PERCEPTUAL DIMENSIONS OF INFANTS' CRY SIGNALS

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ABSTRACT

Two experiments were performed to uncover perceptual dimensions of 24 infant cry signals. In Experiment 1, the 24 cries were rated by listeners on 50 semantic differential scales. A factor analysis of the ratings uncovered three meaningful factors (Effect, Potency & Value) which emphasise emotional aspects of the cries, and support a suggestion that different cry-types essentially differ along a continuum of intensity/aversiveness. In Experiment 2, the method of pair-comparisons was used to obtain cry similarity ratings which were submitted to INDSCAL (a multidimensional scaling program). Three dimension were uncovered which emphasise physical aspects of the cries. These dimensions (Potency, Form and Clarity) were labelled in terms of the 50 semantic differential scales using standard linear multiple regression. For both experiments, accurate predictions of cry recognition results were made from the cry similarity data, suggesting that the listeners attended to the same cry features in each task. A canonical analysis of the semantic differential factor scores and the INDSCAL dimension weights revealed two significant canonical correlations, which suggests that the two techniques are essentially describing the same perceptual space. The relative advantages of the semantic differential and the method of pair-comparisons (coupled to INDSCAL) are discussed, and also the possibility of applying the semantic differential to study different cry-types, clinically abnormal cries, and the effects of crying on the caregiver.

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The cry of the neonate is an important survivial mechanism. According to Brazelton (1962) crying is of physiological and neuro-physiological value because it improves pulmonary capacity and helps to maintain homeostasis. Cries also enable the infant to establish and maintain contact with its caregiver. The complex acoustic characteristics of the cry permit effective communication at a distance, and convey information concerning the infant's state, mood and needs (Illingworth, 1955). Furthermore, clinicians have long recognised that the cries of abnormal infants are characteristically different from those of normal infants (Illingworth, 1955), and may have diagnostic value (Wasz-Hockert, Lind, Vuorenkoski, Partanen & Valanne, 1968).

Both Wolff (1969) and Zeskind & Lester (1968) suggest that the different cry signals emitted by an infant lie on a continuum essentially determined by the intensity of the cry eliciting stimulus. At one end of this continuum is the "pain" cry, whilst at the other is the "basic" or "rhythmical" cry, to which all crying reverts. From an ethological perspective, however, cries are considered to be species-specific signals, characteristic of the cry-eliciting situation, which serve as "releasers" of an innate maternal response (Valanne, Vuorenkoski, Partanen, Lind & Wasz-Hockert, 1967). For example, it has been noted that some mothers can identify the cause of their infant's crying by the nature of the cries (Illingworth, 1955); mothers in a maternity situation have reported awakening to their own infant's cries, but not to the cries of other infants (Illingworth, 1955; Formby, 1967); and lactating mothers have reported milk let-down in response to an infant's crying (Vuorenkoski, Wasz-Hockert, Koivisto & Lind, 1969).

The ethological interpretation of crying has prompted a number of cry recognition studies. Contrary to the early findings of Sherman (1927), a series of studies (Wasz-Hockert, Partanen, Vuorenkoski, Michelsson & Valanne, 1964a; Wasz-Hockert, Partanen, Vuorenkoski, Valanne & Michelsson, 1964b; Wasz-Hockert *et al.*, 1968) consistently found that adult listeners with varying degrees of infant experience could reliably identify different cry-types (birth, pain, hunger and pleasure). Furthermore, Berry (1975) using 15 of the Wasz-Hockert *et al.*, (1968) signals, obtained similar results using children as listeners. However, Muller, Hollien & Murry (1974), using cries of pain, hunger and startle, report that their listeners (mothers):

> were generally unable to successfully match the cry samples with the three cry evoking situations. Further, no differential advantage was found when the mothers were judging samples produced by their own infant. (p89)

The conflicting findings of the recognition studies raise a number of methodological issues (see Muller *et al.*, 1974; Zeskind & Lester, 1978; Murray, 1979), and highlight a limitation of the recognition task itself. When there is a general failure by subjects to identify cry signals, this failure may be attributable to either the ability of the subjects, or to the perceptual qualities of the signals themselves. Failure by experienced mothers, especially when their own infant's signals are involved (Muller *et al.*, 1974), suggests that the cries are perceptually similar and thus easily confused. On the other hand, when the different cry types are reliably identified (Wasz-Hockert *et al.*, 1964a,b; 1968), and hence discriminable (Gibson, 1969) it is of interest to know whether subjects who score poorly do so because they are unable to discriminate between the signals, or because they are unable to label them correctly.

Paradoxically, the signals which so effectively attract the attention of the caregiver may put the infant "at risk" for abuse. Bell (1972) suggests that the cry is an effective signal because of its aversive nature, which essentially coerces the caregiver into attending in order to "turn it off" and discourage its recurrance. The emotional responses to these signals, however, may be intense and lead to acts that are abusive rather than nurturant (Ostwald, 1972; Murray, 1979). Such a response may be common amongst parents. In an "almost baby-bashing" questionnaire

(Kirkland & Hill, 1979), crying was the most common reason provided by parents for their feelings of wanting to "bash" their infants.

The aversive nature of crying has been demonstrated in several studies. For example, Kilpatrick and Kirkland (1977) found crying to cause greater disruption in a Stroop card-sorting task than either non-intelligible speech or silence. And Frodi & Lamb (1978a) found increases in subjects' skin conductance and diastolic pressure, and self-report measures that indicated increased irritability, annoyance and disturbance, in response to a crying infant but not to a smiling infant.

Whilst Frodi & Lamb (1978a) suggest that all infant crying is perceived as aversive by adults, it is apparent that some infant's cries are particularly aversive. Frodi & Lamb (1978b) produced four video-tapes, two of a full-term crying infant, and two of a premature crying infant. The first video-tape of each infant had the infant's own cries on the soundtrack, whilst the second video-tape (visually identical to the first) had the cries of the other infant. Both the physiological and self-report measures gathered from the four sets of subjects revealed that the premature infant's cry elicited greater autonomic arousal and was perceived as more aversive. This effect was pronounced when the premature's visual was coupled to the premature's cries. Frodi & Lamb (1978a) suggest that the production of particularly aversive signals may explain the frequency with which premature infants are abused, and why abusive parents commonly select a particular child as a target.

Analytical studies of the infant cry signal have almost exclusively focussed upon the acoustic features of the cries, and ignored the perceptual characteristics. Cries have been described in terms of music notation (Gardiner, 1838), vowel elements (Irwin & Curry, 1951), and the power spectrum (Tardelli, 1971; Tenold, Crowell, Jones, Daniel, McPherson & Popper, 1974). The most widely used analytical technique, however, is the sound spectrograph

(Lynip, 1951). Spectrographic studies have been made of cries from a variety of clinical conditions, such as meningitis, hydrocephalus, Downes Syndrome and hyperbilirubinemia (Wasz-Hockert *et al.*, 1968); and also of different cry types from normal infants (Wasz-Hockert *et al.*, 1968). Even studies utilizing the perceptual judgements of subjects have tended to require that judgements be made in terms of pre-determined "distinctive features" such as rhythm, pitch, intensity, latency and quality (Wiener, 1974) or melody type, continuity, voicing, oral *vs* nasal, and lax *vs* tense (Wasz-Hockert *et al.*, 1968). However, it should be noted that these features are not necessarily those attended to by a listener under normal circumstances.

