# 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 | |
| | Eigenvalue | 18.638 | 5.037 | 2.171 | 0.903 | 0.816 | 0.645 | 0.463 | 0.572 |
| | % 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)

| | | Factor 1 | | | | | | Factor 2 | | | | | | Factor 3 | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Type | Cry | 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.

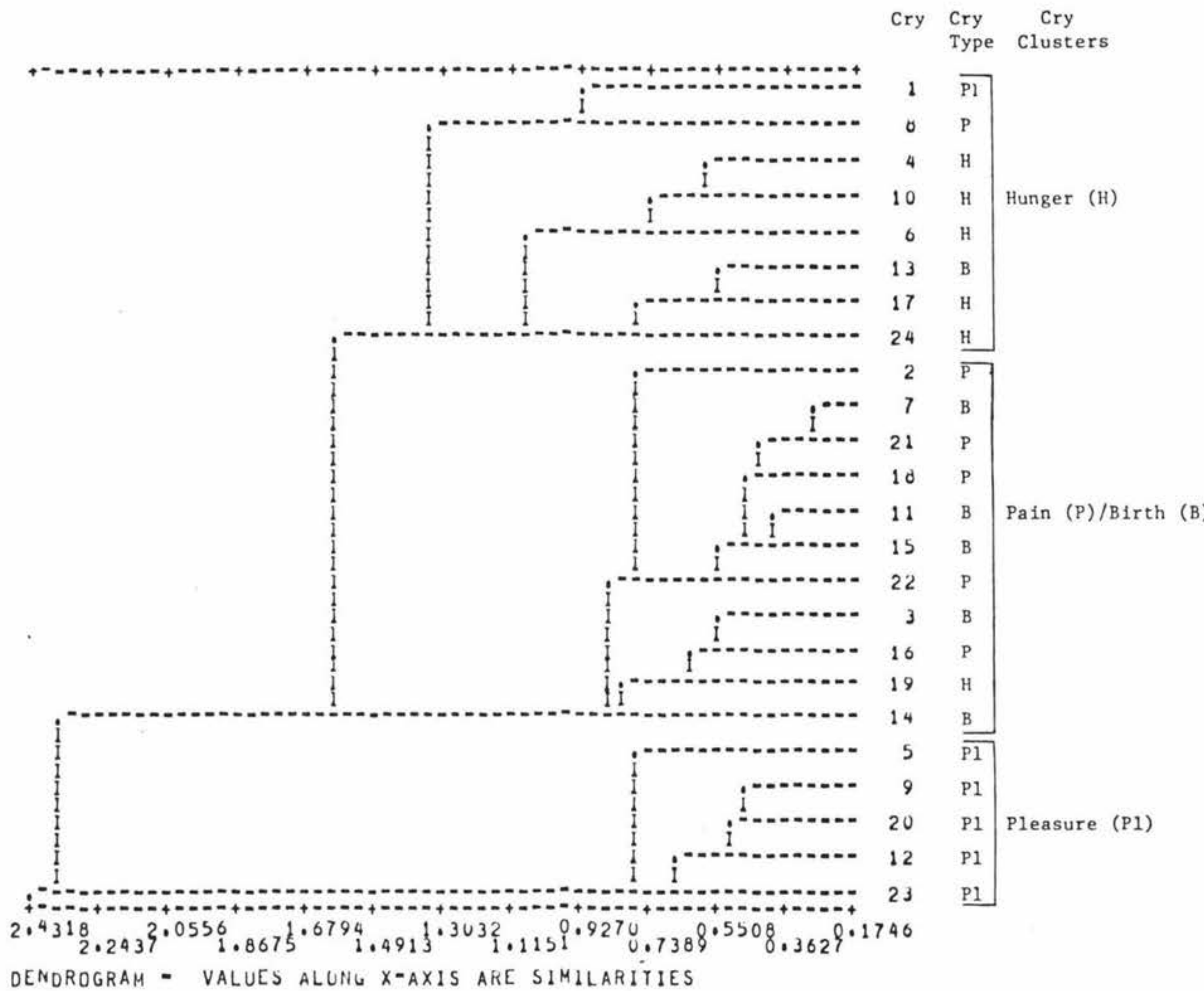


FIGURE 1 Cry clusters using the 15 semantic differential factor-scales

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).

