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VOWEL ELEMENTS IN THE CRYING VOCALIZATION
OF INFANTS UNDER TEN DAYS OF AGE

ORVIS C. IRWIN¹ AND THAYER CURRY²

The present status of research in initial speech sound equipment of the infant has been presented elsewhere (2). It is indicated that there does not exist a large body of data secured from adequate samplings of infants for purposes of statistical analysis, that most of the observations in any given study were made on one or two children, that usually no systematical research methods were formulated and employed, that statistical techniques essential to the analysis of mass data are practically absent, that reliabilities of observers seldom have been established, and that most observers have used an alphabetical rather than a phonetic system of symbols for recording.

The purpose of the present endeavor is to systematically study the vowel equipment during crying of infants under ten days of age. Forty infants varying from one to ten days in age were placed in a Pratt experimental cabinet and their crying sounds were independently transcribed in the International Phonetic Alphabet by two observers. A broad transcription of this alphabet as suggested by Fairbanks (1) was used.

RELIABILITY

The problem of reliability of observers is fundamental to this work. A first attempt involved the use of the short time sample. By means of a stop watch all sounds occurring during one minute were recorded. It was found that this method yielded agreement between the records little better than afforded by chance. Therefore it was abandoned in favor of a method which employed as a standard observation an easily identified behavior unit whose duration is well within the ordinary attention span. A behavior unit which meets this requirement is the single respiration or breath. Since babies vocalize upon the phase of exhalation the problem of the recorder is to focus his attention upon a given breath and record such sounds as occur upon it. In establishing reliabilities of two transcribers, one of them indicates, by pointing, a respiration about to take place as the next one to be observed and recorded. The attention of both recorders is then focussed upon it and such sounds as are carried by it. Consecutive respirations or every other respiration, or any other type of sample, can be observed quite readily. In this study most of the sounds were secured from consecutive exhalations, although a few were from spaced respirations.

A record of the sounds occurring on twenty-five respirations of each of forty infants was made by the two observers. This yielded a sample of 1,000 respirations. A large majority of the respirations carried single sounds, about 200 of them carried more than one sound, and only a very few as many as four sounds.

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The reliability between observers is indicated by the following analyses. The per cent of agreement was determined for each infant and the average per cent for the forty babies was found to be 85 per cent. The following tabulation indicates the degree of success of the method with this type of data.

Agreement, Per Cent	Number of In- fants
100	7
96	8
92	5
88	6
84	2
80	3
72	1
60	1
56	5
52	2
Total	40

The tabulation reveals that with seven infants the transcriptions were identical, that with twenty infants the per cent of agreement is above 90, with thirty-one babies it is above 80, and with nine infants the agreement is not satisfactory, lying below 80. The average of 85 per cent agreement, however, is a value comparable with much work involving the observational technique.

It would be expected that the problem of transcription of sounds occurring singly on a respiration would be less difficult than when two or more sounds occur. About 800 respirations, a considerable majority, carried single sounds. An analysis of these sounds reveals the degree of agreement between transcriptions. The following tabulation gives the number of each of the five vowel sounds heard singly by the two observers, the per cent of the total for each sound, and the per cent of agreement for the most frequently used vowels.

Vowel	Frequency		Frequency, Per Cent		Agree- ment, Per Cent
	C	I	C	I	
æ	710	746	90.2	89.7	95
e	63	68	8.0	8.2	93
^	7	6	.9	.7	
ī	5	7	.6	.8	
i	2	5	.3	.6	
Total	787	832	100.0	100.0	

The tabulation shows that observer C recorded the vowel æ 710 in a total of 787 vowels recorded as single sounds by him, yielding a per cent of 90.2. Observer I heard this sound 746 times in a total of 832 sounds. This is 89.7 per cent, quite comparable with the value of 90.2

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per cent. The agreement between these observers in recording the single vowel æ is 95 per cent. In the case of the vowel ɛ , it is 93 per cent.