Whilst the importance of the subjective or perceptual qualities of cries has been demonstrated with regard to both the ethological studies and those concerned with the effect of crying on the caregiver, only two studies to date have examined these qualities directly. Zeskind and Lester (1978) were able to differentiate between two groups of infants on the basis of listeners' subjective ratings of the infants' cries on eight semantic-differential scales (urgent-not urgent, pleasing-grating, sick-healthy, soothing-arousing, piercing-not piercing, comforting-not comforting, distressing-not distressing, aversive-non aversive). The first group comprised infants who had a low incidence of prenatal and perinatal complications, whilst the second group comprised "clinically normal" infants who had suffered a high number of pre- and perinatal complications. A factor analysis revealed one factor for the low complications group on which all scales loaded highly. Two factors appeared for the high complications group, with the first factor reflecting the unpleasant qualities of the cries, and the second factor reflecting the condition of the infant (sick, urgent). Thus the results suggest the possibility of using subjective judgements on a set of appropriate descriptive scales to identify clinically "at risk" infants.

To investigate the perceived similarities between different cry signals, Brennan (1978) and Brennan & Kirkland (1979) used the method of paired comparisons (similarity analysis) to obtain a cry similarity matrix for the 24 Wasz-Hockert *et al,* (1968) signals the similarity matrix was submitted to a hierachical clustering program which essentially recovered the cry groups, although there was considerable similarity between the pain and birth cries, and the hunger cries formed two distinct groups. However, the apparent correspondence between the clusters and the Wasz-Hockert *et al,* (1968) recognition results was taken as a validation of the technique for use in examining the perceptual similarities of infant cry signals.

Both the semantic differential and similarity analysis have found wide use in acoustic studies. Solomon (1958) used the semantic differential technique to examine the perceptual dimensions of passive sonar signals, and derived a set of descriptive scales to differentiate between the different sound sources (submarine, cargo-ship etc.). The seven perceptual dimensions uncovered (factor analysis) were subsequently related to the spectrum and beat characteristics of the sounds (Solomon, 1959a,b). Solomon's scales were also translated into Finnish and used by Nordenstreng (1968) to rate a variety of musical pieces, for which four factors were extracted (richness, power of serious music, relaxation of light music and calmness). Jost (1967) related the physical attributes of clarinet tones (frequency, amplitude and spectrum) to the subjective dimensions of tone height, loudness and density, and uncovered three factors associated with clarinet timbre (masculine, feminine and clarity) (reviewed by Webster, 1969). And Wedin (1972), although not using semantic differential as such, used a variety of techniques involving "emotionally coloured" adjectives to uncover the perceptual-emotional dimensions in music. These dimensions (intensity-softness, pleasantness-unpleasantness, and solemnity-triviality) were then related to the technical qualities of the music (tempo, pitch and modality).

In a similarity analysis the use of interval scales permits hierachical clustering (Johnson, 1967) of either individual or group data. However, the analyses must be performed separately. An alternative and more powerful technique is to submit all of the individual similarity matrices to a single analysis, using a multidimensional scaling technique, INDSCAL (Carroll & Chang, 1970; Carroll, 1972). The INDSCAL model is based upon the assumption that all individuals use the same set of dimensions in making perceptual judgements, although the dimensions may vary in their importance or salience for different subjects. The method provides saliency weightings on each dimension for both the stimuli and the subjects, indicating not only the dimensions used, but also the relative importance of each dimension (Carroll, 1974; Wish & Carroll, 1974).

However and Silverman (1976) used INDSCAL to examine the perceptual dimensions of 16 complex non-speech sounds which varied systematically along four physical dimensions. A statistically reliable correspondence was found between these physical attributes and the three perceptual dimensions uncovered by the analysis. Furthermore, large differences in featural saliency were found which related to the musical experience of the subjects. The effect of musical experience on the perception of sounds was also noted by Howard (1977), and Miller & Carterette (1975) who suggest that musical subjects have a more stable space of perceptual dimensions.

Whilst the results of a similarity analysis reflect the perceptual dimensions utilised by the listener, describing these dimensions requires relating them to the physical characteristics of the signals. This may be difficult, especially with "real world" signals whose attributes generally do not vary systematically and may be difficult to measure. The semantic differential, on the other hand, provides labels for the dimensions uncovered. These labels may be used to develop rules for discriminating between or identifying the signals in non-technical terms (c.f. Wasz-Hockert *et al.*, 1968; Wiener, 1962). Secondly, the semantic differential scales may be used to compare the signals to entirely different stimuli, such as the concepts of "mother", "baby", or "crying", and may provide insight into the subjective factors influencing the perceptual judgements.

A criticism of the semantic differential is that the listeners are required to evaluate sounds in terms of linguistic dimensions that are not necessarily related to any auditory characteristics in a one to one fashion (Howard, 1977). However, there is evidence to suggest that subjects using the semantic differential scales may in fact be utilizing the same perceptual dimensions as for a similarity task. Nordenstreng (1968) used transformational analysis to compare the factor spaces derived from a similarity analysis and a semantic differential analysis of 10 musical stimuli. He concluded that "The results indicate almost perfect similarity of the factor structures, which suggests that similarity analysis and the semantic differential in fact measure the same thing. (p89)". Dobson & Young (1973) also compared the two techniques in a task involving the perception of bilaterally symetrical forms. In this case, canonical correlations were computed between the saliency weights from a four dimensional INDSCAL analysis and the four sets of factor score coefficients uncovered from a semantic differential. Three common attributes were found to account for the perceptual judgements, although the manner in which the dimensions were used differed with the response procedure (the order in which the techniques were used was counterbalanced over subject groups).

It would appear then, that both the semantic differential and similarity analysis (coupled to INDSCAL) provide the means for examining the perceptual qualities of infant cry signals. The objectives of the present study are to: uncover perceptual dimensions of a set of infant cry signals using both a semantic differential and INDSCAL; compare the solutions obtained from the two techniques; relate the confusions made in a cry recognition task to the perceptual similarities of the signals; use the semantic differential scales to label the perceptual dimenions and to describe the different cry types; and derive a set of semantic differential scales for classifying the different cry types.

EXPERIMENT 1

Experiment 1 had three objectives. Firstly, to uncover perceptual dimensions of a set of infants' cry signals using the semantic differential technique. Secondly, to examine the relationship between the perceptual cry similarities and the pattern of misidentifications in a recognition task. And thirdly, to derive sets of semantic differential scales that may be used to describe and classify the four cry types of birth, pain, hunger and pleasure.

METHOD

SUBJECTS. Thirty-seven multiparous and two primiparous mothers, aged between 23 and 47, were enlisted through local kindergartens. For 37 of the subjects the youngest child was aged five years or less, whilst for the other two subjects the youngest child was eight and eleven years of age respectively. Six of the subjects had maternity nursing experience, and 24 had musical experience.

CRY SIGNALS. The cry signals, six each of birth, pain, hunger and pleasure, were those used by Brennan (1978), and Brennan & Kirkland (1979). They consist of the initial expiratory cry from each of the 24 test signals used by Wasz-Hockert *et al.*, (1968).

The original signals were selected at random from a large sample of recordings made of infants whose ages ranged from a few minutes after birth to seven months. The birth cries were obtained within five minutes of the head appearing and before the cord was clamped. Pain cries were recorded during either BCG or PDT innoculations, or after pinching the skin over the biceps when the infant was in State 3 (Prechtl, 1963). Hunger cries were recorded at four hours plus or minus 20 minutes after the previous meal, and retained only if the infant accepted a feed after the recording was completed. Pleasure cries were recorded after the baby was fed and changed and lying comfortably. In the case of the birth and pain cries, the signals selected were the first utterances, whereas the pleasure and the hunger cries were selected by a phonetician as representative of the recorded sample (Wasz-Hockert *et al.*, 1968).

