168
97

TEMPORAL ORGANIZATION OF CRY SOUNDS: A COMPARISON OF CRY RHYTHMICITY IN INFANTS WITH AND WITHOUT COLIC

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Masters Thesis submitted to the Faculty of

Virginia Polytechnic Institute and State University

in fulfillment of the requirements for the degree of

MASTERS OF SCIENCE

in

Psychology

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December, 1990

Blacksburg, Virginia

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(ABSTRACT)

The temporal organization underlying durational components of naturally occurring infant cries was examined in 46 1-month-old infants, half of whom had been diagnosed as having colic. In a standard 90-sec crying bout for each infant, the presence or absence of expired cry sound was determined at .05-sec intervals. Binary spectrum analysis of the data detected between 8 and 23 reliable cycles in the expiration of sound in the cries of all infants. The data were characterized by a wide range of individual differences in the frequencies at which these cycles occurred and in other characteristics of the spectra. Although infants with and without colic did not reliably differ in the mean, variability, or range of the durations of expirations or bursts, the two groups were distinguished by their distributions of the total number of peaks in the power spectrum and by the frequencies at which the highest power peak, slowest cycle, and fastest cycle occurred. This study provides the first known systematic examination of the rhythmicities underlying infant crying.

ACKNOWLEDGEMENTS

The present work was as much a labor of love as it was lesson in the painful realities of life. My husband, Tim, deserves the most recognition for this accomplishment, as his infinite patience and love has kept my confidence and idealism from dying altogether. I hope he will continue to share the successes and failures in my professional, as well as my personal life. I would also like to thank my parents, Bruce and Christine Parker, and my brother, Tom Parker, for their encouragement and support. They have taught me to keep a sense of humor, a fascination with the unknown, and a commitment to understanding the world around me.

Many friends provided the social support that was necessary for the completion of this project and my degree. Anna, Chris, Sheryl, Lisa, Laura, Joyce, Jeff, and Dean are among those who shared the heights and depths of this experience with me. I would especially like to thank Scott Roth who along with my husband, Tim, contributed technical expertise, patience, and humor during certain phases of this project.

Finally, I would like to thank various members of the faculty and other professional contacts who have contributed to my professional development. I owe many thanks to Sandy Zeskind for contributing the support and guidance that made this project possible. From him, I have learned to write and think more clearly and to descend from the conceptual heights of epistemology. I would also like to acknowledge Ron Barr who contributed the recorded infant cries that were used in this study. Finally, I would like to thank other members of the faculty, Robin Cooper, Bob Lickliter, and Dave Uttal for their professional advice and encouragement.

CONTENTS

TABLES

PAGE

FIGURES

PAGE

Introduction

The concept of behavioral organization has long been used in the study of behavior and its development (Hebb, 1964; Schnierla, 1957). One form of behavioral organization resides in the temporal domain and can be distinguished by its rhythmic or cyclic pattern (Zeskind & Marshall, in press). Such rhythmicity characterizes the activity of the newborn and young infant in a variety of behavioral dimensions. Periodic infant behaviors may appear as relatively slow oscillations, as seen, for example, in the 3- to 4-hr cycles in sleep-wakefulness and 40- to 60-min cycles in cardiac, vocal, and REM activity (Anders, 1982; Kleitman, 1963; Stratton, 1982; Zeskind, Goff, & Marshall, 1987). Additionally, rhythms in infant behavior may occur at relatively high frequencies, such as in the rapid changes underlying sucking, general motor activity and coordinated leg movements (Robertson, 1982, 1987; Thelen, 1979, 1985; Wolff, 1967). The periodic form of temporally organized behavior is hypothesized to reflect the integrity of nervous system function during the first few months of postnatal life, as well as ontogenetic changes in the organization of behavior (Anders, 1982; Stratton, 1982; Zeskind & Marshall, in press).

Crying is one domain of infant behavior that has been described as rhythmical in function (Stratton, 1982; Wolff, 1967, 1969). In his pioneering work, Wolff (1967, 1969) described infant crying as a repeated pattern of four temporal components: an expiratory phase, a brief pause, an inspiratory phase, and a second pause. The expiration contains the actual cry sound, while inspirations range from audible whistles to silent breaths. Pauses are short breaks which divide these two aspects of crying. From his analysis of the durational components of cries that were believed to reflect pain, frustration, and hunger, Wolff (1967, 1969) suggested that different states of infant arousal could be characterized by different durations of these features. Other than Wolff's (1967) anecdotal analysis, however, no known work has systematically explored the temporal organization of the durational aspects of crying.

One purpose of the present study was to investigate whether rhythmicity underlies the temporal organization of particular durational components of the cry sound. As indicated by Stratton (1982) and others (Zeskind & Marshall, in press), spectrum analysis of time-series data may provide a systematic method of inquiry, as well as a stringent test, for the identification of rhythmicities in behavior. Because the cry sounds of young infants have been anecdotally described as rhythmical, we would expect this important social behavior to show an organized temporal structure manifested in the power spectra of its energy.

To the extent that this analysis describes the behavioral organization of young infants, we would also expect infants who are hypothesized to vary in their organizational patterns of crying to vary in the spectral features that describe the temporal organization of this behavior. As such, a second goal of this study was to examine possible individual differences in the temporal organization of the cries of infants with and without colic. Infants with colic are described as healthy infants who over the first few months of postnatal life display excessive crying, particularly during the evening hours (Barr, in press). Additional characteristics which suggest atypical behavioral organization are frequent night wakings, digestive disturbances, hyperreactive responding to stimulation, and poor consolability (Asnes & Mones, 1982; Barr, in press; Ferber, 1985; Hewson, Oberklaid, & Menahem, 1987; Illingworth, 1955; Weissbluth, Christoffel, & Davis, 1984; Weissbluth, Davis, & Poncher, 1982, 1984; Wessel, Cobb, Jackson, Harris, & Detwiler, 1954). Appendix A provides a description of possible causes and consequences of infant colic.

