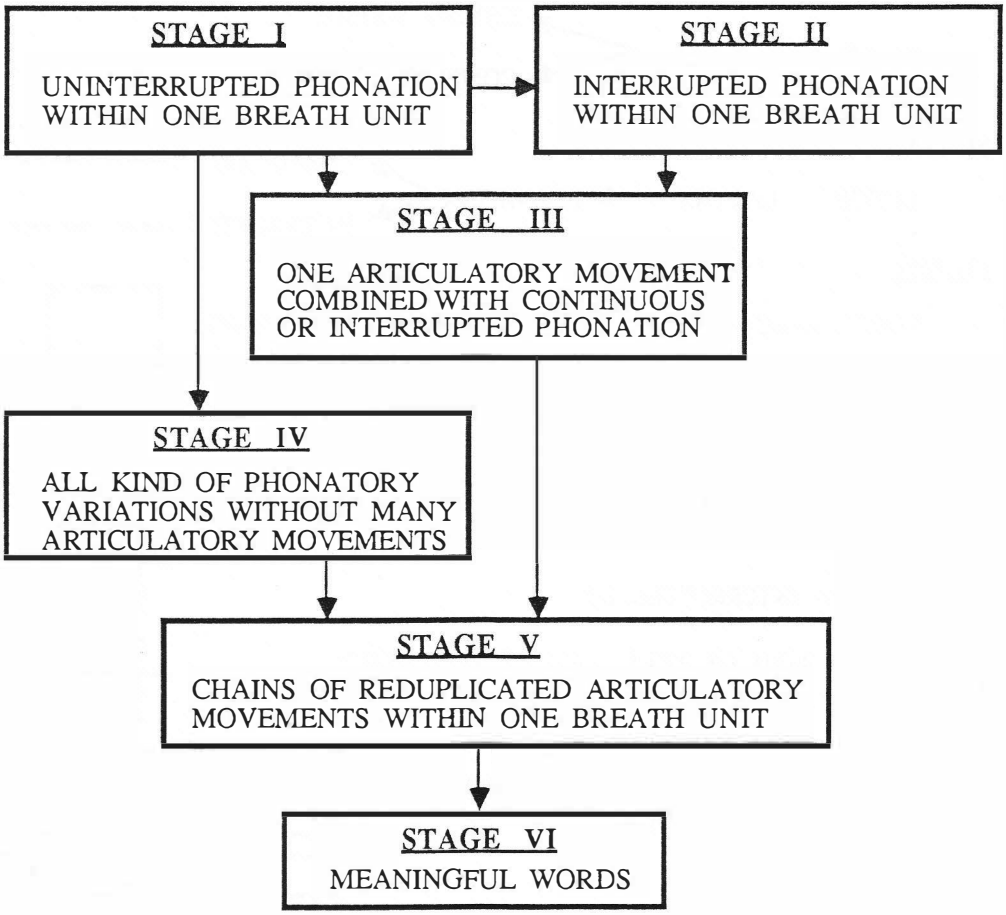

Fig. 4. Infant speech development from birth onward, represented in a hierarchical scheme of subsequent stages. Arrows indicate which aspects are necessary to perform the next stage.

Apart from these perceptual approaches Locke(1983) mentions a number of studies, applying acoustic measurements to distinguish infants with different linguistic backgrounds, on the basis of their sound productions. Again none of them reveals positive results, but here again it is quite possible that in a number of cases, sound productions have been compared from infants in different developmental stages, but selected on *similarity of age*.

The results of the study of De Boysson-Bardies (1986) presented at the above mentioned symposium and sequel to De Boysson-Bardies et al. (1986), are up to now, as far as I know, the only instances of linguistic background influences within the first year of life ever traced. Unlike the other studies, mainly concentrating on consonantal features, she drew her attention to vowel-like sound productions, since they are believed not to make such a high demands upon the infants' motor control system. In this study she investigated the vowel spaces of twenty 10-month old children from French, English, Algerian, and Cantonese linguistic backgrounds. Tape-recordings were made during 40 minute sessions in home situation. Subsequently all the children's sound productions were transcribed into IPA. Next all first vowels within each clear canonic babbling string were analysed, supplied by measurements with some of the second vowels in a string in order to represent in the data the frequency of occurrence of the vowels in the total sound production sample of the infants. Spectral analysis revealed that the centers of the vocalic space, expressed in the median values of F1 and

F2, differed significantly in accordance with the articulatory characteristics of the target languages. The results of De Boysson-Bardies look reliable, although some questions are still remaining. E.g. who made these transcriptions, one or more transcribers per language, knowing or not knowing the target language? Why has this quite unreliable procedure been used, whereas one might attain the same results only by taking all first or second vowels? Another point that did not become very clear, is the question on the base of which data the main characteristics for French, English, Cantonese, and Algerian were defined. Are not here only global articulatory descriptions involved? Acoustic measurements for adults comparable to those of the infants might have been much more convicting.

