The cry thresholds of normal infants and those with brain damage

An aid in the early diagnosis of severe brain damage

A standardized program of successive painful stimuli was applied to nearly 300 children with the expectation that the vocal responses of normal subjects and of those with diffuse brain damage would differ significantly. Infants with diffuse brain damage require more stimulation to produce a standard 1 minute crying response than do normal infants. The efficiency of the technique varies between 74 and 83 per cent, depending upon the age level studied. Other criteria, e.g., shorter periods of crying, patterns of crying, etc., are being explored, particularly for infants under 4 days of age, in the hope of increasing the predictive efficiency of the method.

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WHILE considerable attention has been devoted to the development of speech and to prelinguistic utterances in general,[1] relatively few studies have concerned crying behavior in particular, and practically no efforts have been made to chart systematically the diagnostic potential of the infant's cry until the recent work of Karelitz and associates.[2] The present study is a part of such an effort and provides objective documentation for certain of the observations reported previously, specifically that: 1. Normal infants respond to painful stimuli with crying more consistently than do infants with brain damage. 2. Normal infants cry more rhythmically and for longer periods of time. 3. There are characteristic changes in the cry patterns with aging.

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PROCEDURE

Stimulation. The stimulus used to induce crying was supplied by the snap of a rubber band (R.B.S.) stretched from its ordinary length of 7.4 cm. to about 23 cm. on a gun-shaped apparatus approximately 17 cm. long (Fig. 1). The rubber band was fixed

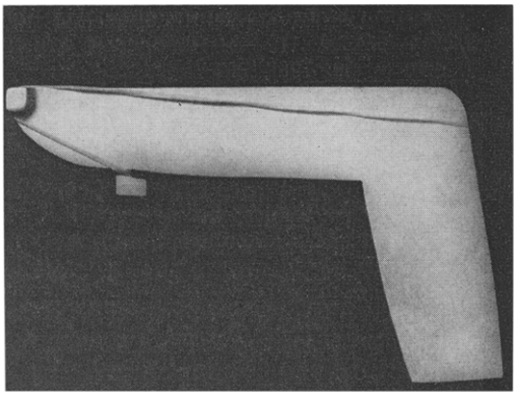

Fig. 1*A*. Rubber band stimulation used to induce crying. At the cock end of the apparatus, which is about 17 cm. long, a marker identifies the point on which the rubber band is to be placed. The band is stretched before it is looped over the front end and the ripples smoothed out.

to a peg on the bottom side of the gun and stretched around over the tip of it. The rubber bands used were the Paar amber No. 32.* A new band was used for each infant. Each and every test session was recorded in its entirety on magnetic tape. Once the tape recorder (Ampex 601 with Electrovoice 666 microphone) was started, the infant was placed on the examining table and the word "Down" was announced. Shoes and socks were removed if necessary and this too was announced. If the infant was in a crib, he was left there but turned on his back. The stimulation program then was started with appropriate announcements as follows: "Pick up foot," "touch," as the stimulator was placed at the center of the sole of the infant's foot, and "one," as the rubber band was released for the first time. If no crying followed or if crying commenced but stopped quickly, approximately 10 seconds was allowed to elapse before the stimulation procedure was repeated. This stimulus was repeated no more than 7 times, but if it did not produce at least a minute of continuous crying, it was followed by 3 clusters of 5 scratches each with the nail of the index finger on the sole of the foot. If no crying ensued the center of the sole of the foot was then flicked with the index finger. This flick was repeated only once if necessary and the stimulation program was then terminated. Identifying and other information, including age, sex, the time of day, the time of last feeding (nearly all experiments were made deliberately before feeding), birth weight, period of gestation, and whether or not the child was under sedation and/or other medication, was fed into the tape recorder.

This program of stimulation was identified as "standard stimulation procedure" (S.S.P.) and it was used throughout this study. A number of infants included in this study cried without need for the standard stimulation procedure. They were not stimulated with the rubber band if they cried for at least 1 minute. All of the cries were designated as "spontaneous" if the infants were brought in crying or if we found them crying without apparent stimulation. Those infants who were quiet but cried when put on the examining table or when their shoes and socks were removed were classified in a separate category (Category 0, Table I) to be described later. It was obvious early in this study that the issue of amount of stimulation would have to embrace those subjects who cried before standard stimulation procedure (Category *S*, Table I) and those who cried under minimal stimulation, as well as those who did not cry at all under the full program of stimulation (Category *A*, Table I). A small number of infants, particularly the very young normal infants and the older abnormal infants, did not receive the full program of stimulation generally because their cry responses, while not sustained for 1 full minute, were so violent and vigorous that it was considered wise to terminate the session. All of these infants were stimulated at least five times and their responses were given a special designation (Category *D*, Table I).