It should be emphasized that the above work was done on newborn infants in whom presumably the speech sound equipment is more meager than with older children. There is also the problem of reliability of the method with children whose speech sound equipment is more extensive.

In an unpublished study (3) on the vowel equipment of a group of infants during the second quarter of the first year of life, the reliability of two observers using the behavior unit method was calculated on data from five subjects. The tabulation below shows the number of times observer I heard eleven vowels in a total of 487 non-crying utterances, and observer K in a total of 490, while both were transcribing simultaneously and independently. The record included thirty respirations of each of the five subjects. Approximately 490 vowel sounds and 300 consonant sounds occurred in a total of 150 breaths. The third column gives the percentage of agreement between observers.

Vowel	Observers		Agreement, Per Cent
	I	K	
ɪ	42	37	88
I	57	60	95
e	7	5	71
ɛ	69	77	90
æ	55	57	96
ʌ	85	92	92
a	7	8	88
ɒ	23	26	88
o	12	12	100
u	122	108	89
ʊ	8	8	100
Total	487	490	

The tabulation shows that all but one of the values are above 80 per cent, the range is from 71 to 100 per cent, and the mean per cent of agreement is 91. When the Chi square test of homogeneity is applied to the two columns of frequencies the probability value is very much smaller than 1 per cent, indicating substantial agreement.

The vocalization of consonant elements is negligible in crying newborn infants. However, the method has been tested on non-crying consonant sounds of the five older infants. The tabulation shows good agreement between observers.

It is seen that all the percentages except one lie above 80, and eleven of the thirteen above 90. The average is 94 per cent. Here also the test for homogeneity of the two arrays gives a probability value of less than 1 per cent, indicating substantial agreement.

In general, then, it may be said that the use of the unit behavior method for the transcription of the phonetic elements in the speech of young infants yields a satisfactory degree of agreement between trained observers.

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Con- sonants	Observers		Agree- ment, Per Cent
	I	K	
h	150	148	99
g	11	11	100
k	38	37	99
t	27	27	100
p	6	6	100
b	18	17	95
d	28	27	96
m	3	3	100
n	5	5	100
x	2	2	100
j	10	8	80
v	2	1	50
l	3	3	100
Total	303	295	

RESULTS

The remaining part of this report is concerned with findings obtained by this method with the vowel vocalization of forty infants during the first ten days of life. The transcriptions of observer C have been used for this purpose.

Table 1 gives the number of infants using the vowel elements and the total number of times these sounds were used. This table reveals that only four vowel sounds are used by newborns with any degree of frequency. These in order are æ, ε, Δ, and I. It is seen that the only vowel element used by all forty babies is the æ sound. The ε sound is uttered by 34 infants, and I and Δ by 21 and 17 subjects respectively. The remaining vowels are used by few of the children. Moreover it is evident that the element æ strikingly exceeds all other vowel sounds in frequency. Data for non-crying sounds have not been included because of the fewness of these sounds in our transcriptions. Newborn infants rarely utter non-crying sounds and the collection of an adequate sample requires a tremendous amount of time and patience.

Table 1

Number of Infants Using a Vowel Sound and the Frequency
That the Sound Occurred in Twenty-Five Observations
(40 Neonates)

Vowels	i	I	e	ε	æ	Δ	ə	a	ɒ	ɔ	o	u	u
Number of cases	6	21	1	34	40	17	0	0	0	1	0	3	1
Frequency	14	72	1	195	903	89	0	0	0	1	0	8	1
Mean frequency per case	2	3	1	6	23	5	0	0	0	1	0	3	1

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The dispersion of the use of the vowel elements for each of the forty infants is presented in Table 2. It is arranged into the three phonetic categories of the vowel elements, front, middle, and back vowels, indicating the mouth parts used in the production of these sounds.

Aside from the piling up of the æ sounds, the table is noteworthy for the fact that of the three categories the front vowels clearly are the most frequent. One of the middle vowels is appreciably present but the back vowels are conspicuously infrequent.