For each cry, which lasted between 1.1 and 2.3 seconds, a tape loop was constructed so as to present the signal followed by a five second pause. The tape loops were then recorded continuously for eight minutes onto separate cassette tapes, for use in the semantic differential task. A further cassette recording was made of the 24 signals (twice: 1, 2, 3... 1, 2, 3...) with a five second pause between each cry, for use in the recognition taks, and as a familiarisation tape.

SEMANTIC DIFFERENTIAL SCALES. Fifty bipolar adjectival scales were selected from those used by Solomon (1958) and those listed by Osgood (1957, pp 37, 53-61, 69, 172). Scales were selected that seemed to represent a number of possible semantic dimensions, seemed appropriate for rating cry sounds, and were clearly understood by a class of third year university students. The scales were arbitrarily divided into two sets of 25 and the scale polarities alternated within each set according to the polarities indicated by Osgood (1957, pp53-61). The 50 scales are listed in Table 1.

The instructions for the semantic differential were based on those of Osgood (1957, pp82-84). Both the instructions and the two sets of seven-point semantic differential rating scales are presented in Appendix A.

DENDROGRAM7. Dendrogram7[1] is a hierachical clustering programme which will accept as input either an M x N data matrix or a lower-half similarity matrix. If a data matrix is entered, it can be transformed if necessary so that either an M x M or N x N similarity matrix is computed.

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[1] Dendogram7 is essentially the set of subroutines reported in Davis (1973). However, the flexibility of the program has been increased considerably by the modifications effected by D. Macfarlane, Department Computor Science, Massey University.

The measure of similarity used is the Distance (D) score, computed by applying the generalised distance formula:

$$D_{ij}^{2} = \sum_{k=1}^{N} (x_{ik} - x_{jk})^{2}$$

where x_{ik} and x_{jk} are the subject's ratings of signals i and j on scale k (see also Osgood, 1952, p252-255).

The program then uses the similarity matrix to perform weighted pair group average clustering and produce a dendrogram. A listing of the program is presented in Appendix B.

PROCEDURE. Four sessions were run (between 10 - 12 am and 1 - 3 pm on two consecutive days) with 11, 8, 11 and 9 subjects respectively. The subjects were seated at tables around three sides of the room facing the sound-source (speaker). After reading the instructions and listening to the familiarisation tape, the subjects rated a single cry on the 50 scales as a practice run. The cry used was the last of the series (either cry 1 or cry 24). The order of cry presentation (either cry 1 - 24, or cry 24 - 1) and the order of the scale presentation (either set 1 - 2 or set 2 - 1) was rotated over sessions. The instructions were repeated by the experimenter, and the session run with a five minute break after the twelfth cry.

At the conclusion of the semantic differential task, the nature of the signals were explained, and the recognition task introduced. Subjects read the instructions and judged the first three cries for practice. The instructions were repeated and the recognition task run. This involved judging two consecutive presentations of the 24 cries in the order cry 1 - cry 24. The instructions and response sheets are presented in Appendix C.

RESULTS

PERCEPTUAL DIMENSIONS. To uncover the semantic (perceptual) dimensions of the cries the semantic differential data were factor analysed across both subjects and cries (SPSS: type = PA2, rotation = varimax). The final rotated factor matrix is presented in Table 1. It is clear that only the first three factors are relevant, with Factor 1 being particularly important. Together they account for 51% of the total variance, compared to the 57% explained by all seven extracted factors. Furthermore, only the first three factors contain "factorially pure" scales, that is, scales that load heavily on only one factor and thus facilitate interpretation.

In order to label the factors and discard redundant and irrelevant scales, five "factorially pure" scales were selected to represent each of the first three factors. These scales, which have the highest factor loadings on their respective factors, are presented in Table 2. The polarity of the factor-scales with negative loadings has been reversed to aid interpretation. On the basis of these factor-scale labels, Factor 1 appears to describe the emotional effect of the cries, and has been labelled "Effect"; Factor 2 appears to describe the physical magnitude or strength of the signals and has been labelled "Potency"; and Factor 3 appears to represent the significance of the cries as signals and has been labelled "Value". Thus in terms of the traditional factors of Evaluation, Potency and Activity (Osgood, 1957), Factor 3 corresponds to Evaluation and Factor 2 corresponds to Potency. None of the present factors correspond directly to Activity.

CRY SIMILARITIES. The group mean factor-scale ratings presented in Table 3 provide a semantic profile of the signals. As one would expect, for any single cry there is little variation in the factor-scale ratings within any one of the factors. However, particular signals such as cries, 1, 8, 13 and 19 have profiles that differ markedly from those of other cries of their cry-type, and one would expect them to be misidentified in a recognition task.