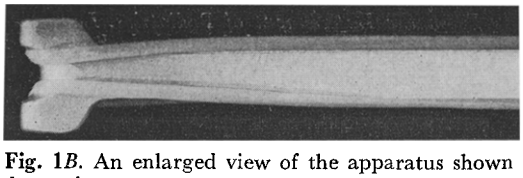

Fig. 1*B*. An enlarged view of the apparatus shown from above.

*Manufactured by the Swingline Company of New York.

The decision to stimulate crying with the snap of a rubber band was made after consideration of other techniques. The flick of the sole of the foot previously employed routinely was not used alone in this study because of the possible variations in the intensity of the flick by different personnel. Electric shock and heat, in common use among psychologists and physiologists to evoke pain, were dismissed because they seemed too severe for use on very young infants. The standard stimulation procedure finally decided upon is effective, simple, and independent of the experimenter's technique. It is a reasonable assumption that differences in the tensile strength of rubber bands are randomly distributed in the normal as well as in the abnormal groups of infants.

The over-all research plan called for testing with standard stimulation procedure as many infants as possible from birth to approximately 3 years of age. As of this writing 293 children have been so tested. Of this number, 63 are unquestionably abnormal, with recognizable syndromes involving some disorder of the central nervous system. Most of these came from hospitals for children with brain disturbances. The single disorder most frequently found in this group was Mongolism (28 cases). Thirteen additional cases were placed in a "doubtful" category: some of these infants showed no symptoms of central nervous system disorder at the time but had histories of having undergone neurosurgery, experiencing a convulsive disorder, or being retarded. Others in this group were infants who could not definitely be classified as abnormal but who presented a variety of symptoms which were suggestive of some central nervous system impairment. All of the infants were given a general physical examination including a complete neurologic survey by pediatricians and by other consultants as indicated, e.g., by neurologists, neurosurgeons, and psychologists. Most of these were examined by one of us (S.K.). Some infants also had electro- and pneumoencephalographic investigation. Nine of the 293 infants were discovered to be premature and were kept in a separate category. Another group of 7 infants who were under sedation for one reason or another, principally convulsions, was given a separate heading. The remaining 201 infants were in the nurseries and Well Baby Clinic of the Long Island Jewish Hospital, were seen in the clinic of the Louise Wise Services, a large adoption agency in New York City, or were on the wards of the New York Foundling Hospital. These infants had been examined repeatedly by pediatricians and had been considered to be free of central nervous system disturbances.

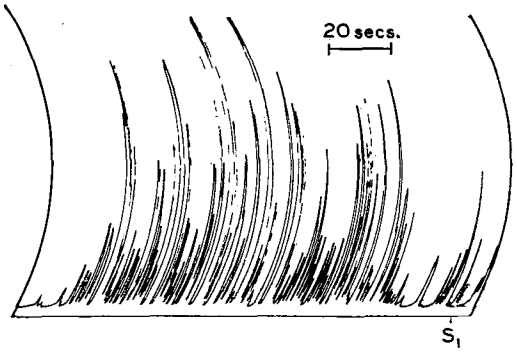

Fig. 2. Volume-unit graph of a cry sample obtained from a normal girl 40 days old. S_1 = point of stimulus. Chart reads from right to left.

After the cries had been magnetically taped in a standardized situation, the tapes were systematically run through an amplifier in circuit with a meter rectifier, a 10 ohm resistor, and a graphic milliammeter. This procedure[3] yielded a permanent visual record of the cry as illustrated in Fig. 2. The synchronous motor of the ammeter was set at 20 seconds to the inch so that time measurements could be made along the base line of each chart reading from right to left. All charts were run off at uniform electronic settings (intensity 3.0, equalization zero). The ordinate scale represents the intensity of the cry expressed in milliamperes. The full scale is 5 ma. All of the measurements reported in this paper were made directly from the volume-unit graphs for the sake of greater accuracy and reliability, but the basic data could be obtained with a stopwatch.

Although a number of children were tested

Table I. Cry categories noted in response to standard stimulation procedure (S.S.P.)*

Category	*Amount of standard stimulation*	*Response*
S	None	At least 1 minute of crying, reason undetermined
0	None	At least 1 minute of crying in response to minimal stimulation, e.g., put down on table, removed shoe, removed sock, etc.
1 to 8	1 to 8 R.B.S. each separated by approximately 10 seconds	At least 1 minute of crying in response to the number of R.B.S.'s indicated
9 to 11	3 clusters of 5 scratches each separated by approximately 10 seconds	At least 1 minute of crying in response to amount of stimulation indicated
12, 13	Flick of finger repeated in approximately 10 seconds	At least 1 minute of crying in response to amount of stimulation indicated
D	Not less than 5 R.B.S. but not full S.S.P.	Less than 1 minute of crying. Program terminated mostly because response was too violent and vigorous
C	Full S.S.P.	Less than 1 minute of crying but brief cry in response to stimuli
B	Full S.S.P.	Less than 1 minute of crying but occasional, sporadic, brief and/or weak response to stimuli
A	Full S.S.P.	No vocal response at all

*Full standard stimulation procedure = 8 rubber band snaps, 3 scratch clusters, and 2 finger flicks.

