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THE VOCALIZATIONS OF INFANTS

PART I. STUDIES

PART II. METHODS OF RECORDING

BY DOROTHEA McCARTHY
NATIONAL FELLOW FOR RESEARCH IN CHILD DEVELOPMENT, 1928–1929
Institute of Child Welfare, University of Minnesota

Introduction: The incomprehensible vocalizing and babbling of infants and the final emergence of true language from this prolonged period of practice have attracted the attention of writers in many fields, and particularly those in the field of child study. The bulk of the literature on this topic consists of a large group of semi-scientific observational studies of a biographical nature, which appeared during the last decades of the nineteenth century and the first part of the present century. Many of these records are concerned, not only with language development but also with motor, social, and emotional development. Other studies, however, are much more defined in purpose, and are somewhat narrower in scope, being confined to the study of the child's acquisition of language. The studies which give adequate reports of the very early stages, however, are much less numerous than those which are concerned chiefly with the period immediately following the appearance of the first word. Unfortunately, the studies which involve the observation of many children under controlled conditions are very few in number and much needs to be done along this line.

Previous Reviews: The literature on this topic has been brought together from time to time by various writers. Most of the available reviews, however, are concerned chiefly with the vocabulary studies

on older children, and little or no space is devoted to the earliest stages of linguistic babbling. They consist chiefly of tabulations of all reports on the appearance of the first word, or of tabular comparisons of different vocabulary counts. In 1833 Feldman (15) gave such a review based on the records of 33 children. The mode of this group for the appearance of the first word was at sixteen months. In 1883 a very brief review of foreign studies was given by Sikorski (55). Preyer (48) in reporting his son's progress in language compares it with the earlier reports in the literature, particularly those of Stumpf (62), Lindner (32 and 33), Sigismund (54), and others. In 1891 Sanford (50) gave a very brief and incomplete summary of what had been done in the field up to that time. Tracy (67) in 1893 gave a very clear and complete summary of the studies of children's language up to two years of age. He calls it "an outline history of the speech-progress of the average child during the first two years, generalizing from a large number of observations made by different persons on different children." While it is difficult to combine the records from these biographical studies because of the different methods of observation, Tracy (67) has made the most satisfactory summary of the literature on these early stages. Neumann (39) gives an excellent discussion of the early anecdotal accounts in the foreign literature, particularly those of Ament (2), Lindner (32 and 33), Gheorgor (20), and others. In 1907 Clara and William Stern in their book called *Children's Speech* (58), gave an excellent account of all the observations on German children as well as on children of other nationalities which were published previous to that time. Doran (11), Gerlach (17), Grant (21), Magni (37), and Pelsma (43), all give tabular summaries of vocabulary studies. All of these summaries appeared between 1907 and 1920. The most extensive of them is by Grant (21) in 1915, which includes a comparative table of 85 vocabularies listed by about 20 different authors, on children varying in age from twelve months to six years. In 1917 Bateman (3) tabulated the age of appearance of the first word as it is reported in the literature. It includes reports on 35 cases, of whom 18 were English-speaking children, 12 were German, and 5 were of various other nationalities. He finds that about 43 per cent of the group used the first word in the tenth month, and that by one year 74 per cent of the children had begun articulate speech. In general, he finds boys reach the stage of the first word later than do girls. There is a wide variation in the age of appearance of the first word

reported in the literature, the range being from six months to three years. It will be noted that the reports which Bateman (3) summarizes give a much earlier average age of appearance of the first word than do those reported by Feldman (15). Since Bateman's (3) report appeared, Bloch (6) has published papers in which he indicates that his two daughters spoke their first words at nineteen and at twenty months, and that his son uttered his first word at eleven months. Esper (14) in 1921 gave a brief review of all the work on language during the five-year period from 1917 to 1921. He reports practically no work on children, and in fact he says of the whole field of language, "this field is not being extensively worked by psychologists."

In the Twenty-eighth Yearbook of the National Society for the Study of Education, which appeared in 1929, and which is devoted to the preschool child and parental education, there is an excellent section on language development. This section includes abstracts of 123 published studies on language development and also of twenty researches in progress. Immediately following these abstracts, this section presents an excellent discussion of the methods used in these studies and of the results obtained by them. The May, 1929, issue of the PSYCHOLOGICAL BULLETIN, which is called a "Special Language Number," contains several reviews on various aspects of language, but none of them is particularly concerned with the linguistic development of the young child and there is hardly a mention of the early babbling stages of infancy.

Of the numerous general discussions on language some are of much greater interest than others. In 1885 Perez (44) gave a very good chapter on the earliest stages. Hall (22), Chamberlain (7), MacDougall (36), and Rasmussen (49) are among the earlier writers who gave discussions of the acquisition of language by infants. O'Shea (42) gives a long and detailed account of the various stages in language development in the young child. Allport (1) gives an excellent description of the organs involved in speech and explains the infant's learning of words on the conditioned reflex principle. Stinchfield (61) and De Laguna (31) are among the more modern writers who give general discussions on language, but they are little concerned with the very early stages.

Biographical Studies: The writer has listed about forty observational studies of single children, all of which are concerned in whole or in part with the earliest utterances of infancy. Many of them con-

tinue up to the later stages of true language, but the present summary will follow them only to the stage of the first word or the first sentence. The earliest reported study of this sort is that by Tiedemann (40) which was done in Germany in 1787, and which has recently been translated into English by Murchison and Langer (40) who said that this study is "usually regarded as the first attempt to make a series of scientific observations on the behavior of young children." In speaking of his son at about four months of age, Tiedemann (40) says: "He also commenced to exercise the tools of speech by all sorts of sounds, without being incited to do so; but he attempted no imitation as yet. . . . Apparently children practice for a long time before they can produce simple inarticulate sounds and easy articulations . . . and the speech-organs, just like the hands, must be prepared by long rehearsal for the production of sounds previously imagined or exampled." This study, and the statements found in it are particularly interesting from the historical point of view, for many observations like the above have been reiterated innumerable times by more recent investigators. Taine (65), another early observer, also notes, "There is the same spontaneous apprenticeship for cries as for movements." At three and one-half months his daughter used only vowel sounds, and he adds, "By degrees consonants were added to the vowels and the exclamations became more and more articulate. It all ended in a very distinct twittering." Prompted by these interesting observations reported by Taine (65), Darwin (9) published about this same time some of the records which he had kept in his diary of his son. In addition to these studies, the most complete and best known include those by Bateman (3), Fenton (16), Mrs. Hall (23), Major (38), Moore (41), Preyer (46), and Shinn (52 and 53).

The birth-cry, as well as all the earliest cries of infants, have been variously interpreted. It seems to have lost its strong emotional connotation of joy or of "wrath" at entrance into the world, until now it is considered by most writers a mere reflex gasp. The Blantons (5) say, "The birth-cry is a reflex activity, the object of which is, apparently, to supply the blood with fresh oxygen. The cry is more or less incidental, as it is the result of the air being pulled rapidly over the vocal bands (or cords) causing them to vibrate." Major (38) also speaks of the first stage of language as "reflexive crying" and he insists that this cry has no intellectual or emotional significance. He points out that such cries "are produced as well by

a child without a cerebrum as by a child with one. . . . What one means then," he says, " by saying that language has its beginnings in these reflexive cries is that much of the physical apparatus which is used in later speech activities is involved in the early reflexive cries."