Methods

Subjects

Subjects for this investigation were recruited as part of a larger study that was designed to explore the acoustic characteristics of the cries of infants with and without colic (Barr, Johnston, & Leduc, 1987). Twenty-three infants with colic and 23 infants without colic were recruited from the practices of two physicians in Montreal, Canada. Infants were selected for study if they were approximately 4-weeks of age, they showed a normal medical history and physical examination, they had at least one parent at home, a prenatal history without major complications, atypical medications, excessive smoking or alcohol consumption, and an uncomplicated postnatal course.

Procedure

Infants were studied in their homes before their scheduled evening feedings. A time-sampled observation period of 10 mins duration was used to tape record naturally occurring infant cry sounds. Crying that ensued during this 10-min observation period was recorded using a Sennheiser MKE 2-3 microphone suspended 20 cm from the infant's mouth. To standardize the duration of the time-series for all infants, recorded samples of crying were truncated at 90 secs.

A Marantz PMD 221 (3 head) recorder was used to replay taped cries into a personal computer that performed an analog to digital conversion of the cry signal via a Micro Speech Lab (MSL) sound analysis program. This program provided a graphical presentation of the amplitude window of the expiratory and inspiratory structure of the cry sound, and the pauses in between. A cry sound was defined as a vocalization that was not a grunt, cough, hiccup, or fussing noise, with fussing distinguished as shorter, lower amplitude expirations. All durational analyses were conducted by an investigator who was blind to infants' classifications regarding diagnosis of colic.

Movement of a cursor across the screen enabled the researcher to measure the duration of two cry features, the Burst Length and the Expiration Length, with a resolution of 250 msecs. A sampling rate of 4000 samples-per-sec (sps) was chosen to enable up to 60 secs of crying to be presented visually for analysis at one time. This sampling rate retained enough of the acoustic quality of the cry to enable the investigator to audibly distinguish cry sounds from other noises. Measurement of cry components was conducted by marking the beginning and end of the expired sound portion of each burst. A series of individual Burst Lengths and their corresponding Expiration Lengths were computed from these measures and truncated at 1 msec. Further reduction of these variables involved separating individual cry bursts into two components, the portion of the cry consisting of expired sound and the portion of the cry that contained inspirations and pauses. Cries were then marked every 5/100ths of a second with a 1 if the interval contained expired sound and with a 0 if it contained a pause or non-expired sound.

The resulting 1800 time-sampled data points for each cry were spectrum analyzed according to the procedures detailed by Gottman (1981). Linear trends in the data were first removed before computing the spectra in order to improve the stationarity of the time-series. The residual variance of each time-series was then subjected to a binary Blackman-Tukey discrete Fourier (spectrum) analysis to partition the total variance into independent components in the frequency domain. The spectral density functions for each infant were derived by smoothing the periodogram with a Hanning window with a lag of 600. As suggested by Jenkin and Watts (1968), spectral peaks were judged to be statistically significant when their 95% confidence interval was above the theoretical cumulative distribution of white noise as determined by a Kolmogorov-Smirnov test. The Kolmogorov-Smirnov test provided a conservative estimate of the number of spectral peaks in the power function. Table 1 shows the means, standard deviations, maximums, and minimums of the spectral density characteristics for the 46 infants studied.

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insert Table 1 about here

Results

<u>Description of Temporal Morphology</u>

The durational features of crying were first analyzed without separating infants according to their classifications of colic. Because each 90-sec sample of crying contained many individual cry bursts, the collection of Expiration Lengths and Burst Lengths from each cry was used to determine a mean, standard deviation, minimum, and maximum for each of these features, per infant. The resulting four variables for Burst Length and Expiration Length were used to compute a mean, standard deviation, minimum, and maximum for the group of 46 infants. Table 2 shows the means, standard deviations, minimums, and maximums of the two durational variables for all infants studied. The mean Burst Length for all infants was approximately 1 1/2 sec, and the mean Expiration Length was approximately 1 sec. The standard deviations for mean, minimum, and maximum Burst Lengths exceeded those for Expiration Length.

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insert Table 2 about here

A series of Chi Square analyses were used to describe the distributions of the means, minimums, and maximums of Burst Length and Expiration Length. First, the mean Burst Lengths of all infants were categorized as either <1 sec, 1 to 2 secs, or >2 secs. The number of infants who had mean Burst Lengths in each of these categories differed from that expected by chance, $X^2(2)=18.565$ ($p<.001$). Most infants had their mean Burst Length between 1 and 2 secs (n=29), with fewer in the <1-sec (n=7) and >2-secs (n=10) categories. Similarly, the minimum Burst Lengths of all infants were grouped using categories of <1/2 sec, 1/2 to 1 sec, and >1 sec. The number of infants whose minimum Burst Lengths occurred in each of these categories differed from that expected by chance, $X^2(2)=25.609$ ($p<.001$). The majority of infants had their shortest bursts between 1/2 and 1 sec (n=31), while the <1/2-sec (n=11) and >1-sec (n=4) divisions were less representative. An analysis of the maximum Burst Lengths was also performed using the categories, <4 secs, 4 to 6 secs, 6 to 8 secs, and >8 secs. The number of infants with maximum Burst Lengths in each of these categories did not differ from that expected by chance, $X^2(3)=7.217$ ($p<.065$), such that <4 secs (n=15), 4 to 6 secs (n=17), 6 to 8 secs (n=7), >8 secs (n=7).