TABLE 1

Final Rotated Factor Matrix for the 50 Semantic Differential Scales

SCALE	LABEL	FACTOR 1	FACTOR 2	FACTOR 3	FACTOR 4	FACTOR 5	FACTOR 6	FACTOR	COMMUNALITY
V 1	pleasant-unpleasant	0.906	0.146	-0.020	0.049	-0.030	0.050	0.017	0.849
V 2	smooth-rough	0.855	0.170	0.017	-0.038	0.111	0.060	0.045	0.780
V 3	repetitive-varied	-0.133	-0.046	0.018	0.031	0.456	0.010	-0.037	0.231
V 4	passive-active	0.622	0.352	-0.209	-0.039	0.168	0.093	-0.113	0.606
V 5	beautiful-ugly	0.873	0.174	0.062	0.044	0.014	0.020	0.017	0.799
V 6	low-high	0.610	0.038	-0.004	0.136	-0.010	0.206	-0.258	0.502
V 7	strong-weak	-0.301	-0.645	0.273	0.073	0.017	-0.120	0.270	0.715
V 8	soft-loud	0.747	0.441	-0.010	-0.050	0.016	0.114	-0.204	0.810
V 9	even-uneven	0.430	0.026	0.172	0.023	0.606	-0.049	0.151	0.609
V10	soothing-arousing	0.899	0.130	-0.014	-0.043	0.056	-0.001	-0.011	0.832
V11	full-empty	0.163	-0.438	0.250	-0.064	0.016	0.016	0.297	0.379
V12	small-large	0.302	0.685	-0.135	0.042	0.110	0.112	-0.169	0.634
V13	clear-hazy	0.074	-0.087	0.414	0.264	0.178	-0.020	0.363	0.419
V14	deep-shallow	-0.112	-0.708	0.246	-0.009	0.090	0.076	0.087	0.597
V15	heavy-light	-0.454	-0.690	0.099	-0.021	0.100	0.120	-0.035	0.719
V16	usual-unusual	0.392	0.072	0.217	0.478	0.095	0.037	0.033	0:447
V17	wet-dry	-0.591	0.002	0.024	0.095	0.059	0.379	0.040	0.508
V18	fine-coarse	0.633	0.487	0.028	0.030	0.000	-0.063	0.166	0.673
V19	relaxed-tense	0.918	0.024	-0.092	0.075	-0.014	-0.075	0.021	0.865
V20	narrow-wide	0.005	0.578	-0.151	-0.054	-0.019	-0.060	0.021	0.364
V21	colourful-colourless	0.173	-0.313	0.426	0.114	-0.104	0.026	0.181	0.368
V22	thin-thick	0.172	0.699	-0.078	-0.028	-0.073	-0.049	0.201	0.574
V23	clean-dirty	0.730	0.112	0.057	-0.027	-0.073	-0.294	0.129	0.659
V24	unintentional-intentional	0.133	0.222	-0.423	-0.127	-0.026	0.099	-0.049	0.276
V25	happy-sad	0.902	-0.023	-0.060	0.075	-0.062	-0.125	0.082	0.850
V26	gentle-violent	0.845	0.298	-0.080	0.010	-0.025	0.152	-0.001	0.834
V27	slow-fast	0.667	0.195	-0.122	0.086	0.007	0.155	-0.035	0.532
V28	rugged-delicate	-0.635	-0.528	0.013	0.033	-0.011	-0.153	-0.065	0.711
V29	simple-complex	0.584	0.234	-0.122	0.350	0.056	0.103	0.069	0.552
V30	new-old	-0.060	0.488	0.101	0.063	0.047	0.185	0.015	0.293
V31	calm-agitated	0.910	0.082	-0.111	0.063	-0.001	0.055	0.054	0.859
V32	long-short	-0.210	-0.337	0.100	-0.093	-0.012	-0.018	0.033	0.212
V33	insincere-sincere	0.008	0.082	-0.689	0.052	-0.052	-0.027	0.012	0.489
V34	near-far	0.215	-0.089	0.559	0.126	0.043	-0.028	0.087	0.210
V35	meaningless-meaningful	0.291	0.127	-0.805	0.125	0.006	0.026	0.106	0.777
V36	healthy-sick	0.607	-0.050	-0.028	0.480	-0.018	-0.098	0.074	0.619
V37	remote-intimate	-0.505	-0.062	-0.355	-0.089	-0.035	0.119	-0.022	0.409
V38	important-unimportant	-0.327	-0.052	0.720	-0.184	-0.002	0.091	-0.058	0.675
V39	soft-hard	0.821	0.344	-0.048	0.059	0.000	0.069	-0.019	0.805
V40	closed-open	-0.199	0.150	-0.230	-0.145	-0.094	0.167	-0.062	0.180
V41	cold-warm	-0.823	-0.099	-0.035	-0.187	0.059	0.227	0.016	0.780
V42	distressing-comforting	-0.896	-0.005	0.116	-0.107	0.009	0.139	-0.044	0.850
V43	sweet-bitter	0.875	0.142	-0.009	0.131	-0.047	-0.079	0.002	0.813
V44	awkward-graceful	-0.831	-0.120	-0.039	-0.118	-0.084	0.096	-0.053	0.741
V45	clinging-yielding	-0.407	0.175	0.013	-0.060	-0.146	0.249	-0.013	0.284
V46	defensive-aggressive	0.301	0.292	-0.108	-0.117	-0.079	0.161	0.033	0.275
V47	formed-formless	0.103	-0.260	0.334	0.147	0.037	0.087	0.123	0.236
V48	falling-rising	0.210	0.059	-0.205	-0.065	0.034	-0.012	-0.228	0.150
V49	sociable-unsociable	0.846	0.025	0.006	0.113	-0.032	-0.038	-0.015	0.732
V50	rounded-angular	0.721	-0.105	0.085	0.139	0.054	0.001	-0.104	0.572
	Eigenvalue	18.638	5.037	2.171	0.903	0.816	0.645	0.463	
	% of variance	.372	0.100	0.042	0.018	0.017	0.012	0.009	
	cummulative % of variance	.372	0.473	0.517	0.535	0.552	0.565	0.574	

TABLE 2

Semantic Differential Factor-scales

Factor 1 (EFFECT)				Factor 2 (POTENCY)				Factor 3 (VALUE)			
scale	label			scale	label			scale	label		
V19	relaxed	-	tense	-V14	shallow	-	deep	-V35	meaningful	-	meaningless
V31	calm	-	agitated	V22	thin	-	thick	V38	important	-	unimportant
V 1	pleasant	-	unpleasant	-V15	light	-	heavy	-V33	sincere	-	insincere
V25	happy	-	sad	V12	small	-	large	V21	colourful	-	colourless
V10	soothing	-	arousing	-V 7	weak	-	strong	-V24	intentional	-	unintentional

TABLE 3

Mean Ratings of the 24 Cry Signals on the 15 Factor-Scales (N=39)

Type	Cry	Factor 1						Factor 2						Factor 3					
		V1	V10	V19	V25	V31	$\bar{X}_{F1}$	V7*	V12	V14*	V15*	V22	$\bar{X}_{F2}$	V21	V24*	V33*	V35*	V38	$\bar{X}_{F3}$
Birth	3	6	6	6	6	6	6.0	6	6	6	6	5	5.8	3	2	3	3	3	2.8
	7	6	6	6	6	6	6.0	6	5	5	5	4	5.0	3	2	2	2	3	2.4
	11	6	6	6	6	6	6.0	5	5	5	5	5	5.0	4	3	2	2	2	2.6
	13	3	3	3	4	3	3.2	2	2	3	3	3	2.2	5	4	4	4	4	4.2
	14	5	6	5	5	5	5.2	5	5	5	5	5	5.0	4	3	3	2	3	3.0
	15	6	6	6	6	6	6.0	6	5	5	5	5	5.2	4	2	2	2	2	2.4
Pain	2	6	6	6	6	6	6.0	5	5	4	4	3	4.2	4	2	3	3	3	3.0
	8	4	5	4	4	4	4.2	5	4	4	4	3	4.0	4	3	4	4	4	3.8
	16	6	6	6	6	6	6.0	6	6	6	6	6	6.0	3	2	2	2	2	2.2
	18	6	6	6	6	6	6.0	6	5	5	6	5	5.4	3	2	2	2	2	2.2
	21	6	6	6	6	6	6.0	6	5	5	5	4	5.0	3	2	2	2	2	2.2
	22	6	6	6	6	6	6.0	6	4	5	4	4	4.6	4	2	2	2	2	2.4
Hunger	4	4	5	5	5	5	5.8	3	3	3	3	3	3.0	4	3	4	3	3	3.4
	6	5	5	6	5	5	6.2	4	4	3	4	3	3.6	4	3	3	3	3	3.2
	10	4	5	5	5	4	4.6	3	3	3	3	4	3.2	5	3	3	3	4	3.6
	17	3	4	4	4	3	3.6	2	2	3	3	3	2.6	4	4	3	4	4	3.8
	19	6	6	6	6	6	6.0	6	6	5	5	5	5.4	4	3	3	3	3	3.2
	24	3	4	4	5	4	4.0	3	2	3	2	3	2.6	4	3	3	3	3	3.2
Pleasure	1	3	5	3	3	3	3.4	6	5	5	4	5	5.0	3	3	3	4	4	3.4
	5	1	1	1	1	1	1.0	4	3	4	2	4	3.4	2	3	2	3	4	2.8
	9	1	2	1	1	1	1.2	5	5	4	3	4	4.2	3	3	2	3	4	3.0
	12	1	2	1	2	1	1.4	4	4	4	3	4	3.8	3	3	2	4	4	3.2
	20	1	2	2	1	1	1.4	4	4	4	3	4	3.8	3	3	2	3	4	3.0
	23	2	2	2	2	2	2.0	4	4	5	3	4	4.0	3	3	3	4	4	3.4

* recoded (X = 8-X) to reverse scale polarity

In order to make predictions concerning cry misidentifications and to describe the rules by which listeners classify different cries, it is necessary to identify perceptually similar signals. To do this, the group mean factor-scale ratings in Table 3 were analysed using Dendrogram7. The resulting clusters are shown in Figure 1, in which it is apparent that cry 1 (pleasure), cry 8 (pain) and cry 13 (birth) all possess perceptual features characteristic of hunger cries; the pain and birth cries are all very similar; and cry 19 (hunger) has the characteristics of a birth/pain cry. One would expect the results of a recognition task to reflect these perceptual similarities.