Table II. Distribution of cry categories for the various groups tested

Stimulus	*Category*	*Normal*			
		0 to 3 days	*4 to 365 days*	*366+ days*	*Total*
One minute of continuous crying obtained					
None	S	6	10	3	19
None	0	0	23	5	28
R.B.S.*	1	19	53	2	74
R.B.S.	2	8	19	0	27
R.B.S.	3	3	4	0	7
R.B.S.	4	5	6	0	11
R.B.S.	5	4	2	0	6
R.B.S.	6	2	2	0	4
R.B.S.	7	2	3	0	5
R.B.S.	8	0	2	0	2
Scratch	9	0	0	0	0
Scratch	10	1	0	0	1
Scratch	11	0	0	0	0
Flick	12	0	0	0	0
Flick	13	0	0	0	0
Not obtained					
< Full S.S.P.	D	7	3	0	10
Full S.S.P.	C	3	0	0	3
Full S.S.P.	B	0	0	0	0
Full S.S.P.	A	1	3	0	4
Total		61	130	10	201

*Rubber band stimulation.

more than once, only the results of the first tests are presented in the study. Where siblings or twins were tested, only the first one tested was included in the computations. This procedure fulfills the assumption of independence required of the statistical techniques employed in this investigation.

RESULTS AND DISCUSSION

Two of the critical observations previously reported by Karelitz and co-workers in the discussion of differences between normal and abnormal infants are: (1) Abnormal infants require more stimulation in order to induce crying than normal infants do. (2) The cry of the abnormal infant is not as sustained as that of the normal infant. In this investigation these two points were expressed in integral form and a single working hypothesis was formulated in which "sustained crying" was defined as 1 minute of continuous crying at any audible level of intensity. The criterion of 1 minute was suggested by observations made in the exploratory phases of this research. Thus, the question was put, "How much stimulation is required to produce at least 1 minute of crying?" Accordingly the volume-unit graph classification system shown in Table I was developed.

In Table II is shown the distribution of the various types of cry patterns in all 293 cases included in this study.

If we ignore for the moment the doubtful and other special cases, Table II reveals that while only 54 per cent of the abnormal infants were able to provide the criterion of 1 minute of crying, 92 per cent of the normal infants gave the 1 minute response, and 74 per cent did so after a maximum of two R.B.S. This will be seen more clearly in Table III which is constructed on the basis of a hypothetical diagnostic cut-off point at 2 or less R.B.S. The statistical difference between the normal and abnormal infants is overwhelmingly reliable. The chi square value obtained for the distribution shown in Table III equals 50.9. For significance at the 0.001 probability level a value of 10.8 is required.[4] Table III also suggests that a diagnostician who calls "normal" those in-

Abnormal				*Matched group*				
0 to 3 days	*4 to 365 days*	*366+ days*	*Total*	*Normal*	*Abnormal*	*Doubtful*	*Pre-mature*	*Sedated*
0	2	3	5	6	4	0	1	0
0	0	5	5	9	0	1	0	1
0	3	2	5	14	4	3	5	2
0	0	0	0	3	0	1	0	1
0	3	2	5	0	3	0	0	0
0	3	2	5	1	3	1	0	0
0	1	0	1	1	1	0	0	0
0	1	1	2	0	2	0	0	0
0	0	1	1	1	0	0	0	0
0	0	0	0	0	0	1	0	0
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0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0
2	3	7	12	0	8	1	0	0
1	0	4	5	0	1	2	2	0
2	2	6	10	0	4	3	0	1
0	4	3	7	1	6	0	1	2
5	22	36	63	36	36	13	9	7

Table III. One minute of crying after 0 to 2 R.B.S.

	Cried	*Did not cry*	*Total*
Normal	148	53	201
Abnormal	15	48	63
Total	163	101	264
Accuracy (%) = 74.2			

Table IV. One minute of crying after 0 to 2 R.B.S. in infants 4 days to 3 years old

	Cried	*Did not cry*	*Total*
Normal	115	25	140
Abnormal	15	43	58
Total	130	68	198
Accuracy (%) = 79.8			

fants who respond with at least 1 minute of crying to 2 or less R.B.S., and "abnormal" those who do not, would be right 196 times in 264 cases. This level of predictive efficiency equals 74.2 per cent. A number of infants, particularly those in the first few days of life, responded promptly to the first and second R.B.S. with lusty, rhythmic crying for shorter periods than 1 minute; therefore, criteria such as shorter periods of crying, burst rate, and pattern of termination are being studied.