There have been various reasons given for the cries of early infancy and many interpretations have been given to them. Champneys (8) says: " The child appeared to cry at first for three reasons: (1) from a feeling of loneliness or fright on awakening from sleep, . . . (2) from hunger, (3) from pain." The cries seemed to be all different in character. Dearborn (10) reports that " on the seventeenth day crying was differentiated according to cause." Darwin (9) also reports, " The noise of crying or rather of squalling, . . . is of course uttered in an instinctive manner, but seems to show that there is suffering. After a time the sound differs according to the cause, such as hunger or pain." The more recent literature contains statements denying any such meaning in the early cries. For example, Fenton (16) says, " During this early period sounds are reflex in character; when the vocal muscles chance to contract, sounds arise, but they are uttered without intent, and are not to be thought of as indicating particular meanings. Variations in sound are more often indicative of differences in intensity than anything else. The greater tension of muscles under stress of excitement flattens the sound and makes it more shrill in extreme hunger or pain."

Two studies which were concerned with groups of infants tend to contradict the earlier interpretations of the first cries, and to substantiate the latter point of view. The first of these is an observational study of twenty-five infants during the first thirty days of life, by Mrs. Blanton (4) who says of the birth-cry, " It differed in no way in timbre, pitch, etc., from other cries of the first few days. The birth-cries of different infants were not alike, ranging from simple *a* (as in *at*) to *u* (as in *cut*)." And again she states, " In the subjects with which I worked I did not find the cries of hunger, to noxious stimuli, to fatigue, etc., uniform. There were differences of vowels and consonants, of timbre and degree, but no one was used as response to one set of circumstances that was not at the same time used to others. . . . The cry of colic was the one exception. . . . The ' hunger cry ' has generally a well marked rhythm." In another reference (5) she says, " During the first months of life, the cries of the infant are in response to hunger and pain and cold, and differ from each other only in intensity."

Another study on a group of infants is the second part of an experiment on the *Differentiation of Emotional Responses in Infants* by Sherman (51). It is concerned with "the ability of observers to judge the emotional characteristics of the crying of infants." The results indicate that "there was very little success in judging the emotional accompaniment of the cry when the stimuli were not known. When the stimuli were known to the observers, they named the emotions which were usually expected to result from such stimuli." This result is very interesting because of the light it throws on the previous studies which have given all the various interpretations of these early cries. It must be remembered that the observers in these early studies always knew the stimuli for the cries, and hence were unduly influenced in their interpretations by the knowledge of the situation, rather than by any peculiar characteristic of the cries.

Sounds Reported in the First Months: According to Preyer (48) "the order in which the separate sounds independently appear varies greatly with different children." He includes a table which shows the different vowel and consonant sounds produced by his own child during the first twenty-seven months. He also says, "Observations have shown that by far the greater majority of the sounds which a child uses after it has learned to talk, and many made in addition to these, are rightly formed by him within the first eight months of his existence. . . . The plasticity of the youthful organs of speech renders this feat easy; and no child has been observed to proceed consistently in accordance with the principle of least effort." Egger (13) reports that at five weeks the mouth and tongue were used to modify the cry. According to Perez (44) De la Calle reports a preference for the vowel *a* during the first three months, that at four and one-half months the first explosive articulation was added to the vowel, and that at five months there was articulation during expiration. Taine (65) says that at three and one-half months vowels only were present, and that by degrees the consonants were added. Fenton (16) states "there is . . . great richness and variety in the babble as a whole. Usually it contains a far wider range of separate sounds than the child will have use for in later life. Among my baby's first sounds were a number of gutturals not used in English at all, among them the German *ch*, and a harsh throaty *gh*. The German sound of *o* and the French *eu* occurred frequently, and a considerable number of slurred vowel sounds which I could not set

down at all in our alphabet. Together with these occurred in many different combinations nearly all the sounds used in English, though put together often in combinations which we never use, such as *dzhi, dth, ngya.* The sounds of *f* and *v* I did not catch at all during the first year, nor *cu,* though the *k* and *w* sounds of which it is composed were common." This is one of the better of the many similar accounts of the sounds of early infancy which are found in the biographical studies. The earlier ones are well summarized by Tracy (67), and on the basis of the many reports which he studied he says: "The next step is taken when these cries and babblings assume an articulate character. The alphabetic sounds begin to be heard. Of these, the vowels usually precede the consonants; and of the vowels, *a* with its various shadings is generally the first to appear." After describing the acquisition of sounds by different children for whom this period has been reported he says: "Long before the sixth month, the primary vowels are combined with one another . . . and with consonants, to produce the first syllabic utterances. . . . In a great many of the cases under consideration, the first consonants to make their appearance are the labials, *b, p, m,* and these are almost always initial at first, and not final. . . . The labials are not always, however, the first consonantal sounds uttered. Sometimes the gutturals (*g* or *k*) precede them; and the two consonants which are usually the last to appear (viz., *r* and *l*) are used by some children quite early." Pollock (45) says that "in some cases nearly all syllables have been correctly pronounced during the first half-year; while in others progress is much slower, very few syllables being mastered before the ninth month." Gesell (19) presents the results of a complete twenty-four-hour record of the vocal activities of a six-months-old child. He says that it was calculated that 3 per cent of the waking time of the child was expended definitely in some form of speech or language activity. At nine months this same child expended 6.66 per cent of its waking time in such activity. He gives the frequency of the various sounds used by this one child during one day at six months of age. "There were 104 separate moments of vocalization during the day, carrying in complexity from one letter sounds to 32 repeated syllables; 75 sounds and combinations of sounds were used."

Thus it seems that there is great individual variation in the make-up of this babbling, and there are divergent opinions as to its content, no doubt due to the fact that different writers observed dif-

ferent children at different stages. Of the more recent studies, the best is Blanton's (4) in which are listed all the sounds made by twenty-five infants in the first thirty days. Among the consonants are *m* as in *ma* (*at*), *n* as in *nga* (*nat*), *g* as in *gah*, *h* as in *ha*, *w* as in *wah*, *r* as in *rah*, *r* as in *burr*, and *y* as in *yah*. The vowels reported by her are *o* as in *owl*, *e* as in *feel*, *oo* as in *pool*, *a* as in *an*, and *a* as in *father*, though the last is rarely heard. Mrs. Hall (23) reports lists of the sounds used by her son at various stages, in the order of their appearance during a day's observation. None of these lists were made, however, before the child was a year old. Holmes (26) gives a recent account of his child's speech in which the International Phonetic Alphabet was used in recording the sounds used.