RECOGNITION TASK. The group mean recognition frequencies are presented in Table 4. Whilst the overall mean recognition frequency is 62%, the mean recognition frequencies for the four cry types vary considerably. The pleasure cries were very successfully recognised (.93), but the birth cries were very poorly recognised (.38). The hunger and pain cries fall between these two (.65 and .54 respectively).

One might expect less success in identifying birth signals, and for listeners to make less use of the birth category, because of the relative lack of experience that even multiparous mothers would have of birth cries. However, considering the frequency with which mothers hear and respond to cries of hunger and pain, the recognition frequencies seem rather low.

A possible explanation for these results can be found in the pattern of misidentifications (Table 4). Within both the pain and hunger categories, three of the signals are successfully identified, whereas the other three are not. Whilst this raises the possibility that the poorly identified cries lack the salient features necessary for positive identification, an alternative view is indicated. There is a tendency for the poorly identified cries to be misidentified as a particular cry-type. This suggests that these signals possess features that are characteristic of a different cry-type, and that the recognition results reflect the effects of the nature of the signals rather than the ability of the listeners to discriminate or identify the cries.

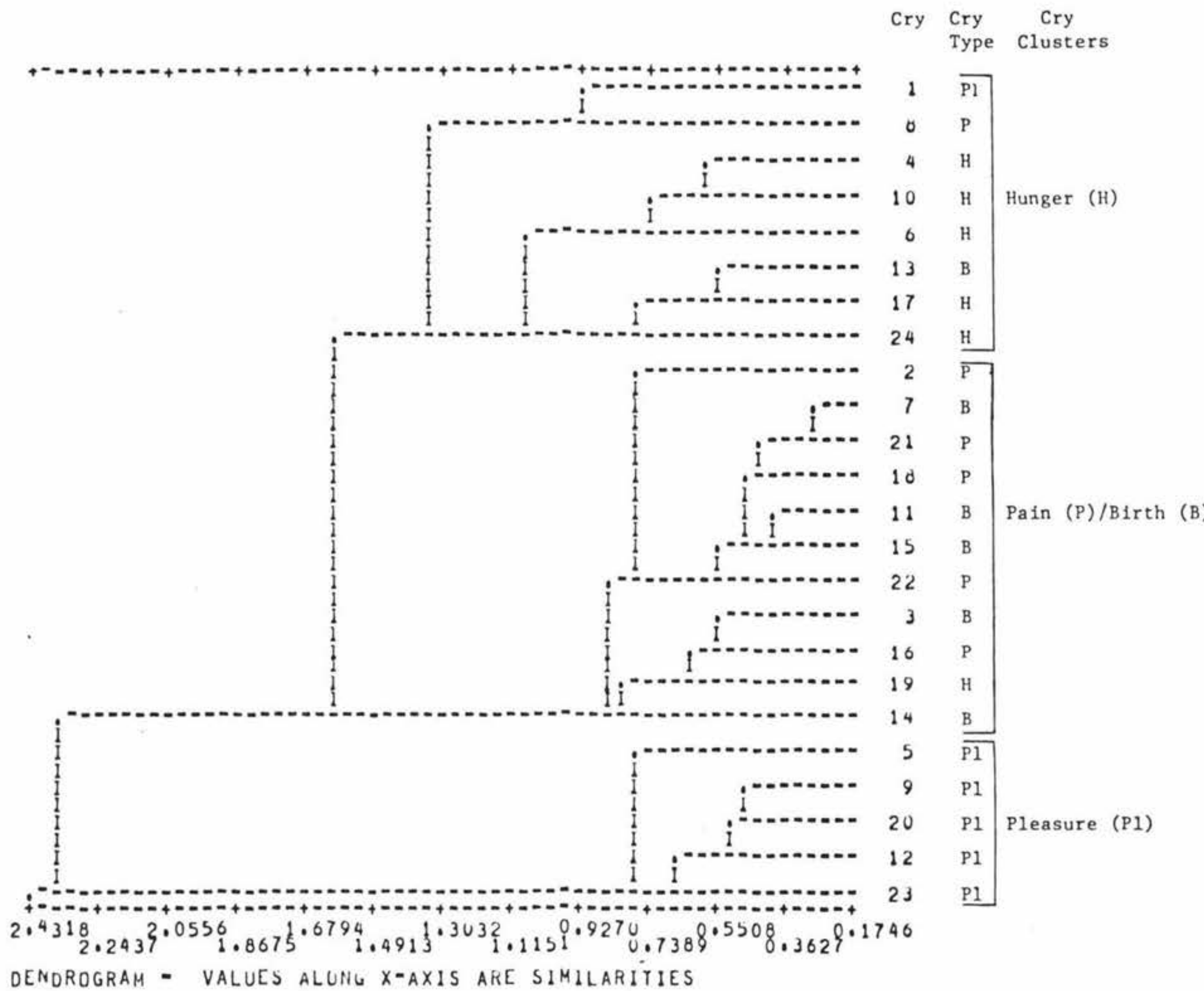

FIGURE 1 Cry clusters using the 15 semantic differential factor-scales

TABLE 4

Relative Frequencies of Correct and Incorrect Identifications of the 24 Cry Signals (N=39)

Cry Type	Cry	Rank	Correct Identification	Misidentifications Birth	Pain	Hunger	Pleasure	Total
Birth	11	1	.64		.31	.05	.00	1.0
	13	2	.46		.05	.41	.08	1.0
	7	3	.33		.54	.13	.00	1.0
	15	4	.31		.56	.14	.00	1.0
	3	5	.28		.21	.49	.03	1.0
	14	6	.26		.39	.36	.00	1.0
	Mean	1-6	.38		.34	.26	.02	1.0
Pain	18	1	.74	.18		.08	.00	1.0
	21	2	.74	.00		.23	.03	1.0
	16	3	.72	.08		.21	.00	1.0
	2	4	.54	.76		.21	.00	1.0
	22	5	.31	.54		.15	.00	1.0
	8	6	.18	.10		.49	.23	1.0
	Mean	1-6	.54	.19		.23	.04	1.0
Hunger	10	1	.82	.15	.00		.03	1.0
	6	2	.74	.08	.15		.03	1.0
	17	3	.72	.21	.03		0.5	1.0
	19	4	.59	.03	.39		.00	1.0
	24	5	.51	.36	.05		.08	1.0
	4	6	.49	.41	.10		.00	1.0
	Mean	1-6	.65	.21	.12		.03	1.0
Pleasure	5	1	.97	.00	.00	.03		1.0
	9	2	.97	.00	.00	.03		1.0
	12	3	.97	.03	.00	.00		1.0
	20	4	.97	.00	.00	.03		1.0
	23	5	.95	.03	.00	.03		1.0
	1	6	.74	.00	.05	.21		1.0
	Mean	1-6	.93	.01	.01	.05		1.0

RELATIONSHIP BETWEEN CRY SIMILARITIES AND CRY RECOGNITION. In order to examine the relationship between the recognition results and the perceived similarities of the cries, distinct cry clusters were formed on the basis of the cry recognition data. That is, the cry recognition and misidentification frequencies in Table 4 were treated as distance profiles (c.f. factor-scale profiles) and entered into Dendrogram7. The resulting dendrogram is presented in Figure 2. The clusters clearly reflect the patterns apparent in Table 4 and have been labelled accordingly.