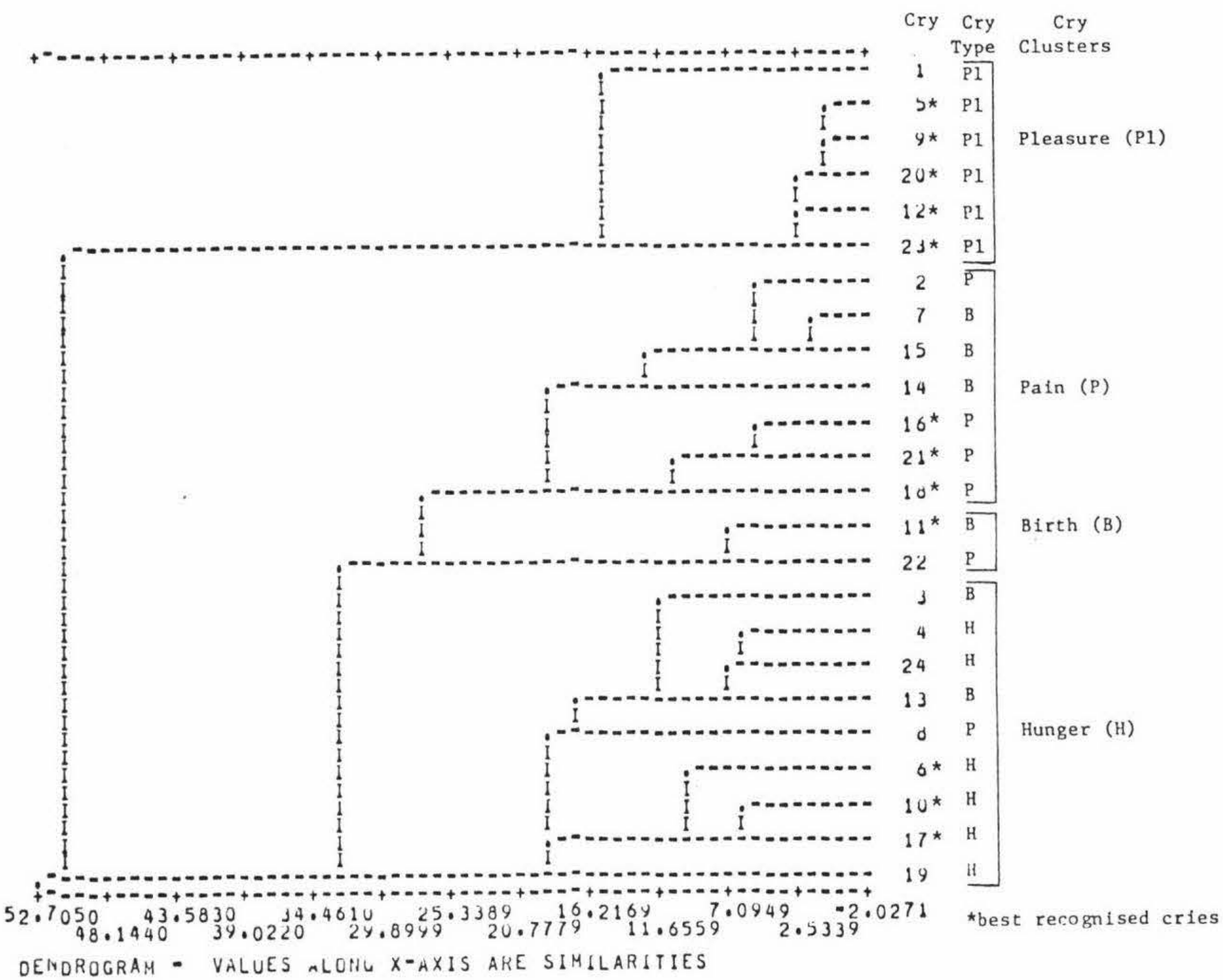


FIGURE 2 Cry clusters using the relative recognition frequencies (Table 4).

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 | Cry-type Profile | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| 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 |
| V 4 | 1 | passive | | | PL | H | | PB | | active |
| V 7* | 2 | weak | | | H | PL | B | P | | strong |
| V 15* | 2 | light | | | HPl | 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 | PlB | | P | | long |
| V 34 | 3 | near | | Pl | P | HB | | | | far |
| V 13 | 3 | clear | | Pl | P | HB | | | | hazy |
| V 37* | 3 | intimate | | Pl | | PBH | | | | remote |
| V 45* | 1 | yielding | | | Pl | | PBH | | | 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 | PlBP | | sincere |
| V 21* | 3 | colourless | | | | HB | PlP | | | colourful |
| V 30 | 2 | new | | | HB | PlP | | | | old |
| V 40 | 3 | closed | | | | H | PlPB | | | open |
| V 20 | 2 | narrow | | | | PlHB | P | | | wide |
| V 11 | 2 | full | | | PlP | HB | | | | empty |
| V 47 | 3 | formed | | | PlP | HB | | | | formless |
| V 48 | 3 | falling | | | | PlPH | B | | | rising |
| V 5 | 1 | repetitive | | | P | PlHB | | | | 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 |