Imitative Stage: After the infant has acquired quite a wide variety of sounds in his repertoire most writers report a tendency to imitation occurring during the second six months of life. Among those reporting this imitative stage is Champneys (8) who states that " from nine months the child distinctly imitated the intonation of the voice when any word or sentence was repeated in the same way several times," Grant (21) says of his child, " It is difficult to say at what age E. began to imitate, but not until she had made sounds and movements similar to those imitated." Mrs. Hall (23) recorded on the 221st day, " very early in the imitative stage the lip movements accompanying such words as *mamma*, *papa*, and *bye-bye* were repeated," and on the 223rd day, " in response to a lady's farewell he imitated both the gesture and the word." Taine (65) says in speaking of this stage in his daughter, that when two sounds which she had discovered by herself were repeated to her several times, " she listened attentively and then came to make them immediately she heard them. . . . In short, example and education were only of use in calling her attention to the sounds that she had already found out for herself . . . but all initiative belongs to her."

Practically all writers on the subject of child language emphasize the tremendous importance of something called imitation in learning to talk. The facts that the deaf child does not talk, and that the normal child learns the language which he hears spoken by those about him regardless of his parentage or the country of his nativity, all bear strong witness to the rôle of imitation in language learning. A clear distinction has to be drawn, however, between exact mimetic imitation, and mere imitative attempts at reproduction of sound, imperfect as they may be. Some writers hold that the first type of

imitation is what is found in the young child who is learning to talk, but the majority seem to consider this exact reproduction very rare, and to agree with the opinion of Taine (65) quoted above, that the child imitates only the sounds which have already occurred in its spontaneous utterances, and that no purely new sounds are added by this process of imitation.

Language Comprehension: The biographical literature under consideration is full of anecdotal accounts as evidence that the children understood what was said to them, and also as evidence of early associations formed by young infants between certain words spoken by others, and certain objects or situations. In many of these statements the unreliability of the parents' report undoubtedly enters in to a marked degree, and hence very little scientific value attaches to such accounts. Some of them have been given extremely doubtful interpretations, many of them are reports of single events, which may have been chance occurrences, and in which the infant could not be induced to repeat the act. Some, on the other hand, have been reported by reliable observers, and probably have not been interpreted too optimistically. One of the best known of these incidents is reported by Sigismund (54) who showed his child a stuffed woodcock and said, "bird," whereupon the child looked at a little stuffed owl in another part of the room. Darwin (9) reports that his son understood words, gestures and sentences long before they were used by him. In many of the reports of children understanding language, the possibility of gestures accompanying the words is not eliminated. Humphreys (27) says that at eight months of age his child knew by name everyone in the house. Drummond (12) reports that at fifteen months his daughter obeyed simple commands, and Mrs. Hall (23) states that on the 150th day her son looked in the mirror when the word "baby" was spoken to him. Thus, it is evident that while these incidents are frequent in the biographical accounts of child development, they vary so much from one child to another, not only in the circumstances surrounding them, but also in the ages of the children at the time of their occurrence, and the observations of the parents are so scanty, and their interpretations so subjective, that this part of the literature contributes practically nothing to our body of scientific knowledge about the young child.

First Words: Nearly all writers on the subject of child language point out the fact that the first words uttered usually consist of reduplicated monosyllables. Perez (44) says that in the language of

children the roots or first attempts are monosyllabic sounds. "They more easily pronounce reduplicated monosyllables. For a long time they rebel against real dissyllables and still longer against polysyllables." Miss Shinn (52), in her *Biography of a Baby,* and also Preyer (48) give descriptions of this type of verbal response. Mrs. Hall (23) states that the first six words articulated by her son were words in which the syllable was doubled as in *bye-bye.* Most writers who mention this peculiarity of the first words point out the ease with which favorite syllables when doubled come to designate familiar persons and objects and hence we have the familiar appellations of babyhood, *mamma, papa, dadda,* and *bebe.* Kroeber (29) in reporting the speech of a Zuni child says that by his second birthday he "was drifting away from his early leaning to make every word consist of two identical but separate syllables." In concluding his study of the appearance of the first word, Bateman (3) states that the first words are usually nouns and interjections.

Among other studies which have been done with groups of young infants is the vocabulary study by Smith (57), based on 273 children, ranging from eight months to six years of age. Thirteen of these children were eight months of age, and none of them had begun to talk at that time. Seventeen of them at ten months of age had an average vocabulary of one word, and fifty-two at one year of age had an average vocabulary of three words. Hetzer and Reindorf (24) studied the language development of a large number of infants from different social classes. The children ranged in age from nine to thirty months, and records were kept for 103 half-day periods. Where the cries were purely instinctive no difference was found between the upper and lower classes. In all other verbal activities those of the laboring classes lagged definitely behind.

The earliest reactions to the sound of the human voice have been studied by Hetzer and Tudor-Hart (25), who observed 126 children ranging in age from three days to five months.

McCarthy (35) found that in her group of twenty children eighteen months of age, only 26 per cent of their responses were comprehensible, the boys having only 14 per cent comprehensible and the girls 38 per cent. The mean length of response for this group was 1.2 words. A clear superiority of the upper occupational groups was found.

Language in Intelligence Testing at Early Ages: In view of the foregoing discussion and in view of the important rôle which lan-

guage plays in measurements of intelligence in older children, it might be of interest here to consider the rôle of language in the few attempts that have been made to devise intelligence tests for the infant levels. Kuhlmann (30) was the first to attempt to measure intelligence at these early ages. The three- and six-months tests do not involve language at all, but at twelve months, the examiner is to note the spontaneous vocalizations of the child, their character, and the number of syllables that are combined. The test is "passed if there is satisfactory evidence that the child frequently combines two or three syllables (these may be reduplicated monosyllables), or words spoken to it, with some success." The speech test is passed at eighteen months "if the child unmistakably uses some words or understands a question without gesture." These tests, it must be admitted, are very subjective, especially so since the evidence of the mother or nurse is allowed. Also the Kuhlmann test at these early ages was standardized on a very few cases, and subsequent use of the scale has indicated that it is rather unsatisfactory.

Gesell (19) next took up this difficult problem of intelligence testing at the infant level. He uses language tests much more in his scale, and he divides them into three parts. The first group consists of tests of spontaneous vocalizations, the second of tests of language comprehension, and the third of language reproduction. There are nine items in these groups, each of which receives a number and letter score according to Gesell's norms. The standardization group used in this test was much better than that used by Kuhlmann (30) but the scoring system is less satisfactory, because each item is scored separately on a sort of sliding scale depending on the age of the child, and the quality of his performance.

The Linfert and Hierholzer (34) scale for measuring the mental development of infants contains three articulation tests in Series I, which is used for children from one to five months of age, and there are seven tests of language and language comprehension in Series II, for children from six to twelve months. These tests have norms based on 300 infants with fifty at each age level, and the percentages of success with each test item at each age are given, so that the developmental significance of the language tests can be determined. Of the articulation tests, those of *eh* and *ooh* show the best developmental trends, the former appearing first. In Series II, saying *bye-bye,* and saying more than one word give the best curves in relation to age in the range studied in the experiment.