6. EARLY INTERACTION

When discussing the theoretical framework (section 3.) we stated already that a main aspect within the development of speech communication is the role of interaction. In the preceding sections 4. and 5. we discussed the possibilities of the instruments for speech communnication, in this section attention will be focussed on learning to play the instruments. As demonstrated in Fig. 5 this can be done in various aspects: e.g. studying the relationship between coding system and result, viz. between form and content, or studying the role of imitation within speech development, or studying the developing interaction process of adult and infant as a whole (cf. Clark, 1978). The first aspect has been taken up by Franco and D'Odorico (1986), the second aspect by Kuijpers (1987: this volume), and the total interaction process by Van der Stelt (1986, 1987: this volume).

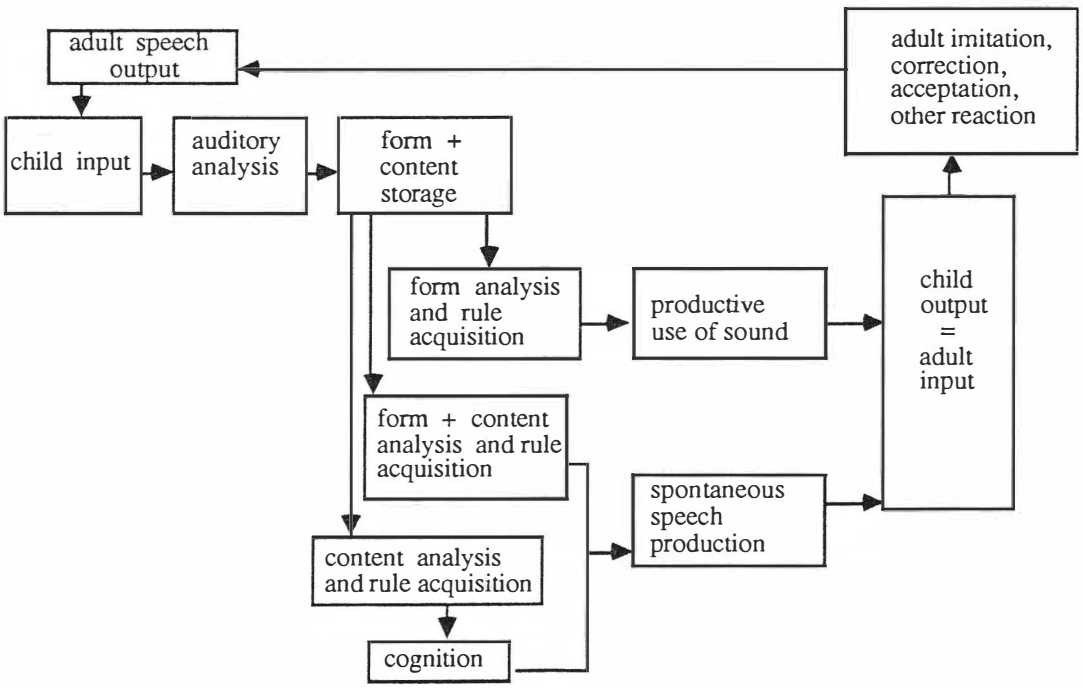

Fig. 5. Model of the role of interaction within the development of early speech communication.

In the early seventies Delack (1974) and Delack and Fowlow (1978) were among the few studying speech development from a non-linguistic point of view, focusing on the ontogenesis of the relationship between sound and meaning (or form and content). Apart from that, studies of Muller, Hollien, and Murry (1974) and of Murry, Hollien, and Muller (1975) involved identification of infant cry types, as well as maternal recognition of sex and infant on the basis of the infants' cry sounds.