This result has been summarized in the following tabulation:

Vowels	Fre- quency, Per Cent
Front	92
Middle	7
Back	1
Total	100

Front and middle vowels constitute 99 per cent of all vowels produced by newborns and back vowels only 1 per cent.

These data indicate decisively, then, that newborn infants use almost exclusively such vowels as are made by the front mouth parts and do not use the vowels formed by the back parts of the mouth. Since older children and adults employ all mouth parts in speaking, the course of development during the first and second years is indicated. It must consist in the increasing use of back vowels.

In order to render the values in Table 2 comparable, they are given as percentages in Table 3. In addition, the data have been separated according to sex. The mean percentages for each vowel for the boys and the girls lie close together. In the case of the sound æ , the percentage for the girls is 73, for the boys it is 67. Table 4 shows Students' t-test to determine the significances of these differences. The t-ratios all are too small to be of consequence.

It is of interest to learn if there are differences in the use of vowel sounds from day to day during the first ten days. The situation is revealed in Tables 5 and 6. Since the number of infants for each day is rather small, the data have been recast into three periods; 1 to 4 days, 5 to 7 days, and 8 to 10 days. It is apparent from Table 7 that the differences are not statistically significant. The minimum t value at the 5 per cent level would have to be 2.06 to indicate significance. None of these ratios equal this value.

In order to compare the frequency of vowel usage in newborn and adult speech, data from Voelker's (4) study on phonetic dispersion in vowel pronunciation in radio announcements has been selected because it represents the most adequate and carefully collected materials in the literature of this subject. The tabulation presents the infant and the Voelker data together with the percentages of frequency for each of twelve vowel elements for both groups.

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Table 2

FREQUENCY OF OCCURRENCE OF VOWEL SOUNDS IN NEWBORN INFANTS

Infant Number	Front					Middle		Back							Total
	i	I	e	ɛ	%	ʌ	ə	a	b	ɔ	o	u	u		
1	3	4		7	18	1								33	
2		3		16	21	5								45	
3		1		4	21	4								30	
4				8	21	7								36	
5	6	6		14	13									38	
6	1	3		11	22	1								38	
7		3		13	18									34	
8		3		3	24									30	
9		1		4	21	3								29	
10	2	8		10	17	1								38	
11		12		1	25	19								57	
12		6			26	11								43	
13		6		1	25	11								43	
14		2		18	16	6								42	
15		2		5	23	9					3			42	
16					25									25	
17		3		10	23	3								39	
18		1		8	23									32	
19		2		3	24				1					30	
20				7	23									30	
21					25	1					4	1		31	
22				3	23									26	
23				4	21	1								26	
24	1			4	23									28	
25		1		1	25									27	
26		3		3	24									30	
27				2	24									26	
28					25									25	
29				1	25	5					1			32	
30		1		6	22	1								30	
31				8	22									30	
32			1		25									26	
33	1	1		1	23									26	
34					25									25	
35				9	20									29	
36				2	25									27	
37				2	24									26	
38				1	25									26	
39				1	25									26	
40				4	23									27	
Total	14	72	1	195	903	89		1.			8.	1.		1,284	
Means	.35	1.8	.03	4.9	22.6	2.2		.03			.2	.03			
S.E. _M	.17	.41	-	.74	.41	.64		-			.12	-			