From the appearance of these language tests and their relative importance in the different series, it will be seen that considerable emphasis is laid on the very earliest beginnings of language in all the work that has been done in the intelligence testing of infants. From the norms of these tests it is possible to glean some information as to the development of these different abilities, and their relative importance in the developmental process.

It may be said in conclusion that while the vocalizations of infants have long held the attention of writers, and publications on the subject have been quite numerous in the last century, information on the topic is still very scanty, and in a vague and hazy state. In general the last few years have been marked by a decided falling off in the biographical reports, and the increased appearance of studies on groups of children under controlled conditions. And even in these studies, the vocalizations of infants are usually incidental to studies of larger scope. The Twenty-eighth Yearbook of the National Society for the Study of Education points out: "The uncontrolled observations of a single child which filled the earlier literature on language development are yielding to the influence of the test, experimental, and clinical methods. . . . Our knowledge of language ability needs supplementing in every direction. More information is needed on sound production and intonation of young children, particularly of infants." And in conclusion it states: "To answer many of these questions, new techniques should be devised and the techniques already available be applied in new ways."

Part II. Methods of Recording

Psychologically the first word is quite an advanced stage in the linguistic development of the child, and the true beginnings of language, or perhaps, the necessary precursors of language, have long been going on in the early babblings of the infant. All the cries and various vocalizations of the infant which are preliminary to the complexities of language proper include many sounds for which we have no adequate written symbols, and hence some satisfactory method of recording them must be found before they can be studied scientifically.

The problem is of special interest, not only because of the light it would throw upon the origin of language, but also because of its relation to the whole problem of learning. There are two opposing views held as to the nature of the acquisition of language by infants. The first point of view, which is in accordance with what is known

about learning in most other situations, maintains that language learning occurs very gradually, the complex being built up from the simple. However, the facts that there are so many sounds made by infants which do not appear in any single language, and that any child, regardless of his parentage, learns the language which he hears spoken by those about him tend to give some support to the second theory, which holds that the child makes a very wide variety of sounds in his daily babblings, and that his repertoire includes many sounds which drop out later.

A scientific study of this problem, involving an accurate record of such sounds so that any sound could be identified when it appeared again, should throw light on many scientific problems.

Many investigators have indicated interest in this topic, and a scientific study of it is likely to be undertaken soon. The experimenter is immediately confronted, however, with a number of difficulties of methodology, which are described here in order to facilitate the work of those who may undertake the problem in the future.

Obviously, it is quite impossible to take down the sounds as they are made by the infant, in writing, in shorthand, or in a phonetic system. They occur too spontaneously, and too rapidly; they have no meaning to the experimenter, there is no conventional form for them, which can be abbreviated, and probably most serious of all is the subjective factor of the experimenter's error of listening. Even if we had symbols for the variety of sounds, they would have no meaning to the experimenter if he had never experienced the sounds which they represented.

There are two main types of permanent record which could be used in a scientific study of this sort. The first is the graphic type of representation, involving a wave tracing on a rotating cylinder representing the physical equivalents of the sound waves. The second is an audible record, such as the dictaphone or phonograph records of sound, involving the reproduction of sound from tracings in a wax or other type of record. In view of the serious limitations and subjective factors which enter into the use of the latter type of record, the first type would be much more desirable, if feasible.

The next problem which confronts the investigator is a survey of the available devices which give this type of record, and a consideration of the relative adequacy of the various instruments for the purposes of the experiment at hand. One of the earliest methods of securing a visible record of the sound waves produced during

speech was that of the manometric flame, invented by Koenig in 1862. In this device, the flame of a burning gas jet vibrates in response to the variations in pressure in a sound wave. Various methods of photographing the vibrating flame have been developed by many different workers; but, according to Brown (69), these photographs were rather unsatisfactory, because the flame has a very complicated manner of vibrating, particularly at the tip, and this method showed only the vertical movements of the flame. Richardson (84) points out, with regard to this technique, that "owing to its inconstancy the instrument is unsuited to absolute measurements of the pressure amplitude."

Another early device which led to further inventions along this line was the phonautograph invented by M. Leon Scott in 1859, which was the first instrument to make use of the vibrating diaphragm, discovered by Chaldin, for recording sound waves. This device records the sound waves directly, and consists of a membrane stretched across the focus of a parabolic sound reflector. The movements of the membraneous diaphragm are recorded by means of a lever, bent at right angles, and having one end resting on the membrane, and the other carrying a stylus, which traces the wave form on smoked paper, mounted on a hand driven cylinder. According to Seymour (91), the waves varied with the pitch and intensity of the sound, but were invariably constant for the same sounds. This machine, in its original form, was limited in its application, and usefulness, and was indeed open to many criticisms. However, as Scripture (88) says: this apparatus "is the prototype of the later machines that make speech records by registering the vibrations of a diaphragm on a moving surface by means of a lever."

This type of apparatus underwent numerous modifications, most of which were minor in character, the principle remaining the same. The Marey tambour was adapted to use with kymographs by many investigators. Some of the most thorough researches with apparatus of this sort were carried on by Abbe Rousselet (85), who has described his various investigations in two volumes called *Principes de phonetique experimentale*. He made records of the air vibrations issuing from the mouth during speech, and he studied in a similar manner the air vibrations from the nostrils by the use of nasal olives. He gives elaborate descriptions of the many devices which he used for detecting the movements of the tongue, the lips, the larynx, and nearly all the organs of speech. His studies also included

the use of a pneumograph, and of an explorer which he called an artificial palate. The system of levers which he used enlarged movements of the stylus, which registered the vibrations on smoked paper mounted on a drum which was rotated at a regular speed by a motor and not by hand as in the phonautograph. Scripture (88) says that this method registers the amount of breath issuing from the mouth, but, that it tells nothing of how the changes were produced by the speech organs. More recent investigations with apparatus of this sort have been carried on by D. Jones (74), who presents simultaneous curves for the mouth, nose, and larynx.

The phonograph, of which there have been so many modifications, as well as the various types of dictaphones, make use of the same principle of recording as was noted in the phonautograph. In these devices, however, the original record is very minute, and the reproduction of the original sound, as an audible record, is the final result.

Another method of securing a graphic record of sound waves is one which, like those just discussed, involves the use of the vibrating diaphragm but, in addition, involves the use of light. One of the best devices of this type is the phonodeik invented by D. C. Miller (79) in 1909. This instrument gives photographic records of the sound waves with no way of obtaining an audible reproduction. It consists of a diaphragm so construcetd that its free period can be calculated exactly. This diaphragm is mounted on the smaller end of a horn, designed to produce the least possible distortion. Attached to the center of the diaphragm is a fine fiber or a platinum wire which, after passing around a small spindle mounted in almost frictionless jeweled bearings, is fastened to a delicate spring. On the free end of the spindle is mounted a minute mirror, which reflects a fine beam of light shining through a pinhole, onto a moving photographic film. This instrument is so delicate that it responds to 10,000 complete vibrations per second. It is possible to regulate the speed of the film over a range of from one to fifty feet per second. According to Richardson (84), the spot of light tracing a record of the sound waves magnifies the motion of the diaphragm 2,500 times, and gives a record 2½ inches wide. Time flashes are kept by recording the vibrations from a tuning fork. However, the diaphragm, and especially the horn, have their own natural periods of vibration which it was found impossible to eliminate. Miller (12) therefore calibrated the instrument with tones of constant loudness, over the whole range of frequency, so that it is possible to make accurate

corrections for the distortion thus introduced. Richardson (84) says, "Probably the phonodeik is the most accurate and elaborately developed sound-recorder of this class."