Similar comparisons were conducted for the means, minimums, and maximums of the Expiration Lengths for all 46 infants. The mean Expiration Lengths of all infants were grouped using categories of <3/4 sec, 3/4 to 1 sec, 1 to 1 1/4 sec, and >1 1/4 sec. The number of infants who showed mean Expiration Lengths in each of these categories did not reliably differ from that expected by chance $X^2(3)=4.609$ ($p<.203$). The distribution of infants in each of the mean Expiration Length categories was as follows: <3/4 sec (n=16), 3/4 to 1 sec (n=11), 1 to 1 1/4 sec (n=13), and >1 1/4 sec (n=6). The distribution of minimum Expiration Lengths was described using categories of <1/4 sec, 1/4 to 1/2 sec, and >1/2 sec. The number of infants who had their minimum Expiration Length in each of the three categories differed from that expected by chance, $X^2(2)=13.087$ ($p<.001$). Most infants showed their minimum Expiration Lengths at <1/4 sec (n=19) or between 1/4 to 1/2 sec (n=23), with fewer in the >1/2-sec (n=4) category. Maximum Expiration Length was categorized as <2 secs, 2 to 4 secs, and >4 secs. The number of infants whose longest Expiration occurred in each of the categories differed from that expected by chance, $X^2(2)=14.652$ ($p<.001$). A preponderance of infants showed their maximum Expiration Lengths between 2 and 4 secs (n=25), with fewer in the <2-secs (n=17) and >4-secs (n=4) categories.

Spectrum Analysis of Temporal Morphology

Time-sequential analyses of individual infant's cries revealed significant peaks in the spectra of all 46 infants. The Total Number of Peaks for each infant was derived.

Table 3 shows that the Total Number of Peaks ranged from 8 to 23 and had a mean of 16. Infants displayed a relatively even distribution across the range of values for Total Number of Peaks.

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insert Table 3 about here

To provide a more detailed description of these spectra, specific features of the arrangement of peaks were analyzed. Fastest and Slowest Cycles within the spectra were targeted for analysis, as these features reflect the range of rhythms which result from changes in the temporal morphology of crying. As shown in Table 3, the average length of the Fastest Cycle, or the time required for that cycle to complete one oscillation, was .52 secs. The duration of the Fastest Cycle was categorized as $.50 \pm .02$ sec (approximately one cycle per 1/2 sec). The number of infants who had their Fastest Cycles occurring in each of the categories marginally differed from that expected by chance, $\underline{X}^2(2)=5.78$ ($\underline{p}<.056$). More infants displayed Fastest Cycles in each of the extreme categories, <.48 sec (n=17) and >.52 sec (n=21), than in the .48- to .52-sec (n=8) range.

The length of the Slowest Cycle was also compared across infants. As Table 3 shows, the mean duration of the Slowest Cycle was 11 secs, with infants displaying basic cycles from 1 to 46 secs in length. The duration of the Slowest Cycle was analyzed using four categories, <10 secs, 10 to 20 secs, 20 to 30 secs, and >30 secs. The number of infants who had Slowest Cycles in each of the categories did not reliably differ from that expected by chance, $\underline{X}^2(3)=6.0$ ($\underline{p}<.112$). Still, the distribution of infants among these categories revealed that most had Slowest Cycles that were >30 secs (n=12) or 20 to 30 secs (n=18) in length, as opposed to 10 to 20 secs (n=9) or <10 secs (n=7) in length.

Two aspects of the most powerful rhythm, or the cycle that accounted for the largest portion of the variance within each infant's spectra, were of interest. These two variables were the frequency and amplitude of the highest power peak. These peaks of highest amplitude ranged from relatively slow cycles (1.3 cpm or approximately 46 secs in length) to those of higher frequencies (89.3 cpm or approximately 2/3 sec in length). To further describe the distribution of the frequency of the most powerful rhythms, infants were grouped according to the length of their dominant cycles using four categories, <2 secs, 2 to 10 secs, 10 to 30 secs, and >30 secs. The number of infants whose peak of highest amplitude occurred in each of the categories differed from that expected by chance, $X^2(3)=11.22$ ($p<.011$). A preponderance of infants had highest power peaks that represented cycles of <2 secs (n=20) in duration, whereas fewer showed their peak of highest amplitude occurring in cycles of 2 to 10 secs (n=13), 10 to 30 secs (n=8), or >30 secs (n=5) in length.

The power of this dominant rhythm was also compared across all 46 infants. The distribution of the amplitude values of infants' highest peaks was analyzed using the categories <.5, .5 to 1.0, and >1.0. The number of infants whose peak of highest amplitude had its power in each of the categories differed from that expected by chance, $X^2(2)=7.87$ ($p<.02$). Most infants had the power of their highest peak occurring between .5 and 1.0 (n=24), with fewer showing amplitude values in the extreme categories, <.5 (n=13) and >1.0 (n=9).

Comparison of Infants With and Without Colic

In order to examine individual differences among infants, comparisons of the Colic and Non-Colic groups were performed. As Table 4 illustrates, no reliable differences were found between infants with and without colic for the mean, minimum, and maximum Burst Lengths and Expiration Lengths. However, the time-series analyses differentiated the temporal organization of crying that characterized each of the groups.

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insert Table 4 about here

For the variable, Fastest Cycle, the number of infants in the Colic and Non-Colic groups in each of the three categories differed from that expected by chance, $X^2(5)=9.90$ ($p<.007$). Unlike infants without colic who showed a relatively even distribution across the three categories, >.52 sec (n=9), .52 to .48 sec (n=8), and <.48 sec (n=6), infants with colic had their Fastest Cycles occurring at frequencies that were either >.52 sec (n=12) or <.48 sec (n=11). As Figure 1 demonstrates, no infants in the Colic group showed their Fastest Cycle in the .5 ± .02-sec range.

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insert Figure 1 about here

A similar comparison of the Colic and Non-Colic groups for Slowest Cycle demonstrated that the number of infants in each of the categories differed from that expected by chance, $X^2(3)=9.24$ ($p<.026$). Infants without colic were evenly distributed among the first three categories, 2 to 10 secs (n=8), 10 to 30 secs (n=8), and >30 secs (n=6), but few had Slowest Cycles that measured <2 secs (n=1) in length.

Infants with colic were under-represented among those whose Slowest Cycle was 2 to 10 secs (n=1) in length, but displayed a relatively even distribution across the other three categories, <2 secs (n=6), 10 to 30 secs (n=10), and >30 secs (n=6). Figure 2 shows a comparison of the distributions for the Slowest Cycles of infants with and without colic.