A comparison of Figure 1 with Figure 2 reveals a striking correspondence between the two sets of clusters. From Figure 1 one would predict that: (a) cry 1 (pleasure), cry 8 (pain) and cry 13 (birth) would be classified as hunger, (b) cry 19 (hunger) would be classified as birth/pain, (c) birth and pain cries would be perceived as being of the same cry type and the two categories confused, and (d) the hunger cries, except cry 19, and the pleasure cries, except cry 1, would be clearly identified.

Figure 2 shows these predictions to be quite accurate. Although cry 1 (pleasure) is not clustered with the hunger cries, Table 4 indicates that cry 1 was in fact frequently judged to be hunger. Thus the only notable exceptions to the predictions are cries 3 and 19. It would appear then that the cry recognition results in fact reflect the perceptual similarities of the signals. Furthermore, the semantic differential factor-scales appear to describe the salient cry characteristics by which they are identified as one of the four cry types.

CRY-TYPE DESCRIPTIONS. The four cry-types of birth, pain, hunger and pleasure can be described in terms of the semantic differential scale labels. Using the cry recognition frequencies in Table 4, cries were selected to represent each of the four cry-types. These were: cries 5, 9 and 12 (pleasure); cries 16, 18 and 21 (pain); 6, 10 and 17 (hunger); and 11 and 22 (birth).

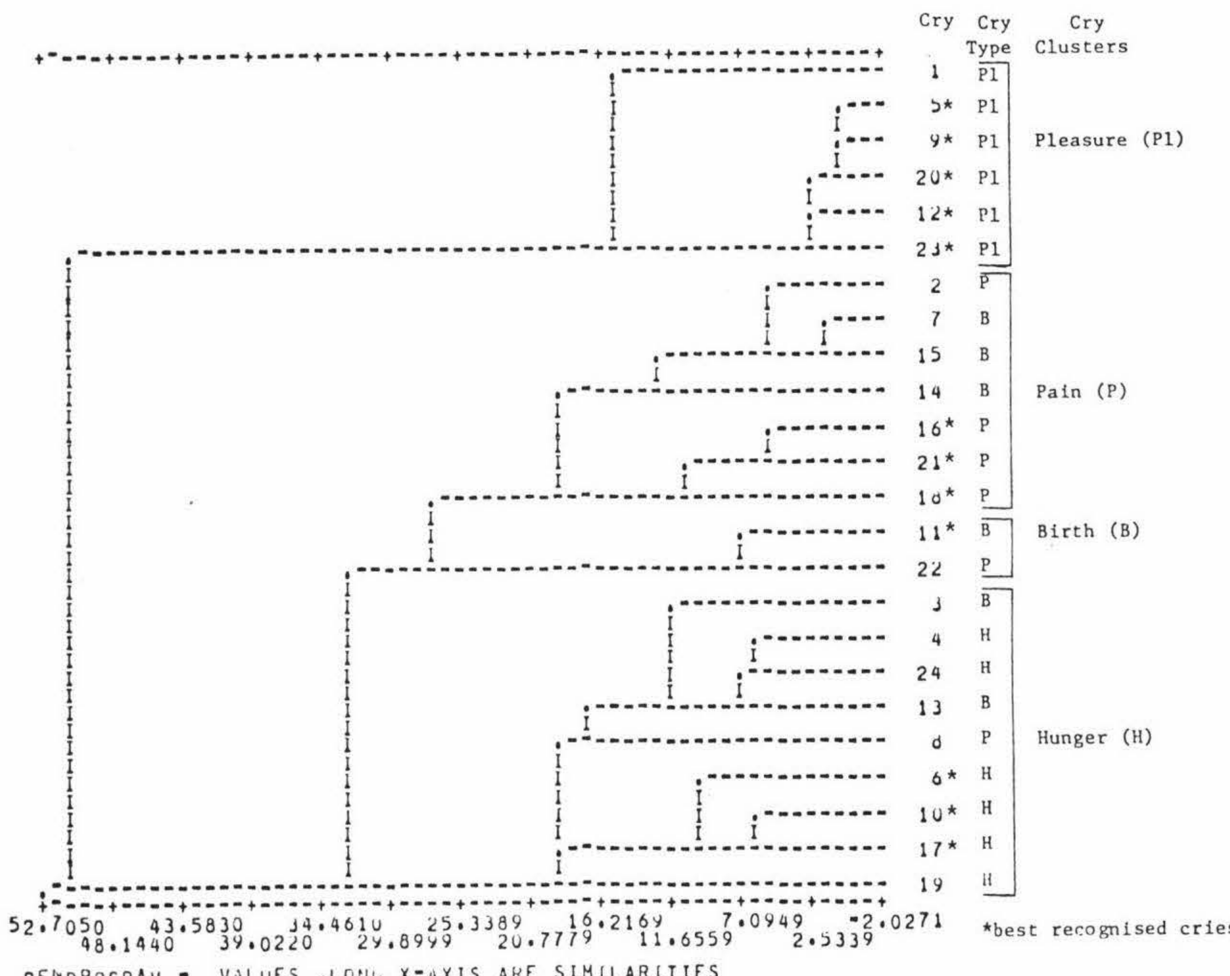

FIGURE 2 Cry clusters using the relative recognition frequencies (Table 4).

For each of these sets of cries, the mean semantic differential ratings were computed on each of the 50 scales, to produce the cry-type profiles displayed in Figure 3. Scales with negative factor loadings were reversed, and the order of the scales changed to group scales exhibiting similar profiles.

The scales which most clearly characterise or describe a particular cry-type are those on which the cry is rated on a scale position that is extreme and not shared by other cry-types. Thus the pleasure, pain and birth cries may be clearly described in terms of the Factor 1 scales, although few of these scales differentiate the pain and birth signals. It is more difficult to describe the hunger cries, for most of the ratings are centre scale, and even on the Factor 2 scales, the polar position is not extreme. However, the following cry-type descriptions can be given:

Pleasure - signals that are comforting, sociable, gentle, pleasant relaxed, happy and calm.

Pain - heavy, long aversive signals that also sound rugged, fast and strong.

Birth - uneven aversive signals that also sound sick, coarse, angular, high, unusual and sick.

Hunger - signals that sound fairly weak, light, shallow, thin, small and short.

Overall, it would appear that the Factor 1 and Factor 2 factor-scales adequately describe and differentiate the different cry-types, although the addition of scale 9 (even-uneven) and scale 32 (short-long) would improve the differentiation of pain and birth signals. As all of the cry-types cluster around the same scale position on the Factor 3 scales, these are of little value for describing or differentiating the different cry-types, but seem to project the listeners' perceptions of crying in general.