This description of the apparatus seems rather promising for the purposes of the investigation under discussion, but in Miller's (80) description of his work with it, a number of difficulties are revealed which make it entirely useless for this purpose. In the first place, he has been able to get satisfactory records of all the vowel, but of only one or two of the consonant sounds. The acquisition of consonantal sounds by the infant should be one of the chief concerns of the experimenter in the proposed investigation. Secondly, he tells us that in the recording of vowel sounds it is possible to obtain distinctive curves for the different vowels, when they are all uttered in the same pitch. He says, however, that since the pitch region of the maximum emission of energy for a certain vowel is fixed, and is independent of the pitch of the fundamental, it follows that the different vowels cannot be represented by characteristic wave forms, and that wave form depends on pitch of intonation as well as on the vowel. He gives sample oscillograms which indicate that two dissimilar vowels give similar curves when spoken in different pitches, and likewise, the same vowel spoken at different pitches gives different types of curves. This type of record has possibilities for some kinds of work, particularly for work with adults when the vowel spoken is known, and the subject can be instructed in the manner of utterance. Such limitations in the method, however, make this device entirely useless for work with infants.

Another device which employs a beam of light for the recording of sound, and which also gives only a graphic record without audible reproduction, is the oscillograph. The instrument was first devised by Blondel in 1893, but the practical application of the idea was carried out by Duddell. According to Ramsay's (15) definition, an oscillograph is "a moving coil galvanometer, the deflection of which at any instant is practically proportional to the current flowing through it at that instant, in spite of the fact that the current may be varying very rapidly in strength and direction." Miller (80) says that the waves received by the oscillograph set a minute mirror into corresponding vibrations, which may be recorded photographically. Gavey (74) pointed out the remarkable superiority of the oscillographic records over the old phonautograph records, especially in the sharpness and detail of the curves. The older type of oscillograph

is a very large and cumbersome piece of apparatus which requires very skilled operation. This instrument is so accurate, and has such wide applications, not only as a phonoscope, but also in the fields of electrical engineering, physiology, and medicine, that it has been worked on a great deal in an attempt to make it portable, and less complex in operation. This end has been achieved by the Westinghouse company in the portable "Osiso" which weighs less than one-tenth as much as the older oscillographs, is much more compact, and is extremely easy to operate. One of the most intensive studies of speech sounds is that of Crandall (71) who used the older type of oscillograph in conjunction with a condenser transmitter and a seven-stage amplifier. He obtained characteristic curves for the various vowel sounds and also for a few of the consonants when they were carefully spoken into the instrument. He gives sample records which give some idea of their detail, and of the unwieldy length which such records would attain even if they could be used for the investigation of infant vocalizations. It is also evident from scrutiny of these curves, how difficult it would be to identify sounds from the curves alone.

One of the difficulties met with in devices of this sort is that they seldom cover a wide enough frequency range to include all the sounds of speech with equal accuracy. These devices all depend on the amount of energy carried by the sounds of speech, and since this is very small, very minute measurements are necessary. The vowel sounds carry by far the largest percentage of the total amount of energy in speech sounds, they are the sounds which are prolonged, and hence are those which constitute the major portion in any graphic record. Yet it is the consonants by which we distinguish words, and since these sounds carry so little energy, and are so short in duration, they are hardly discernible in the graphic records. The oscillations of the beam of light are so fine and so rapid that when a permanent photographic record is desired, it is necessary to have the film run at a very high speed in order not to obscure the details of the waves. The optimum speed is about 40 feet per second so that even with the long-film attachment only short sentences can be recorded. Such a method obviously is not suited to large scale studies of language, for it is practical to study only a few isolated sounds, or at most only small groups of sounds in this way. The number of sounds recorded accurately would be limited to the vowels, and while those who have worked with oscillograph records say that each

vowel has a characteristic curve, this is true only for the pure vowels. Certainly, in working with infants, there would be many sounds which would be mixed vowels which it would be most difficult to identify from the graphic record. No doubt, the same difficulty would also be encountered in this type of record as was mentioned in connection with Miller's (80) phonodeik; namely, that variations in pitch would change the form of the curve, so that the sounds could not be identified merely from the curves.

The most serious criticism of all of these instruments which involve the use of vibrating diaphragms and mechanical connection with styluses, etc., have been well summarized by Liddell (77). He points out that the mechanical energy in a sound wave is very slight when it is compared with that required to produce an appreciable movement in a solid mass of matter, however small. To measure it in terms of the movements of solid bodies requires that these bodies should be in a very delicate equilibrium, capable of being restored in intervals less than those between the successive impacts of the sound waves. Nearly all of the earlier sound measurements were subject to certain errors due to inertia of some parts of the instruments. The first of these is the inertia of the levers, styluses, etc., which, as noted above, were really intrinsic parts of most of the devices described above. In the second place, Liddell (9) says that the system of solid bodies has a free period of its own. The characteristics of the diaphragm, the material it is made of, the frame or mounting used, and many other factors determine its responses to the various frequencies. The natural period of the diaphragm will tend to overemphasize certain frequencies and underemphasize others, because the diaphragm will not respond equally over the whole range involved in speech sounds. Efforts are now being made to have diaphragms whose natural periods are not within the range being studied. This peculiarity which is inherent in most of the devices is known as frequency distortion. According to Wente (92), "The electrical method of recording . . . has been developed primarily so that a diaphragm giving a uniform response may be used and at the same time a record of sufficient amplitude may be obtained." Another source of error found in the earlier types of instruments is also brought out by Liddell (77). He says that any volume of confined air, when brought in contact with vibrating free air, may have a free period of its own. This is likely to occur when a horn is used for amplification as in the phonographs and in the

phonodeik. Mechanical devices have an added disadvantage in that they develop frictional contacts which produce high frequency vibrations, and thus introduce additional error. While most of the energy of speech which is carried by the vowel sounds is below 1,000 vibrations, the consonants, which are the sounds which usually determine the interpretation of words, are almost all in the higher frequency ranges. Most of the oscillographs now in use, respond evenly over a frequency range up to 5,000 vibrations per second, but most authors agree that it would be desirable to extend this range up to 10,000 vibrations or higher, so that there would be no distortion of the consonant sounds in the higher frequency ranges. It will be seen that one or more of these criticisms applies to all of the instruments so far described. Miller (80) says that in the phonautograph, not only are the records small in size, but the essential characteristics are distorted or obliterated by friction and by the momentum of the stylus. The same thing holds true of all the machines of the kymograph type. In the systems such as the phonograph which involve the reproduction of sounds, there is the added distortion due to the surface noise of the tracer following the record, and in this type of apparatus there is not only the distortion of the recorder, but also that of the reproducing system. The oscillograph is the only type of device in which most of these difficulties have been overcome.