The study of Franco and D'Odorico concerns the infant's sound productions in interactive situations, cry sounds as well as non-cry sounds. Their premise is that one of the prerequisites for the development of speech communication is the developing correspondence between sound and meaning. So the aim of their study is to indicate the origin and development of any sound-meaning regularity. They therefore analysed non-segmental features like intonation pattern, manner of phonation, and duration of cry and non-cry vocalizations in various interactional situations. Data were obtained from four subjects, video- and audio-recorded bi-weekly during five months from four or five months of age onward. Franco and D'Odorico's analyses of cry sounds concern the period from 4 to 9, or 5 to 10 months, and their data on non-cry vocalizations concern the period of 6 to 9 months.

Their results indicate an early, functional, sound-meaning correspondence along a developmental route with cry and non-cry vocalizations having specific communicative functions. But here again the methodological problem, mentioned before, arises. Within these periods of analysis all measurements of Franco and D'Odorico are grouped together. In our own research on early non-cry vocalizations (Koopmans-van Beinum and Van der Stelt, 1979, 1986) we discerned various developmental stages of sound production in the first year of life. In my opinion it is absolutely necessary to indicate the developmental course within these periods to get a better insight into the problem of continuity and discontinuity in the development of sound and meaning correspondence? The results on cry behaviour, for phonation as well as for intonation, reveal large differences between the four children in the study of Franco and D'Odorico. This might be the result of grouping together the data of too large periods. Another possibility is that each child displays his or her own behaviour, possibly depending of the special mother-child pair. But it is not possible to resolve this problem, as long as no information on the developing interaction processes is available.

In the symposium paper of Van der Stelt (1986) she discussed the development of interaction (the arrows in the scheme of Fig. 1) between mother and child in the first six months of life. She demonstrated for this purpose her multichannel coding system, trying to trace recurring and at the same time developing patterns of interaction in the total communication. The development of social responsiveness, which is one of the cornerstones of speech communication, starts in the development of patterns within the total communication in the individual mother-infant pair. So the study of the interactional processes is basic for all speech communication research, and it is therefore, in my opinion, very short-sighted to unlink this area from speech and language development or from speech communication in general.

The research of Van der Stelt (1985, 1986, 1987) focuses on the development of the interaction process in the total communication of individual mother-child pairs. It is more and more common to consider the pair as a self-adjusting system (Schaffer, 1977; Kaye, 1979; Trevarthen, 1979). Internal and external feedback within and between mother and infant play an essential role here. In the first instance it is therefore important to study each mother-infant pair individually. However, it might very well happen that one will find totally different patterns within each new mother-child pair. So if it is believed that each mother has her own pragmatic and interactive style and her own program, which she adapts to the stagewise growing competence of the infant, it will only be possible to speak of *the* development of interaction and communication, if identical stages can be established within the interactional process. The results of Van

der Stelt (1987, this volume) up to now seem to point into that direction and are perfectly in agreement with stages in motor behaviour, as indicated by Von Hofsten (1986) and by Trevarthen and Marwick (1986).
Within this view speech or sound production is to be considered as part of a multichannel coding system, more and more growing in importance and taking over several aspects of other channels. It is clear that physiological and neurological maturation and development will play an essential role here and are basic for the whole interactive process of speech communication development. Studying the role of imitation within this process (a recently started research project in our institute) provides us with the possibility to trace the speech learning process in the acoustic-phonetic aspects as well (Kuijpers, 1987: this volume).

7. CONCLUSION

Without nursing the illusion of being able to treat this subject exhaustively, I tried to give an outline of the early capacities for the development of speech communication. Within a tentative theoretical framework of the infant's growing capacities several pieces of an immense jigsaw puzzle occupy their places. At the same time it becomes obvious that an multitude of problems still have to be solved. The course of very early infant perceptual development owes our close attention, especially to establish at what moment we might discern the influences of linguistic interaction and the influences of the specific language environment. But for this purpose we need to know the ways by which interaction develops and which is the normal developmental course of social responsiveness. Is there any system in the way infants make intentional use of their sound production tools or is each infant using his own individual system to express his feelings or intentions? And we urgently need longitudinal studies to establish whether it is possible to indicate the first evidences of specific language sound production capacities as the result of highly developed perception and interaction capacities, apart from physiologically determined capacities.
In our own research as well as in studies directly related to our institutional research program we will focus our attention especially on some of these black holes in the puzzle of the development of early speech communication.

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