Scale	Factor		1	2	3	4	5	6	7	
V 42*	1	comforting	Pl			H		PB		distressing
V 49	1	sociable	Pl			H		PB		unsociable
V 26	1	gentle	Pl		H			PB		violent
V 1	1	pleasant	Pl			H		PB		unpleasant
V 19	1	relaxed	Pl				H	PB		tense
V 25	1	happy	Pl				H	PB		sad
V 31	1	calm	Pl			H		PB		agitated
V 10	1	soothing		Pl			H	PB		arousing
V 43	1	sweet		Pl		H		PB		bitter
V 5	1	beautiful		Pl		H		PB		ugly
V 8	1	soft		Pl	H			PB		loud
V 39	1	soft		Pl	H			PB		hard
V 2	1	smooth		Pl			H	PB		rough
V 44*	1	graceful		Pl			H	PB		awkward
V 28*	2	delicate		Pl	H		B	P		rugged
V 27	1	slow		Pl	H		B	P		fast
V 36	1	healthy	Pl		H	P	B			sick
V 18	1	fine		Pl		H	P	B		coarse
V 50	1	rounded		Pl		H	P	B		angular
V 6	1	low		Pl	H		P	B		high
V 16	1	usual		Pl	H	P	B			unusual
V 9	1	even			Pl	P	H	B		uneven
V 41*	1	warm		Pl		H	PB			cold
V 29	1	simple		Pl	H		PB			complex
V 23	1	clean		Pl		H	PB			dirty

Scale	Factor		1	2	3	4	5	6	7	
V 4	1	passive			PL	H		PB		active
V 7*	2	weak			H	PL	B	P		strong
V 15*	2	light			$\overset{H}{Pl}$	B		P		heavy
V 14*	2	shallow			H	PL	PB			deep
V 22	2	thin			H	PlP	B			thick
V 12	2	small			H	Pl	PB			large
V 32*	2	short			H	Pl^{B}		P		long
V 34	3	near		Pl	P	HB				far
V 13	3	clear		Pl	P	HB				hazy
V 37*	3	intimate		Pl		$P^{B}H$				remote
V 45*	1	yielding			Pl		$P^{B}H$			clinging
V 46	2	defensive			Pl	H	PB			aggressive
V 17*	1	dry			Pl	H	BP			wet
V 38*	3	unimportant				PlH		PB		important
V 24	3	unintentional					PlH	PB		intentional
V 35	3	meaningless					PlH	PB		meaningful
V 33	3	insincere					H	Pl^{B}_{P}		sincere
V 21*	3	colourless				HB	PlP			colourful
V 30	2	new			HB	PlP				old
V 40	3	closed				H	Pl^{P}_{B}			open
V 20	2	narrow				Pl^{H}_{B}	P			wide
V 11	2	full			PlP	HB				empty
V 47	3	formed			PlP	HB				formless
V 48	3	falling				Pl^{P}_{H}	B			rising
V 5	1	repetitive			P	Pl^{H}_{B}				varied

*Scale polarity reversed.

FIGURE 3. Semantic differential profiles of the four cry-types: Birth (B), Pain (P), Hunger (H) and Pleasure (Pl).

CLASSIFICATION OF CRIES. To develop a set of objective rules for classifying cries as either birth, pain, hunger or pleasure, the data on all 50 semantic differential scales were subjected to a multiple discriminant function analysis (SPSS: method = RAO). The predictor items were the best recognised cries of each cry-type: cry 11 (birth); cries 16, 18 and 21 (pain); cries 6, 10 and 17 (hunger); and cries 5, 9 and 12 (pleasure). With the exception of cry 22, these were the cries used in Figure 4.

Three significant discriminant functions were extracted, for which the tests of statistical significance are reported in Table 5. As the eigenvalues and the associated canonical correlations denote the relative ability of each of the functions to separate the groups (Nie, Hull, Jenkins, Steinbrenner & Bent, 1975), Function 1 clearly accounts for most of the discriminating power. The fact that three functions are statistically significant confirms the existance of four distinct cry groups.

The discriminant functions can be thought of as the axes of a geometric space, thus the role of the functions can be determined by examining the cry group centroids in this space, presented in Table 6. Function 1 serves to separate the cry-types into three groups: hunger, pleasure and pain/birth. Function 2 separates the hunger group from the other three, and Function 3 separates the pain and birth cries.

The scales contributing to the discriminant functions and their classification function coefficients are presented in Table 7. Surprisingly, only seven of the 15 factor scales are included, and a number of the scales did not appear to differentiate the cries in Figure 3. However, the effectiveness of the function is indicated by the prediction results produced by the analysis: 82% of the criterion items were correctly classified.

Classifications are made by computing cry classification scores using the following equation:

TABLE 5

Tests of Significance for the Discriminant Functions

Discriminant function	Eigenvalue	Relative percentage	Canonical correlation
1	8.38231	82.80	0.945
2	1.47762	14.60	0.772
3	0.26340	2.60	0.457

Functions derived	Wilks' Lambda	Chi-square	DF	Significance
0	0.0340	1265.785	75	0.000
1	0.3195	427.345	48	0.000
2	0.7915	87.561	23	0.000

TABLE 6

Cry Group Centroids for the Discriminant Functions

		Function 1	Function 2	Function 3
Group Birth	1	-0.90936	-0.11182	-1.29392
Group Pleasure	2	1.34607	-0.41477	-0.04751
Group Hunger	3	-0.10977	1.14919	0.14400
Group Pain	4	-0.93318	-0.69715	0.33482

TABLE 7

Classification Function Coefficients

Scale	Group 1 Birth	Group 2 Pleasure	Group 3 Hunger	Group 4 Pain
V 2	1.602	0.560	1.481	1.507
V 4	0.077	0.237	0.427	-9.111
V 6	-0.463	-0.587	-0.758	-0.190
V 7	3.051	3.079	3.659	3.062
V 9	0.985	1.172	0.955	0.740
V10	5.108	4.417	5.204	5.523
V13	1.454	1.221	1.400	1.165
V16	1.590	1.150	0.896	0.908
V18	1.636	1.452	1.473	1.085
V19	4.363	2.718	3.717	3.701
V21	1.201	1.299	1.465	1.185
V22	2.147	1.648	1.840	2.178
V25	9.293	6.607	9.548	9.354
V26	2.495	0.495	0.837	2.738
V27	0.198	0.052	-0.093	0.309
V30	0.964	2.063	1.098	1.459
V32	2.8227	2.001	2.175	2.407
V33	4.369	5.011	4.131	4.121
V39	2.255	1.678	1.165	2.570
V40	1.156	1.639	1.486	1.380
V42	9.871	11.180	10.328	9.442
V44	8.164	7.668	7.263	8.307
V45	1.35516	1.419	1.282	1.126
V46	1.306	1.270	1.064	1.467
V48	1.813	1.912	2.081	1.703
CONSTANT	-152.236	-125.945	-130.856	-145.620

$$C_i = c_{i1}V_1 + c_{12}V_2 + c_{i3}V_3 + \ldots + c_{ip}V_p + c_{i0}$$

where C_i is the classification score for group i (i = 1 to 4, where 1 = birth, 2 = pain, 3 = hunger, 4 = pleasure), the c_{ij}'s are the classification coefficients (presented in Table 7), with c_{i0} being the constant, and the V's are the raw scores (ratings) on the discriminating variables (the 28 semantic differential scales).

As there is a separate classification for each cry-type, four classification scores are produced for each cry and the cry is assigned to the group receiving the highest score (Nie *et al.*, 1975). The 24 cry signals have been classified in this way, and the relative classification frequencies are presented in Table 8. These classification frequencies may be treated as distances or profiles, and were entered into Dendrogram7 to produce the cry cluster, (as for Figures 1 and 2) presented in Figure 4.

It is apparent that the discriminant classification equations are very effective in classifying the cries. Not only do the clusters in Figure 4 correspond closely to those in both Figures 1 and 2, but the overall frequency of correct classifications (64%) is actually slightly higher than that achieved in the recognition task (62%).