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insert Figure 2 about here

Comparisons of the distributions of the power and frequency of the highest peak were also performed. The number of infants with and without colic who showed the amplitude of their highest power peak in each category did not differ reliably from that expected by chance, $\underline{X}^2(2)=1.47$ ($\underline{p}<.48$). Infants with colic had amplitude values of their highest power peaks occurring more often in the .5 to 1.0 (n=24) range, with fewer infants in the extreme categories, <.5 (n=5) and >1.0 (n=4). Infants without colic showed a similar distribution of amplitude values for highest power peaks, such that, <.5 (n=8), .5 to 1.0 (n=10), and >1.0 (n=5).

Unlike the amplitude value of the highest power peak, the frequency at which this dominant cycle occurred differentiated the distributions of the two groups. The number of infants in each group whose peak of highest amplitude occurred at a cycle length (or frequency) in each category differed from that expected by chance, $\underline{X}^2(3)=11.97$ ($\underline{p}<.008$). Infants in the Non-Colic group were common in the 10- to 30-secs (n=8) and <2-secs (n=10) categories, while few had highest power peaks of 2 to 10 secs (n=3) and >30 secs (n=2) in length. Conversely, infants in the Colic group tended to have their most prominent rhythm occurring at cycles of very short duration, 2 to 10 secs (n=10) or <2 secs (n=10) in length, rather than at lower frequencies, 10 to 30 secs (n=0) or >30 secs (n=3). Figure 3 shows the distributions for the length of the dominant cycle of infants with and without colic.

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insert Figure 3 about here

The Total Number of Peaks found in the spectra of infants with and without colic was compared using a Wald-Wolfowitz runs test. The results of this analysis revealed that the distributions for this variable differed to a greater extent than would be expected by chance. As Figure 4 demonstrates, infants without colic show a tendency toward a higher Total Number of Peaks than infants with colic.

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insert Figure 4 about here

Discussion

Rhythms have been used to characterize the organization in various domains of behavior in the newborn and young infant (Anders, 1982; Kleitman, 1963; Robertson, 1982, 1987; Stratton, 1982; Thelen, 1979, 1985; Wolff, 1967, 1969; Zeskind et al., 1987). Crying, in particular, has been described as rhythmic in its character (Stratton, 1982; Wolff, 1967, 1969), but no research has systematically analyzed the temporal organization underlying this important behavior. The present study provides a systematic description of two aspects of the temporal morphology of infant cries (Burst Length and Expiration Length), as well as an analysis of the rhythmicity that underlies these components. The results of this study provide the first stringent evidence that crying in the young infant is cyclically organized in a complex pattern of rhythms. The temporal organization underlying the cries of all 46 infants could be characterized by reliable rhythmic cycles of activity.

Time series analysis was used to describe the the cyclic activity underlying infant cry sounds. This method enables the regularity in individual burst durations or in sequences of bursts to be reflected in cycles at various frequencies. Spectral analysis of time-series data illustrates temporal organization by the number of cycles and by the frequencies at which these cycles occur. Through this analysis, the characteristics of the temporal organization of crying was described for all infants studied and used to differentiate infants with and without colic.

The complexity of the rhythms underlying infant cry sounds is evidenced by the total number of cycles detected in the power spectra. In this study, spectrum analysis detected a wide range of reliable rhythms in all infants' bouts of crying. An average of 16 reliable cycles were discernable in these spectra, with some infants having as few as 8 and others as many as 23. That is, the variability in whether or not an infant produced expired cry sound over time could be reliably described by a complex wave-form. In essence, these multiple cycles represent rhythms in the expiration of sound, each fluctuating around a point of equilibrium which may, in turn, show rhythmic organization at a wide range of other frequencies. The detection of these cycles provides some of the first systematically derived evidence of the temporal organization of infant crying.

The frequencies at which particular cycles occurred reveal patterns in the spectra of infant cry sounds that can be used to support anecdotal descriptions of rhythmicity. The length of the cycle that accounted for the most variance in infants' cries was usually <2 secs. The most common range of the variable, mean Burst Length, 1 to 2 secs, suggests that these most powerful rhythms reflect changes occurring within individual bursts. To the extent that anecdotal reports of rhythms in crying reflect the presence or absence of expired sound, these dominant cycles can be said to illustrate a periodicity that contributes to the perception of crying as rhythmical.

In addition to these relatively high frequency cycles, most infants had Slowest Cycles in crying that were >20 secs in length. The typical range of mean Burst Length, 1 to 2 secs, can also be used to describe the Slowest Cycle in terms of variability in the temporal morphology of crying. However, a cycle duration of >20 secs reflects changes that occur over a sequence of 10 to 20 bursts. Such lower frequency cycles may indicate a series of bursts that are organized in a sinusoidal pattern of increasing and decreasing length. These Slowest Cycles may not be perceived as rhythmical in the same sense that cycles of <2 secs in length reflect the changes from expired sound to an interval between two expirations. Rather, a cycle of >20 secs in duration may signal a rise and fall in infant arousal to the adult listener underlying the higher frequency rhythms of variations within bursts.

Similarly, individual differences in the temporal organization of crying may signify differences in the patterns of arousal that characterize particular infants. Infants with and without colic showed distributions that differed for the Total Number of Peaks and for the frequency of their Fastest Cycle, Slowest Cycle, and most powerful rhythm that could not be explained by differences in the mean, standard deviation, minimum, and maximum values of Expiration Length and Burst Length. Interestingly, hypotheses that address the etiology of colic suggest differences in the patterns of arousal that characterize such infants (Barr, in press; Illingworth, 1955). Colic has been attributed to various physiological dysfunctions that cause infants to display general hyperreactivity and a poor ability to dampen their responding. This unusual behavioral organization may influence the development of infants with colic through a cycle of perceptual and behavioral transactions with the caregiving environment (see Appendix A).

In conclusion, results of the present study can be interpreted based on several views of crying. First, differences in the temporal organization of the cries of young infants may reflect differences in the organization of physiological and behavioral systems. Specifically, the rhythmicity that underlies aspects of the durational features of crying may signify the coordination of vocal, respiratory, and autonomic nervous systems (Lester, 1984).