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Table 3

Per Cent of Total that Each Vowel Sound Occurs per Infant

Infant Number	Front					Middle		Back						
	i	I	e	ɛ	æ	ʌ	ə	ɑ	ɒ	ɔ	o	u	ʊ	u
Newborn Girls														
2		7		35	47	11								
3		4		13	70	13								
6	2	8		29	59	2								
9		4		14	72	10								
10	5	21		26	45	3								
12		14			60	26								
13		14		2	58	26								
17		8		26	58	8								
20				23	77									
22				12	88									
24	4			14	82									
25		4		4	92									
26		10		10	80									
28					100									
30		3		21	73	3								
32			4		96									
33	4	4		4	88									
36				7	93									
38				4	96									
39				4	96									
Mean per cent	.8	5.5	.2	15.4	73	5.1								
S.E. _M	.4	1.3	.2	2.4	3.1	1.9								
Newborn Boys														
1	9	12		21	55	3								
4				22	58	20								
5	15	15		36	34									
7	9			38	53									
8		10		10	80									
11		21		2	44	33								
14		5		43	38	14								
15		5		12	55	21								
16					100							7		
18		3		25	72									
19		7		10	80									
21					81	3								
23				15	81	4								
27				8	92									
29				3	78	16								
31				27	73									
34					100									
35				31	69									
37				8	92									
40				15	85									
Mean per cent	1.7	6.9		17	67	5.7				.2		1.2	.3	
S.E. _M	.9	1.4		3.1	4.4	2.7				.1		.7	.1	

Table 4

Student's t-Test to Determine the Significance of the Difference in the Occurrence of Vowel Sounds in Newborn Girls and Boys (Data in the Form of Per Cent of Total Sounds of the Infant)*

Vowel Sounds	i	I	e	ɛ	æ	ʌ	ɔ	u	u
Boys' mean N = 20	1.7	3.9	0.0	17.0	67.0	5.7	0.2	1.2	0.3
Girls' mean N = 20	0.8	5.5	0.2	15.4	73.0	5.1	0.0	0.0	0.0
Difference in means	0.9	1.6	0.2	3.6	5.0	0.6	0.2	1.2	0.2
S.E. diff. in means	1.0	1.9	0.2	3.9	5.4	2.8	-	0.7	-
t ratio	0.9	0.8	1.0	0.9	0.9	0.2	-	1.7	-

*For 38 degrees of freedom, which is the case here, the null hypothesis could be rejected at the 5 per cent level if the t ratio were 1.95. None of the ratios here meet that criterion.

Table 5

Per Cent of Total Vowel Sounds that a Sound Occurs for Each of the First Ten Days of Infancy

Day	N	Front					Middle		Back							
		i	I	e	ɛ	æ	ʌ	ə	ɑ	ɒ	ɔ	o	u	u		
1	3	0	1	1	7	84	2						4	1		
2	3	5	5	0	16	74										
3	3	0	6	0	22	63	9									
4	5	1	8	0	17	66	7			1						
5	4	1	6	0	16	63	14									
6	4	1	4	0	7	88										
7	3	0	0	0	14	78	7						1			
8	5	2	8	0	24	65	1									
9	5	0	1	0	13	84	2									
10	5	0	6	0	11	72	11									

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The tabulation discloses an exceedingly interesting contrast. Whereas in adult speech eleven of the twelve vowels are very appreciably present, in newborns only four vowels are produced. There are further

Vowels	New- borns	Adult
i	.1	7.4
I	5.6	20.5
ɪ	.1	5.2
ɛ	15.2	8.0
æ	70.3	8.1
ʌ	6.9	.1
ə		17.8
a		10.9
ɔ	.1	5.6
o		5.5
u	.6	4.6
ʊ	.1	5.2
Total	99.0*	98.9

*Due to rounding, these values do not total exactly 100 per cent.

differences. The sound I is the most prominent in adult usage constituting about 20 per cent of vowel sounds. In contrast to this in newborns the element æ completely outnumbers other vowel sounds, its value amounting to 70 per cent. Moreover, there is a peculiar inversion in the use of the two middle vowels ʌ and ə. Newborns use the first but not the second. On the other hand, in adult speech ʌ is the infrequently used middle vowel while ə ranks second in use among all vowels. Finally, among newborns back vowels are practically absent but among adults these sounds constitute 32 per cent, or one-third of adult vowel usage.

Table 6

Per Cent of Total Vowel Sounds that a Sound Occurs
for Each Third of the First Ten Days

Days	N	Front					Middle		Back						
		i	I	e	ɛ	æ	ʌ	ə	a	ɔ	ɒ	o	u	ʊ	u
1 to 4	<u>14</u>	2	6	-*	15	71	5							1	-
5 to 7	<u>11</u>	1	4		12	76	7							-	
8 to 10	<u>15</u>	1	4		16	74	5								

*Percentage too negligible to indicate.