Thus it seems that the investigator finds none of the graphic methods of recording suited to this problem of infant language. The second method which suggests itself is that of the audible record, which can be reproduced again and again for repeated observation by a number of judges. The first problem, in an approach such as this, is that of securing an accurate record of the sounds made. Secondly, there is the problem of accurate reproduction. The next two sources of error are not mechanical ones, but are due to the personal equation of the experimenter; namely, the accuracy with which he hears the record, and the accuracy with which he represents symbolically the sounds which he hears. These four aspects of the problem suggest many pitfalls of this method of approach, which upon further inspection, prove much more serious than they appear at first sight.

First of all, it should be considered, what instruments are available for accurate audible records of speech sounds. The best known, of course, is the phonograph, the limitations of which for the problem under discussion have already been pointed out. The dictaphone type of instrument has practically all the same limitations as have

been mentioned in connection with phonographs and similar devices. It has the additional disadvantage that the records deteriorate after each repetition because, in order to permit shaving and use of the same cylinder a number of times, the records are made in very soft wax. The reproduction is less and less clear each time, and after four or five tracings it is very badly distorted.

Another type of instrument which gives an audible record only, without a graphic record first, is the telegraphone invented by Poulsen of Copenhagen. In this device, the sounds are recorded by means of inducing variations of magnetism in a fine steel wire, or on a smooth steel disc, which correspond accurately to the vibrations in the diaphragm of a telephone circuit. Records so made can be preserved as long as desired, and can be played over as many times as necessary without undergoing any depreciation in quality or clearness. This device also has the advantage of giving a record which is continuous for thirty minutes. Records may be erased by demagnetization, and the same record wire used indefinitely. This apparatus, however, requires the use of some sort of microphone, at the receiving end, and also of an amplifier, or loud-speaker at the output, so that there are two sources of distortion introduced. Every microphone and every amplifier has a free period of its own, and usually these frequencies are well within the range of the speech sounds. The carbon granules in the microphone of the telegraphone are likely to settle, so that its efficiency varies greatly from time to time. Ear-phones used with the telegraphone give only a very faint record, so that an amplifying device is quite essential. It is well known how greatly amplifiers differ in the quality of reproduction, and none of them is really satisfactory.

Assuming, however, that corrections could be made for the distortion so introduced, how satisfactory would such a device be for the problem of studying the vocalizations of infants? In the first place, it is essential to keep in mind the fact that the material with which this experiment deals is meaningless to the experimenter, and there is no context to guide him in a correct understanding of it. The question is, how accurately is it possible to hear single sounds which are reproduced with a device of this sort? Fletcher (73) performed an experiment, the results of which partially answer the question at hand. He used a condenser transmitter which is the most perfect apparatus yet devised for the reproduction of sound in a telephone circuit. A series of nonsense syllables, planned so that each type of

sound appeared an equal number of times, was spoken into the receiving end of the apparatus, and several judges wrote down, according to a very simple phonetic system, what each syllable sounded like to them. It must be remembered also that in this experiment only the pure vowel and consonant sounds were used. There were none of the more difficult mixed or muted vowels. Only those which are usually indicated in the vowel triangle were represented in the series. The results indicated that only *83.4* per cent of the vowels, and *65.8* per cent of the consonants were heard correctly. If this is the greatest accuracy that can be obtained, using the most perfect device known, and comparatively simple material, it hardly seems as if with the use of a much poorer instrument, and much more complex and varied material, anything of scientific value could be derived.

Before dismissing this aspect of the problem, it might be well to mention here still another serious difficulty which is inherent in any method involving the use of an auditory record. It is one matter to hear the sounds in the record correctly, but is a very different matter to represent these sounds accurately, and so that their meaning will be as constant from time to time, and from one person to another, as our system of writing. The available systems of phonetics are many and varied. The systems which are encountered most frequently in dictionaries and in glossaries are based on one language, and since the English language contains fewer single sounds than any other language, there are only about 36 to 40 sounds represented in most of the English systems. Even these systems are most confusing, for with only 26 letters in the alphabet, many of the letters have to appear in various modifications, with various diacritical marks, etc. In many of the latest advances in phonetics, diacritics have been most severely criticized, and the most recent changes have been in the direction of getting away from the use of diacritics entirely, and in the development of new symbols which have no other associations for most people. Another difficulty with most of these systems is that the symbols do not readily lend themselves to writing by hand, since many of them depend upon the printed forms. This difficulty might be overcome by the use of shorthand which is phonetic in its elements; but here again there is a different system of shorthand for each language. Shorthand is based on the words, and on the particular sound combinations which are found in any given language. In most cases the consonants only are represented, at least only enough is indicated so that the word can be identified, and

much of the reading of shorthand depends upon context. Shorthand is never regarded as a final, permanent record, as it would have to be in the experiment for which it is suggested; but it is always translated into the longer form which it represents. In most cases, too, it is necessary to translate the shorthand as soon as possible after it is taken, as it is likely to get "cold." The distinctions between various sounds as represented in shorthand depend upon such slight variations as the length of line, or the angle of a line, or the length of a curve, all of which are extremely variable from one writer to another, and even in the same writer from time to time. The reason such a system works in practical use with meaningful material, is because questionable or doubtful strokes can be interpreted correctly because of the context. The same principle is involved in the interpretation of shorthand, and even of longhand writing, as was noted above in connection with the interpretation of sounds heard. Meaningful context is needed as a guide in both instances.

It has been mentioned above that these systems are based on particular languages, and that each language is limited in the sounds which it includes. The young infant frequently uses sounds which do not appear in our language. He uses sounds resembling the German gutturals, the French nasal sounds, and the Parisian "r," which are more or less familiar to most English-speaking people, and which are quite easily recognizable. There are, however, many other sounds which are encountered in the infant's repertoire and which must be accounted for in the phonetic system which is adopted. It seems, then, that the system best suited to the needs of the investigation under consideration is the International Phonetic System. This system is indeed most complex, as it contains about 96 different symbols, each representing a different sound, and makes provision for innumerable modifications indicating slight changes of length, stress, pitch, nasality, breath, voice, etc. This system necessitates the use of odd and peculiar type, and is not readily adaptable to handwriting. It is possible to secure an attachment for the Hammond typewriter which has most of the symbols of the International Phonetic Alphabet. This system seems as if it would meet the needs of the present problem in this respect, but many of the sounds which are represented in it are found only in such obscure language as Eskimo, Arabic, Hindu, Persian, etc., so that it is practically impossible for the English-speaking person to learn what sounds these symbols represent so as to be able to recognize them when they are

heard. Liddell (77) is very severe in his renunciation of all such phonetic systems. He contradicts their most fundamental assumptions when he says: "It is usually assumed by phoneticians that speech sounds, especially vowel sounds are determined by the shape of the mouth cavities during utterance. It is a well known fact of physics that it is not the shape of the resonance chamber, but its volume, that is one of the fundamental factors in determining the quality of the resonating sound; the other is the size of its openings." The same speech sounds, he says, may be made in various ways.