Rhythms at various frequencies in crying may also convey important perceptual messages to the caregiving environment, such that variations in the temporal morphology of crying may provide a means by which caregivers can monitor the well-being of an infant over time. Such messages would be of particular importance in cases where infants cry for especially long periods, as in the case of infants with colic. Differences in the temporal morphology of infant cries have been found to affect adults' perceptions of individual infants (Zeskind, Hartford, Marshall, & Wilhite, 1990).

To the extent that changes in this morphology constitute the temporal organization of infant crying that was analyzed in the present study, infant cries that differ in their organizational structure are expected to elicit different perceptual responses from adult listeners. The functional significance of the temporal organization underlying infant cries derives from these hypothesized variations in the perceptions of caregivers and from the effect of these perceptions on infant-adult social interaction, a factor that has been implicated in the social and intellectual development of infants and young children (Crnic et al., 1983; Isabella, Belsky, & von Eye, 1989; Lester et al., 1985; Sameroff & Chandler, 1975; Zeskind & Ramey, 1978, 1981).

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Table 1

Description of General Characteristics of the Spectra Generated from Infant Cries

Characteristics	Mean	SD	Min	Max
Residual Variance	0.01	0.02	0.00	0.112
Summed Spectral Density Values	30.54	3.21	21.749	35.569
Cumulative Distribution of White Noise	0.03	0.00	0.024	0.040

Table 2

Descriptive Statistics of the Durational Components of Infant Cries

	Mean	SD	Min	Max
		Burst Length (in secs)		
Mean	1.58	0.61	0.879	3.819
SD	1.23	1.65	0.017	9.226
Min	0.64	0.21	0.319	1.228
Max	5.41	2.52	1.192	12.991
		Expiration Length (in secs)		
Mean	0.93	0.28	0.463	1.699
SD	0.23	0.20	0.015	0.914
Min	0.30	0.17	0.061	0.910
Max	2.58	1.17	0.889	7.119

Table 3

Description of Characteristics of the Temporal Organization of Infant Crying

Characteristics	Mean	SD	Min	Max
Total Number of Peaks	16.00	4.27	8.00	23.00
Duration of Fastest Cycle (secs)	0.52	1.97	0.33	1.20
Duration of Slowest Cycle (secs)	11.05	5.98	1.14	46.15
Power of Peak of Highest Amplitude	0.73	0.30	0.32	1.48
Duration of Peak of Highest Amplitude (secs)	1.92	2.12	0.67	46.15

Table 4

Comparison of Burst Length and Expiration Length in Infants With and Without Colic

	Colic		Non-Colic				
	mean	SD	mean	SD	t	(df)	$p<$
			Burst Length (in secs)				
mean	1.67	0.69	1.49	0.52	-1.01	44.0	0.317
min	0.67	0.18	0.62	0.23	-0.88	44.0	0.383
max	5.55	3.14	5.23	1.77	-0.38	34.7	0.709
			Expiration Length (in secs)				
mean	0.95	0.30	0.92	0.26	-0.39	44.0	0.700
min	0.29	0.14	0.32	0.20	0.55	44.0	0.585
max	2.72	1.37	2.45	0.95	-0.78	44.0	0.439

Figure Captions

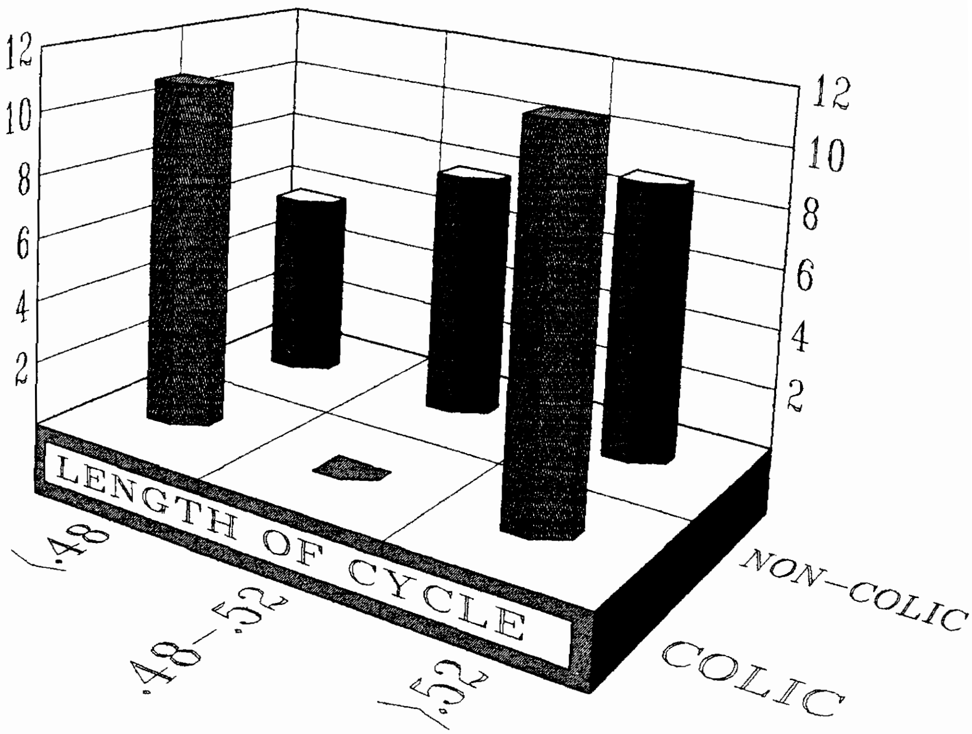
Figure 1. The _X_ axis shows the categories of lengths of Fastest Cycles (in secs) that occurred in infants cries. The _Y_ axis measures the number of infants who had their Fastest Cycles in each of these groups. Colic classification is indicated by the _Z_ axis.