TABLE 8

Relative Classification Frequencies for the 24 Cry Signals Using Classification Function Coefficients

Cry-type	Cry	Rank	Birth	Pain	Hunger	Pleasure
	11	1	.74	.23	.03	0
	15	2	.49	.46	.05	0
	7	3	.36	.59	.05	0
Birth	3	4	.28	.64	.08	0
	14	5	.15	.44	.33	.08
	13	6	.03	0	.77	.21
	Mean 1-6		.34	.39	.22	.05
	18	1	.08	.90	.03	0
	16	2	.13	.87	0	0
	21	3	.10	.80	.10	0
Pain	22	4	.44	.54	.03	0
	2	5	.33	.51	.13	.03
	8	6	.10	.18	.59	.13
	Mean 1-6		.20	.63	.14	.03
	10	1	.05	.03	.90	.03
	17	2	0	0	.90	.10
	24	3	.05	.03	.82	.10
Hunger	4	4	.03	.10	.82	.05
	6	5	.18	.08	.72	0
	19	6	.54	.33	.10	.03
	Mean 1-6		.14	.09	.71	.05
	5	1	0	0	0	1.00
	12	2	0	0	0	1.00
Pleasure	9	3	0	0	.03	.97
	20	4	.03	0	.05	.92
	23	5	0	.03	.18	.80
	1	6	.10	.15	.18	.56
	Mean 1-6		.02	.03	.07	.88

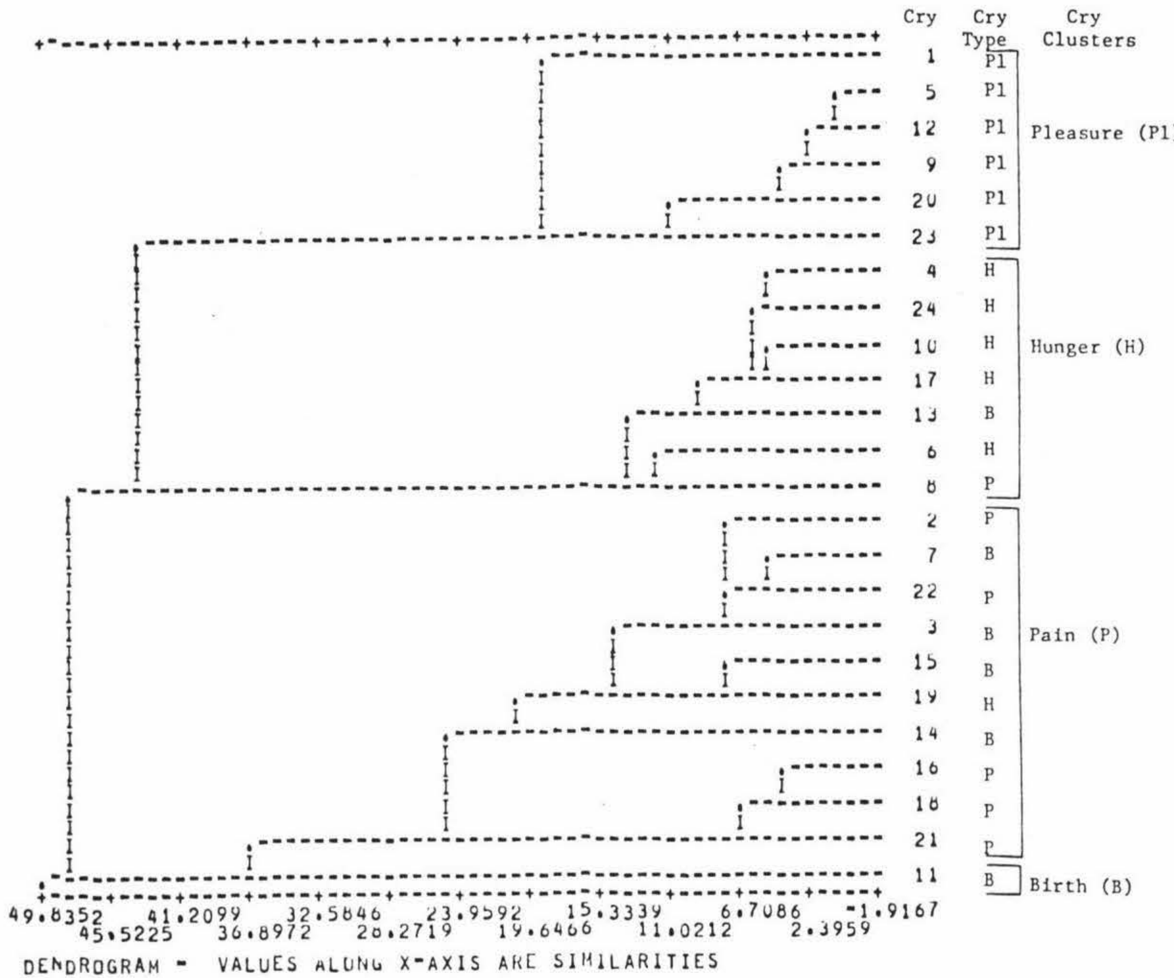

FIGURE 4 Cry clusters using the discriminant classification frequencies

DISCUSSION

The factor analysis of the semantic differential data uncovered three meaningful factors, labelled "Effect","Potency" and "Value" respectively. Factor 1 appears to reflect the listeners' emotional responses to the cries, Factor 2 describes physical qualities of the signals, and Factor 3 appears to reflect the importance that listeners attach to the cries.

With the exception of the pain and birth groups, Factor 1 effectively separates the different cry-types along a continuum that describes the aversiveness of the signals, with "pleasant" pleasure cries at one end and "unpleasant" pain and birth cries at the other. In fact the perceived aversiveness of these cry-types appears to correspond closely to the intensity of the cries. Commenting on the acoustic analyses of the present cries by Wasz-Hockert *et al,* (1968), Murray (1979) notes that:

> the Wasz-Hockert results seem to indicate that the cries were not uniquely different according to what caused them, but rather differed in intensity according to the degree of discomfort experienced by the infant. One might expect that a baby experiencing hunger would be less distressed than one experiencing birth or pain (p16).

Thus the present results indicate that the signals represent three perceptually distinct cry classes (pleasure, hunger, and birth/pain). They also support the view that cries are perceived as aversive (Zeskind & Lester, 1978), and appear to support the possibility that the different cry types differ according to the intensity of the cry eliciting stimulus (Zeskind & Lester, 1978; Wolff, 1969).

The cry recognition results were accurately predicted from cry ratings on the semantic differential factor-scales. This suggests that the listeners were attending to the same cry features in both tasks, and that the poorly identified cries possess features characteristic of a different cry type. Thus the semantic differential offers an effective means of distinguishing between effects due to the perceptual characteristics of the signals, and effects due to the perceptual ability of the listener.

In the recognition task, the recognition frequencies for the four cry types (birth = .38, pain = .54, hunger = .65, pleasure = .93) correspond closely to those obtained by Wasz-Hockert *et al,* (1968) (birth = .48, pain = .63, hunger = .68, pleasure = .85), in spite of a difference in the test-signals used. Wasz-Hockert used composite signals in which each of the cries (used in the present study) was repeated seven times with a short pause between each repeat, thus producing an artificial rhythm effect. A notable difference in the results of the two studies, however, is that in the present study both the pain and the hunger cries were frequently misidentified as birth, whereas this did not occur in the Wasz-Hockert study. Whether this difference was due to sample size (N = 39 c.f. 483) or bias, the signals, or some other factor is unclear.

Lastly, the semantic differential scales provide a convenient means of classifying and describing cry signals. Classification of different cry-types was achieved very effectively using the discriminant classification function coefficients, and cry descriptions were derived from the semantic cry profiles. Clearly the same approach could be used to analyse other cry types and to develop rules for facilitating recognition of particular cry signals.