In addition to the graphic record and the audible record there is the combination of the two in the most recent development in the synchronized recording and reproducing of sound and scene as used in the talking moving picture. There are three kinds of records used in this type of work, which are well described by Wente (92) and other investigators of the Bell Laboratories. One involves the phonograph type of recording, which has the disadvantages described above. The other two methods involve photographing the sound on the film by means of a photoelectric cell. The one produces a deposit of constant width but of varying density, while the other gives one of constant density but of varying width. These devices are as yet in the experimental stage, and no doubt many improvements will be made in them in the near future. Probably this type of technique will have to be used eventually in the solution of the problem under discussion, for it has the decided advantage of synchronized audible and graphic records. The expense of the apparatus needed for this project, however, is at present prohibitive for the carrying on of such investigations by most research laboratories.

Thus it seems that the difficulties attending the undertaking of this problem of the language of infancy are many and varied. It seems as if the method which employs only the auditory record will never be well suited to such a study. The graphic method, particularly with the use of the latest developments in oscillographs, seems promising, as does also the sound motion picture method, but there remain many problems to be solved by the electrical engineer, and many modifications for him to make in the apparatus before even these methods will be satisfactory for this project.

BIBLIOGRAPHY

For Part I

1. Allport, F. H., *Social Psychology.* Houghton Mifflin, New York, 1924.
2. Ament, W., *Die Entwicklung von Sprechen und Denken beim Kinde.* Leipzig, 1899, p. 213.
3. Bateman, W. G., Papers on Language Development. I. The First Word. *Ped. Sem.*, 1917, **24**, 391–398.
4. Blanton, M. G., Behavior of the Human Infant During the First Thirty Days of Life. *Psy. Rev.*, 1917, **24**, 456–483.
5. Blanton, S. and M. G., *Child Guidance.* Century, New York and London, 1927.
6. Bloch, O., Les premiers stades du langage de l'enfant. *J. de Psy.*, 1921, **18**, 693–712.
7. Chamberlain, A. F., *The Child: A Study in the Evloution of Man.* W. Scott, London, 1903, Ch. V, p. 495.
8. Champneys, F. H., Notes on an Infant. *Mind*, 1881, **6**, 104–107.
9. Darwin, C., Biographical Sketch of an Infant. *Mind*, 1877, **2**, 285–294.
10. Dearborn, G. V. N., *Motor-Sensory Development: Observations on the First Three Years of Childhood.* Warwick and York, Baltimore, 1910, p. 215.
11. Doran, E. W., A Study of Vocabularies. *Ped. Sem.*, 1907, **14**, 401–438.
12. Drummond, M., Notes on Speech Development, I. *Child Study*, 1916, **9**, 83–86.
13. Egger, M. E., *Observations et Reflexions sur le Developement de l'Intelligence et du Langage.* A. Picard, Paris, 1879.
14. Esper, E. A., The Psychology of Language. Psy. Bull., 1921, **18**, 490–496.
15. Feldman, *De Statu Normali Functionem Corporis Humani.* Disert Bonner, 1833.
16. Fenton, J. C., *A Practical Psychology of Babyhood.* Houghton Mifflin, Boston, New York, 1925.
17. Gerlach, F. M., *Vocabulary Studies.* Studies in Educ. Psy. No. 1, Colorado College, Colorado Springs, 1917, p. 123.
18. Gesell, A., *Infancy and Human Growth.* Macmillan, New York, 1928.
19. Gesell, A., *Mental Growth of the Pre-School Child.* Macmillan, New York, 1925.
20. Gheorgor, J. A., Die Ersten Anfange des Sprachlichen Ausdrucks für das Selbstbemusstsein bei Kindern. *Arch. f. d. Psy.*, 1905, **5**, 329–404.
21. Grant, J. R., A Child's Vocabulary and Its Growth. *Ped. Sem.*, 1915, **22**, 183–203.
22. Hall, G. S., Notes on the Study of Infants. *Ped. Sem.*, 1891, **1**, 127–138.
23. Hall, Mrs. W. S., The First 500 Days of a Child's Life; V. *Child Stud. No. 2*, 1896–7, pp. 586–608.
24. Hetzer, H., and Reindorf, B., Sprachenwicklung und Soziales Milieu. *Zeit. f. angew. Psychol.*, 1928, **29**, 449–462.
25. Hetzer, H., and Tudor-Hart, B. H., Die fuhresten reaktionen auf die menschliche Stimme. *Qual. u. Stud. z. Jugkd.*, 1027, Heft **5**, 103–124.
26. Holmes, U. T., The Phonology of an English Child. *Amer. Speech*, 1926–7, **2**, 219–225.

27. HUMPHREYS, W., A Contribution to Infantile Linguistics. *Trans. Am. Phil. Assn.*, 1880, **9**, 5–17.
28. KENEYERS, E., Les Premiers mots de l'enfant et l'apparition des especes de mots dans son langage. *Arch. de Psychol.*, 1927, **20**, 191–218.
29. KROEBER, A. L., The Speech of a Zuni Child. *Amer. Anthrop.*, 1916, **18**, 529–534.
30. KUHLMANN, F., *A Handbook of Mental Tests.* Warwick and York, Baltimore, 1922, p. 208.
31. DE LAGUNA, G. A., *Speech, Its Function and Development.* Yale Univ. Press, New Haven, 1927.
32. LINDNER, G., *Aus dem Naturgarten der Kindersprache.* Leipzig, 1898.
33. LINDNER, G., *Observations and Remarks Concerning the Development of Speech in Children,* 1882.
34. LINFERT, H. E., and HIERHOLZER, H. M., *A Scale for Measuring the Mental Development of Infants During the First Year of Life.* Stud. in Psy. and Psychiatry fr. Cath. Univ. of Amer., 1928, **1**, 1–34.
35. MCCARTHY, D. A., *The Language of Development of the Preschool Child.* Inst. of Child Welfare, University of Minnesota, Monograph No. **4**, University of Minnesota Press, 1929.
36. MACDOUGALL, R., The Child's Speech. *J. Ed. Psy.*, 1912, **3**, 423–429, 507–513; 1913, **4**, 29–38.
37. MAGNI, J. A., Vocabularies. *Ped. Sem.*, 1919, **26**, No. 3.
38. MAJOR, D. R., *First Steps in Mental Growth.* Macmillan, New York, 1906.
39. MEUMANN, E., *Die Entstehung der ersten Wortbedeutungen beim Kinde.* Engelmann, Leipzig, 1908.
40. MURCHISON, C., and LANGER, S., Tiedemann's Observations on the Development of the Mental Faculties of Children. *Ped. Sem.*, and *J. Gen. Psy.*, 1927, **34**, 205–230.
41. MOORE, K. C., The Mental Development of a Child. *Psy. Rev. Mono.*, 1896, **1**, No. 3, 150.
42. O'SHEA, M. V., *Linguistic Development and Education.* Macmillan, New York, 1907, 337 pp.
43. PELSMA, J. R., A Child's Vocabulary and Its Development. *Ped. Sem.*, 1910, **7**, 328–369.
44. PEREZ, B., *The First Three Years of Childhood.* London, 1889, 2nd ed. Syracuse, 1899.
45. POLLOCK, F., An Infant's Progress in Language. *Mind,* 1878, **3**, 392–401.
46. PREYER, W., *Mental Development in the Child.* (Trans. by H. W. Brown.) Appleton, New York, 1901.
47. PREYER, W., *The Mind of the Child. Part II. The Development of the Intellect.* Appleton, New York, 1889.
48. PREYER, W., *The Soul of the Child.* Extracts from the record of observations on his own son. Pub. as Pt. II of *Conscious Motherhood* by Emma Marwedel. Heath, Boston, 1889.
49. RASMUSSEN, V., *Child Psychology.* (Trans. by Berry.) Knopf, New York, 1923. (Also trans. by Pritchard.)
50. SANFORD, E. C., Notes on Studies of the Language of Children. *Ped. Sem.*, 1891, **1**, 257–260.