Figure 2. The lengths (in secs) of infants' Slowest Cycles are displayed on the _X_ axis in four categories. The number of infants occurring in each category is represented by the _Y_ axis. Colic and Non-Colic groups are distinguished by the _Z_ axis.

Figure 3. The most powerful rhythm that was discernable in the spectra of infants' cries is represented by four ranges of cycle durations (in secs) on the _X_ axis. The _Y_ axis shows the number of infants who had their dominant rhythm in each of the categories. The _Z_ axis differentiates the distributions of the Colic and Non-Colic groups.

Figure 4. The _X_ axis represents the Total Number of Peaks that were discernable in each infant's spectra. The _Y_ axis measures the number of infants, and the _Z_ axis separates the distributions of infants with and without colic.

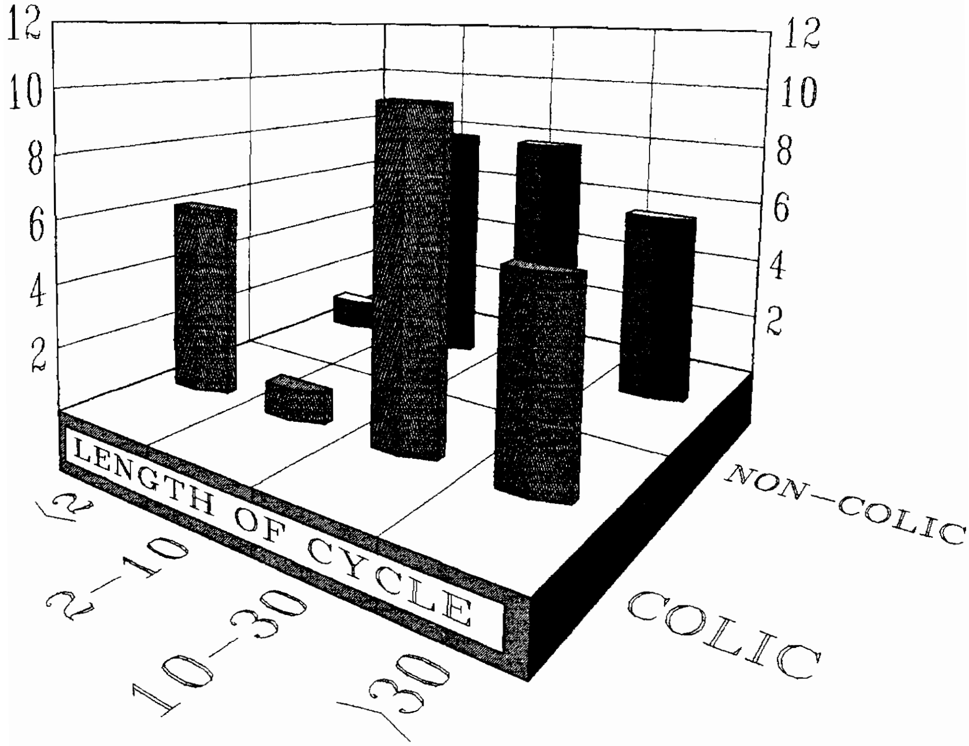
FASTEST CYCLE



(in seconds)

Figure 1.

SLOWEST CYCLE



(in seconds)

Figure 2.

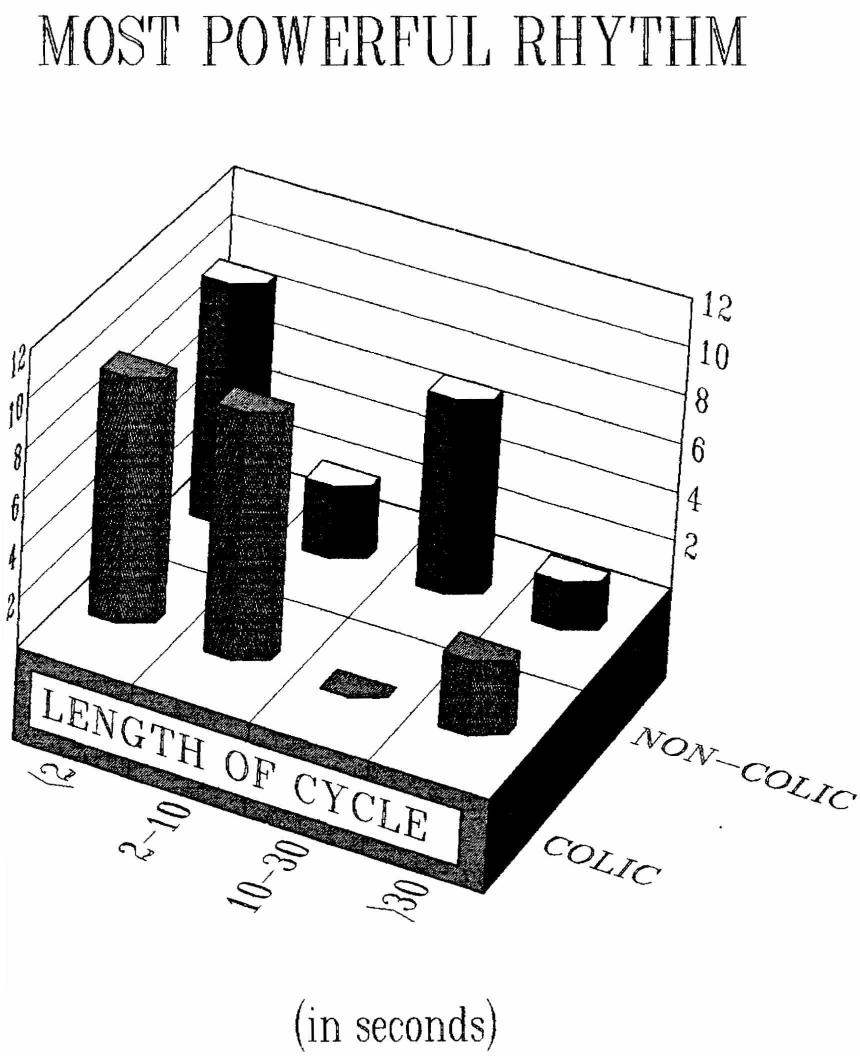

MOST POWERFUL RHYTHM
12
10
8
6
4
2
LENGTH OF CYCLE
<2
2-10
10-30
>30
NON-COLIC
COLIC
(in seconds)

Figure 3.