Table 7

Student's t-Test to Determine the Significance of the Difference in the Occurrence of Vowel Sounds in Newborns for Different Thirds of the First Ten Day Period (Data in Per Cent Form)

Vowel Sounds	Days Compared	Difference in Means	S.E. Diff.	t Ratio
i	1-4 vs 5- 7	0.9	1.2	0.7
	5-7 vs 8-10	0.2	0.7	-
	1-4 vs 8-10	1.1	1.2	0.9
I	1-4 vs 5- 7	2.2	2.2	1.0
	5-7 vs 8-10	1.0	2.1	0.5
	1-4 vs 8-10	1.2	2.4	0.5
e	1-4 vs 5- 7	0.4	0.3	1.3
	5-7 vs 8-10	0.0	-	-
	1-4 vs 8-10	0.4	0.3	1.3
ɛ	1-4 vs 5- 7	3.5	5.2	0.7
	5-7 vs 8-10	4.1	4.6	0.9
	1-4 vs 8-10	0.6	5.1	0.1
æ	1-4 vs 5- 7	5.3	7.8	0.7
	5-7 vs 8-10	2.5	6.8	0.4
	1-4 vs 8-10	2.8	7.6	0.4
ʌ	1-4 vs 5- 7	2.1	3.8	0.6
	5-7 vs 8-10	2.1	3.7	0.6
	1-4 vs 8-10	0.0	-	-
ɔ and u	1-4 vs 5- 7	0.2	0.2	1.0
	5-7 vs 8-10	0.0	-	-
	1-4 vs 8-10	0.2	0.2	1.0
u	1-4 vs 5- 7	0.6	1.0	0.6
	5-7 vs 8-10	0.3	0.3	1.0
	1-4 vs 8-10	0.9	0.9	1.0

In some phonetic classifications middle vowels are grouped with back vowels. On this basis, 92 per cent of all vowels uttered by babies are front vowels and 8 per cent are back vowels. The ratio is about 9 to 1. On this basis also adults use about 49 per cent front vowels and 51 per cent back vowels, a ratio of 1 to 1. These ratios, however, should be used with caution. They are more suggestive than conclusive, for more comparable values would be furnished by a comparison of the non-crying sounds of newborns with those of the adult group. These data, however, are not yet available.

Regardless of what phonetic classification is used there still is

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good indication of the probable course of vowel usage during infancy and childhood. Apparently the crucial aspect of the change lies in the use of back vowels. The actual stages of this development are now under investigation.

SUMMARY AND CONCLUSIONS

Forty infants, twenty boys and twenty girls, under ten days of age were used for the purpose of studying the vowel sound equipment of newborns. Vocalization was entirely of a crying nature. The vowel elements appearing on each of twenty-five respirations were transcribed in the symbols of the International Phonetic Alphabet simultaneously and independently by two observers. A total of 1,000 respirations constitutes the data of the study. It was found that:

1. The time sampling method is inadequate.
2. A behavior unit method (the single respiration) of observation enables the observer to easily transcribe such sounds as occur during the unit.
3. Agreement between observers averages 85 per cent and in certain situations is well over 90 per cent.
4. Only four vowels occur with appreciable frequency in newborns: I, E, X, and A.
5. The most frequently used vowel element in the vocalization of newborns is the sound X. It is the only vowel sound formed by all forty babies.
6. Front vowels are more frequently used than middle and back vowels.
7. Among the front vowels the i and e sounds are least used.
8. Back vowels are almost entirely absent.
9. There are no sex differences in the use of vowels.
10. There are no age differences within the period studied.
11. A comparison of these data with data in vowel usage in adult speech reveals striking differences.

It is inferred from these data that the course of development during infancy in the use of vowel sounds is the increasing use of back vowels.

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