51. SHERMAN, M., The Differentiation of Emotional Responses in Infants, II. *J. Cf. Psy.*, 1927, **1**, 335–351.
52. SHINN, M., *The Biography of a Baby.* Houghton Mifflin, Boston, 1900, 247 pp.
53. SHINN, M. W., *Notes on the Development of a Child.* Univ. of Cal. Studies, Berkeley, 1893, 178 pp.
54. SIGISMUND, B., *Kind und Welt.* Braunschweig, Vieweg, 1856, 221 pp.
55. SIKORSKY, M., Du Developpement du Langage Chez les Enfants. *Arch. de Neurol.*, 1883, **6**, 319–336.
56. SILBER, M., Die Sprache Meiner Kinder. *Kinderfehler*, 1906, **11**, 242–250, 268–275.
57. SMITH, M. E., *An Investigation of the Development of the Sentence and the Extent of Vocabulary in Young Children.* Univ. of Iowa Studies in Child Welfare, Vol. III, No. 5, May 15, 1926.
58. STERN, C. and W., *Die Kindersprache.* Barth, Leipzig, 1922, 3rd ed., 434 pp.
59. STERN, W., *Psychology of Early Childhood.* Holt, New York, 1924, Part III.
60. STEVENSON, A., The Speech of Children. *Science*, 1893, **21**, 118–120.
61. STINCHFIELD, S. M., *The Psychology of Speech.* Expression Co., Boston, 1928.
62. STUMPF, C., Eigenartige Sprachliche Entwicklung eines Kind. *Z. Pad. Psyychol.*, 1900, **2**, 1–29.
63. SULLY, J., Baby Linguistics. *Eng. Ill. Mag.*, Nov., 1884.
64. SULLY, J., *Studies in Childhood.* Appleton, New York, 1908, 527 pp.
65. TAINE, H., Acquisition of Language by Children. *Mind*, 1877, **2**, 252–259.
66. TANNER, A. E., *The Child, His Thinking, Feeling, and Doing.* Rand McNally, Chicago, 1903.
67. TRACY, F., The Language of Childhood. *Am. J. Psy.*, 1893, **6**, 107–138.
68. WOLFFLIN, E., Reduplikation in der Kindesprache. *Zeits. f. deuts. Wortforschung*, 1901, **1**, 263 f.

FOR PART II

69. BROWN, J. G., New Records of Sound Waves from a Vibrating Flame. *Phys. Rev.*, 1911, **33**, 442–446.
70. CRANDALL, I. B., The Composition of Speech. *Phys. Rev.*, 2nd Ser., 1917, **10**, 74–76.
71. CRANDALL, I. B., The Sounds of Speech. *Bell Sys. Tech. J.*, 1925, **4**, 586–626.
72. CRANDALL, I. B., and SACIA, C. F., A Dynamical Study of the Vowel Sounds. *Bell. Sys. Tech. J.*, 1924, 232–237.
73. FLETCHER, H., The Nature of Speech and Its Interpretation. *J. Franklin Inst.*, 1922, **193**, 729–747.
74. GAVEY, J., Inaugural Address. *Proc. Inst. Elec. Eng., No. 176*, 1906, **138**, and *The Electrician*, **56**, 151 and 172.
75. JONES, D., Analysis of the Mechanism of Speech. *Nature*, 1917, **99**, 285–287.
76. LEGG, J. W., The Osiso as a Phonoscope for the Deaf. *Electrical J.*, 1927, 398–405.

77. LIDDELL, M. H., *The Physical Characteristics of Speech Sound.* Bull. No. 16, Purdue Univ. Engineering Expt. Sta., 1924, **8**, No. 1, 1–55.
78. MAXFIELD, J. P., and HARRISON, H. C., High Quality Recording and Reproducing of Music and Speech. *Bell Sys. Tech. J.*, 1926, 493–523.
79. MILLER, D. C., *The Photographic Registration of Sound Waves.* Report before Br. As. Adv. of Sci. 1909, Winnipeg, pp. 414–415. *Phy. Rev.*, **28**, 151, and *Science*, 29, 471.
80. MILLER, D. C., *The Science of Musical Sounds.* Macmillan, New York, 1916.
81. MOORE, C. R., and CURTIS, A. S., An Analyzer for the Voice Frequency Range. *Bell Sys. Tech. J.*, 1927, 217–229.
82. NICHOLS, E. L., and MERRITT, E., Photographing Manometric Flames. *Phy. Rev.*, 1898, **7**, 93–101.
83. RAMSAY, D. A., Oscillographs and Some of Their Recent Applications. *The Electrician*, 1906, **57**, 884–887.
84. RICHARDSON, F. G., *Sound: A Physical Textbook.* Arnold, London, 1927.
85. ROUSSELET, L'ABBE P. J., *Principes de Phonetique Experimentale.* Didier, Paris, 1924, 2 vols.
86. SACIA, C. F., Speech Power and Energy. *Bell System Tech. J.*, 1925, 627–641.
87. SACIA, C. F., and BECK, C. J., The Power of Fundamental Speech Sounds. *Bell Sys. Tech. J.*, 1926, **5**, 393–403.
88. SCRIPTURE, E. W., *Elements of Experimental Phonetics.* Scribners, 1902.
89. SCRIPTURE, E. W., *Researches in Experimental Phonetics.* Pub. No. 44 of the Carnegie Inst., Washington, 1906.
90. SCRIPTURE, E. W., The Study of English Speech Sounds by New Methods of Phonetic Investigation. *Proc. Brit. Acad.*, 1923, **10**.
91. SEYMOUR, H., *The Reproduction of Sound.* Tattersall, London, 1918, 324 pp.
92. WENTE, E. C., General Principles of Sound Recording. *Bell Lab. Record*, Nov., 1928.