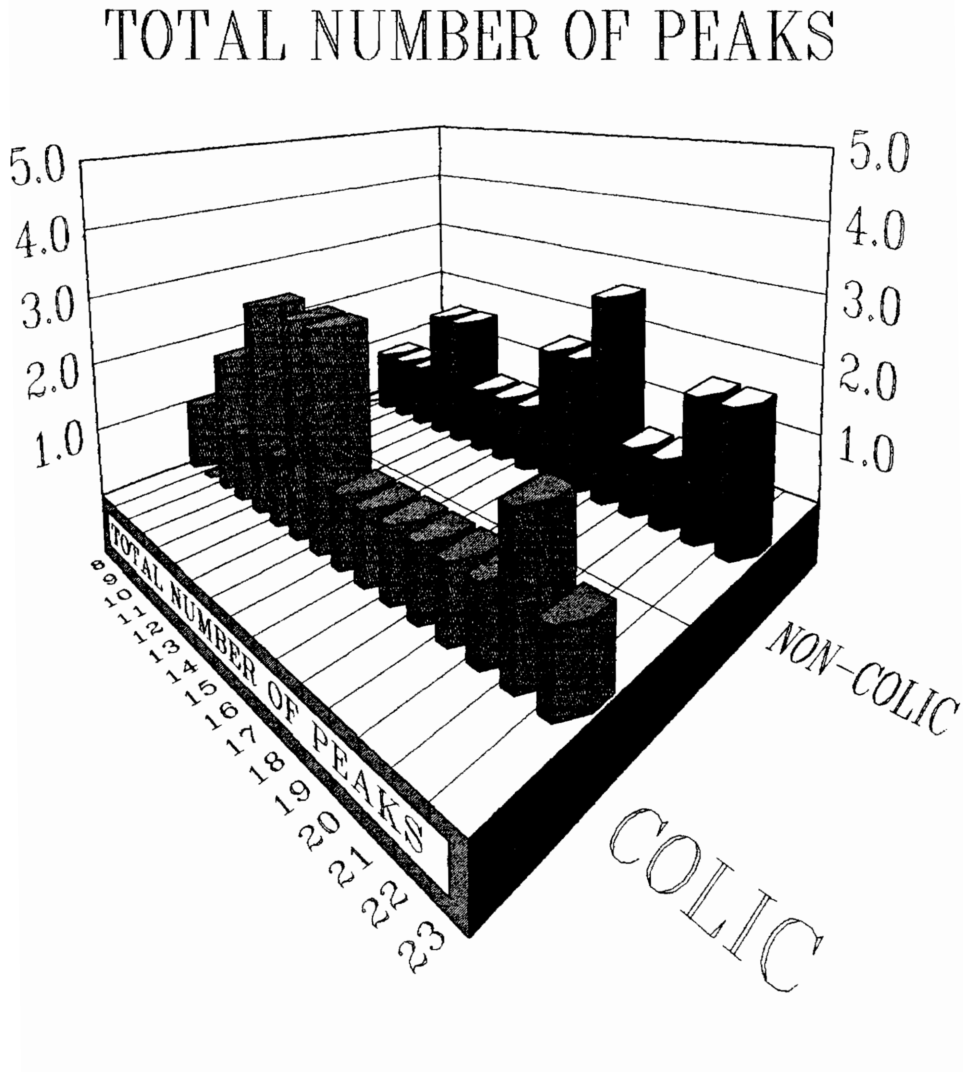

TOTAL NUMBER OF PEAKS
5.0
4.0
3.0
2.0
1.0
TOTAL NUMBER OF PEAKS
8
9
10
11
12
13
14
15
16
17
18
19
20
21
22
23
NON-COLIC
COLIC

Figure 4.

Appendix A

Although a number of theories have been proposed, little is known about the etiology of colic. In a review of the literature integrating colic, Hewson, Oberklaid, and Menahem (1987) grouped theories into categories based on the following causes, infant food allergies, immaturity of infant digestive systems, and nervous system imbalances. Explanations of digestive malfunctioning as origins of colic include protein intolerance, problems of feeding type (breast verses formula), problems of feeding style (frequent/brief verses infrequent/prolonged feedings; swallowing of air during sucking), lactose intolerance, excessive colon motility, and overproduction of prostaglandins (Barr, in press). Another hypothesis which proposes that an imbalance in nervous system activity may underlie colic consists of fewer variations than the digestive malfunction hypothesis. Such explanations usually emphasize the role of the autonomic nervous system and often attribute colic to sympathetic dominance that is mediated by the vagus nerve (Hewson et al., 1987; Lester, in press). Whether colic originates from variations in infant digestion or nervous system function remains an issue for debate. However, reports of the behavioral organization that characterizes infants with colic are consistent over descriptions of symptomology (Illingworth, 1955).

Because the etiology of colic remains uncertain, no attempts have been made to explain the syndrome in terms of the history of experiences that may determine its onset. However, experiences that seem to precipitate differences in the organization underlying various domains of infant behavior may provide a model for the development of colic. A variety of nonoptimal prenatal and early postnatal conditions, such as fetal malnutrition, maternal diabetes, and preterm birth, characterize infants who differ in the temporal organization of their behavior (Crnic, Ragozin, Greenberg, Robinson, & Basham, 1983; Field, Healy, & LeBlanc, 1989; Lester, Hoffman, & Brazelton, 1985; Robertson & Dierker, 1986; Zeskind et al., 1987). The organizational differences in some domains of early infant behavior have been suggested as indicators of individual differences in autonomic function (Robertson, 1987; Zeskind et al., 1987; Zeskind & Marshall, in press). For example, infants whose neonatal anthropometry suggests prenatal nutritional deficits have been found to differ from typical infants on a variety of behavioral measures, as well as in the temporal organization of their heart rate (Zeskind et al., 1987). The present study demonstrates that infants with and without colic who have been hypothesized to differ in their autonomic function show differences in the patterns underlying the temporal organization of their crying. The developmental model that is implied in some studies of the organization of infant behavior suggests that differences in the temporal organization of crying in infants with colic may also reflect atypical prenatal and early postnatal experiences.