The number of cases in the doubtful and other special categories is too small to warrant statistical analysis. The collection of data under these headings continues in the hope that additional light might be shed on a variety of such problems as the effect of sedation and the role of prematurity. The 2 premature infants listed next to cry type C in Table II were also abnormal infants.*

The age of the subjects is a critical factor if one considers the possibility that older abnormal children may behave as much younger normal infants do. This point was made clear in the paper by Karelitz already referred to. Accordingly, it was decided to analyze the findings in terms of age. Of the 61 normal infants in this study who had not yet reached their fourth day of life, 33 cried for 1 full minute after 2 R.B.S. but 28 did not, and 11 of these 28 did not cry for 1 minute at all. On the other hand, not one of the 5 abnormal infants in the same age group cried for 1 continuous minute. If these 66 cases are excluded from the total tally, the distribution of normal and abnormal infants who did and did not respond with 1 minute of crying is as that shown in Table IV. The level of predictive efficiency thus increases to 79.8 per cent if judgment is reserved for all infants less than 4 days of age. The chi-square value obtained for distribution shown in Table IV equals 57.1, $P < 0.001$. The fact that 11 normal newborn infants could not produce a minute of continuous crying may be due to such factors as slow rate of maturation, birth trauma, the kind of delivery, and the amount of anesthesia and analgesia given to the mother during labor. These possibilities are being explored.

The observation mentioned earlier that abnormal infants tend to cry more as they grow older is supported by the fact that only 5 of the 27 abnormal babies less than 1 year old cried for 1 full minute with 2 or less R.B.S., but 10 of the 36 abnormal ones more than 1 year old were able to do this. Another 6 of these 36 infants cried for at least 1 minute with 3 to 7 R.B.S. Twenty were unable to produce 1 full minute of crying. All of the 10 normal infants more than 1 year old responded with 1 full minute of crying to 1 R.B.S. or less stimulation. It is clear that abnormal infants require less stimulation for crying as they get older.

A final and more rigorous analysis of the

Table V. One minute of crying after 0 to 2 R.B.S. in 36 pairs of infants matched for age and sex

	Cried	*Did not cry*	*Total*
Normal	32	4	36
Abnormal	8	28	36
Total	40	32	72
Accuracy (%) = 83.3			

*The scratching and finger flicking are no longer used in standard procedure since they produce practically no crying.

differences between normal and abnormal infants can be made if they are matched for age and sex. From the total of 264 infants, 36 clearly normal and 36 abnormal infants were matched as closely as possible for age and sex. The distribution of cry categories of these 2 groups is shown in Table V.

The level of predictive efficiency for the criterion of 2 or less R.B.S. for 1 full minute of crying increases to 83.3 per cent. The chi-square value obtained for the distribution shown in Table V equals 32.4 and $P < .001$.

Since a search for sex differences in all 264 cases proved fruitless, it is apparent that the critical factor, where cry thresholds are concerned, is age as well as normality or abnormality. The fact that no sex differences were found in this study does not preclude the possibility of differences in other features of their cries.

SUMMARY AND CONCLUSIONS

Studies of infantile vocalizations currently in progress at the Long Island Jewish Hospital are directed at a number of hypotheses, one of which concerns the possibility of making an early diagnosis of brain damage in infants from their crying behavior. A total of 293 children have been subjected to a standardized stimulation procedure in an effort to determine their cry thresholds. The present findings may be summarized as follows:

1. Abnormal infants require more stimulation than normal infants in order to evoke the same amount of crying.

2. The diagnosis of "abnormal" for infants who do not respond with 1 full minute of crying after 2 rubber band stimuli, and of "normal" for those who do so cry is 74.2 per cent effective.

3. Normal infants under 4 days of age may not cry as readily under this form of stimulation as older normal children do. The criterion of crying for 1 minute may be too severe for these infants. Other criteria are being explored. If judgment is withheld on all infants less than 4 days of age, the level of predictive efficiency under conclusion 2 increases to 79.8 per cent.

4. When 36 pairs of normal and abnormal infants were matched for age and sex, the level of predictive efficiency, using the same criterion described above, rose to 83.3 per cent.

5. Abnormal infants aged 1 year or more cry more readily and for longer periods of time than do younger abnormal infants, but they do not cry as readily as normal infants in the same age group, i.e., a smaller proportion of the older abnormal infants met the cry criterion for normality than of normal children of the same age.

6. No significant sex differences were found.

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