While no research has explored prenatal factors that may facilitate the development of colic, some studies of infants with colic suggest that their atypical behavior in various domains may lead to nonoptimal postnatal experiences (Barr, in press; Lester, in press). The behavioral symptoms of colic suggest that infants who demonstrate the syndrome could be considered a subgroup of "difficult" infants (Weissbluth et al., 1984b). As such, the functional significance of colic may lie in the types of responding that infants who manifest the syndrome engender within the caregiving environment. Infants with colic can be seen as negatively affecting their social transactions with caregivers who become frustrated by the prolonged periods of unexplained crying, poor consolability, hyperreactive responding, frequent night wakings, and digestive disturbances that typify the syndrome. Because crying is the behavioral domain that is usually used to differentiate infants with and without colic, characteristics of cry sounds are hypothesized to reflect these differences in the organization of infant behavior. This study distinguished infants with and without colic according to the temporal organization underlying the expirations of sound in crying. Future studies are needed to describe other aspects of the cries that typify infants with colic and to examine the effects of these sounds on the perceptions of potential caregivers.

The relationships between infants and their caregiving environments may determine whether or not colic persists. However, the ages when colic typically disappears suggest that ontogenetic changes are also implicated in infants' recoveries from the syndrome. Hide and Guyer (1982) reported that 47% of infants lost their symptoms by 3 months of age, a time which corresponds to a possible shift in behavioral organization (Emde, Gaensbauer, & Harmon, 1976; Gaensbauer & Harmon, 1981). During the third month of postnatal life, the amount of daily crying decreases, and infant crying changes from a predominantly reflexive behavior to one that is increasingly contingent upon activities in the caregiving environment (Brazelton, 1962; Emde & Gaensbauer, 1981). For approximately half of the infants diagnosed as having colic, therefore, this developmental shift in behavioral organization and the experiences which surround it may play a role in ameliorating colic (Barr, in press). By the sixth month of postnatal life, most infants who had colic at 6 weeks of age no longer show symptoms associated with prolonged periods of crying (Hide & Guyer, 1982). Interestingly, Emde, Gaensbauer, and Harmon (1976) found evidence of a second shift in behavioral and nervous system functioning between the seventh and ninth postnatal month, a period which seems to correspond to the disappearance of colic in this second group of infants.

Following their recovery from colic, infants who exhibited the syndrome in the first few months after birth show similar characteristics. Infants who had colic are more likely than infants who never received such diagnoses to develop "difficult" temperaments and to show atypical sleep patterns once they have recovered from the syndrome (Weissbluth et al, 1984a). This continuing pattern of temperamental difficultness may reflect a series of age-related individual differences, thereby supporting the view that infants with colic are a subset of "difficult" infants. Their apparently chronic sleep disturbances, which include frequent wakings during the night and a preponderance of restless activity, suggest that infants who had colic may exhibit differences in nervous system function even after the syndrome has disappeared (Weissbluth et al, 1984a).

In addition to the persistence of particular patterns of behavior, the temperament ratings that characterize infants with colic may reflect a complex set of social circumstances. Because the perceptions of particular caregivers are used to determine temperament classifications, the conceptions of infants and patterns of caregiver-infant social interaction that developed when colic was present may further explain the perpetuation of "difficultness". Further studies are needed to determine the changes in infant crying when colic is present and after the syndrome has disappeared and also to compare the cries of infants who have recovered from colic to those of typical infants of the same age. If differences in the cries of infants with colic persist after the syndrome has disappeared, it will also be important to discern whether adult listeners, and particularly those who have cared for infants with colic, respond differently to these cries. As such, infant crying may continue to affect the relationship between caregiver and infant even after the disappearance of colic.

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Research

1990	Co-Investigator, Psychology Department, Virginia Polytechnic Institute & State University, Blacksburg, VA; Temporal Organization of Cry Sounds: A Comparison of Cry Rhythmicity in Infants With and Without Colic, Master's Thesis, supervised by Dr. Philip Sanford Zeskind
1990	Family Interviewer, Psychology Department, University of Virginia, Charlottesville, VA; Child Care and Family Project, supervised by Dr. Sandra Scarr

1989 Research Assistant, Psychology Department, Virginia Polytechnic Institute & State University,

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1987-88 Research Assistant, Center for Gerontology, Virginia Polytechnic Institute & State University, Blacksburg, VA; Social and Psychological Adjustment to Widowhood, supervised by Dr. Rosemary Blieszner

Instruction

1990-91 Instructor, Laboratory in Cognitive Psychology, Psychology Department, Virginia Polytechnic Institute & State University, Blacksburg, VA

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American Psychological Association; Student Member
Psi Chi, National Honor Society in Psychology; Member
Phi Upsilon Omicron, National Honor Society; Member
Omicron Nu, National Honor Society; Member
Graduate Student Assembly, Virginia Polytechnic Institute and State University; Psychology Department Delegate, 1990-91
Virginia Tech Gerontological Association; Vice-President, 1987-88
Volunteer Advisory Council, RAFT Community Crisis Center; President, 1989-90

AWARDS AND HONORS

Contributions to Faculty and Fellow Students Award from the Department of Family and Child Development, 1988
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PAPERS PRESENTED

Parker-Price, S., Zeskind, P. S., and Barr, R. G. (October, 1990). Temporal organization of infant crying. Paper presented at the Virginia Developmental Forum, Fairfax, VA.
Parker-Price, S. and Blieszner, R. (May, 1988). Widowers' maintenance of social support systems as related to their sex stereotyping tendencies. Paper presented at the meeting of the American Home Economics Association, Roanoke, VA.