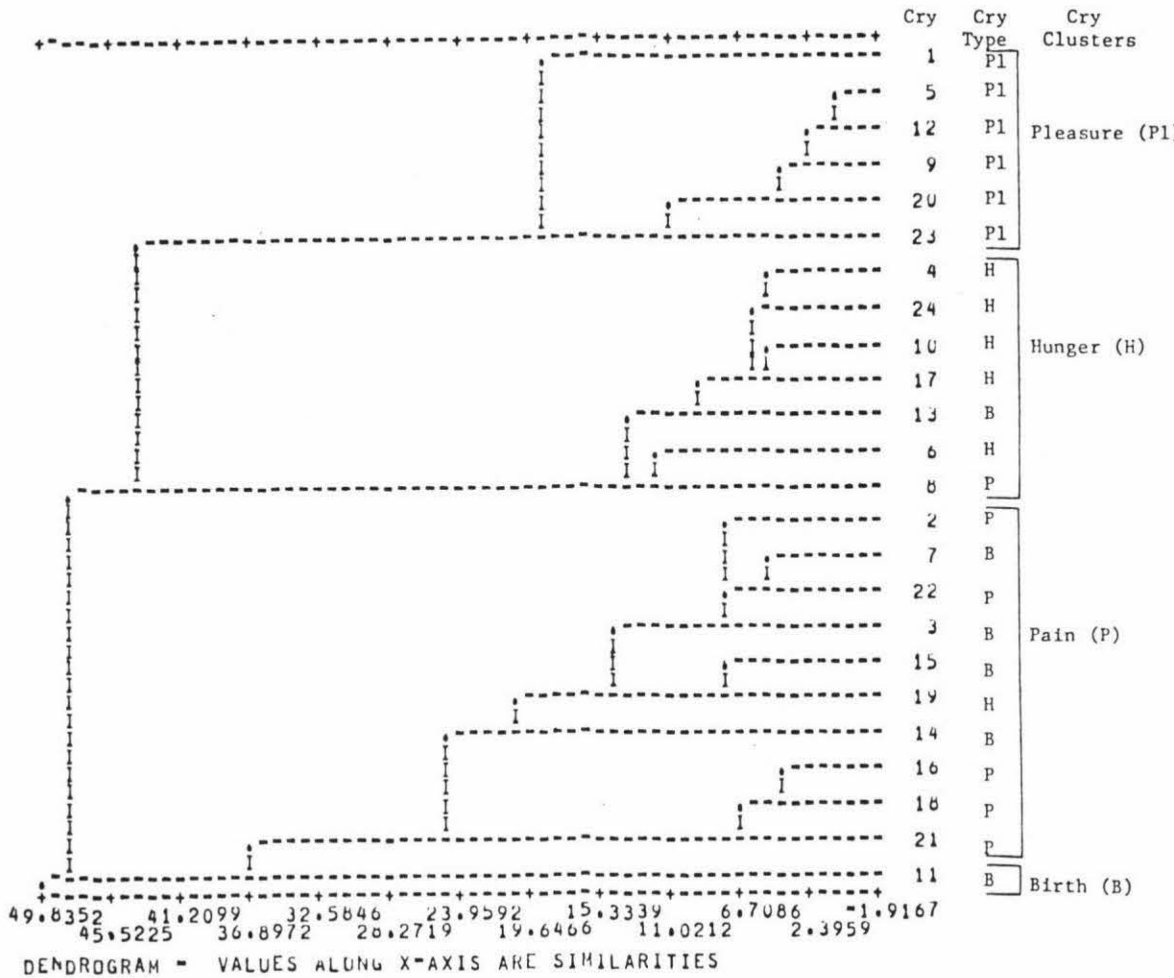


FIGURE 4 Cry clusters using the discriminant classification frequencies

## 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.

# EXPERIMENT 2

Experiment two had three objectives. Firstly, to examine the relationship between the perceptual cry similarities uncovered by a similarity analysis, and the pattern of misidentifications from the recognition task in Experiment 1. Secondly, to uncover perceptual dimensions of the cries used in Experiment 1, but using INDSCAL. And thirdly, to examine the relationship between the solutions obtained from the semantic differential (Experiment 1) and INDSCAL.

## METHOD

SUBJECTS. The subjects were 26 multiparous mothers, including 13 from Experiment 1. All were aged between 23 and 47, and had a youngest child aged less than five years. Two subjects had maternity nursing experience, and 15 had musical experience.

CRY SIGNALS. The cry signals were those used in Experiment 1. Each of the 24 cries was paired with every other cry to give 300 cry-pairs. The cries in each pair were separated by a two-second pause, and each cry-pair was followed by a seven-second pause. Every block of ten cry-pairs was followed by a pause of ten seconds. The first 15 blocks were recorded onto one cassette tape (Tape 1), and the second set of 15 blocks were recorded onto a second cassette (Tape 2). The order of the cry-pairs was determined by moving down consecutive columns, beginning with column one, of a lower half (including diagonal ) 24 x 24 matrix. Thus each of the first 24 cry pairs began with cry 1 followed in turn by cries 2 - 24. The next 23 cry-pairs began with cry 2 followed in turn by cries 3 - 24, and so on.

PROCEDURE. Three two-hour sessions were run as for Experiment 1, but one week later, involving 10, 11, and 5 subjects respectively. After reading the instructions (see Appendix b) and listening to the familiarisation tape, the subjects were given a practice run using the first two blocks from Tape 2. The instructions were repeated and the session run, with a five minute break after Tape 1. All subjects listened to Tape 1 first.

## RESULTS

SIMILARITY ANALYSIS. To uncover groups of perceptually similar cries, the mean group similarity matrix was submitted to Dendrogram7. The resultant cry clusters are presented in Figure 5. On the basis of these clusters, one would predict that:

(a) the pleasure cries would be clearly identified, with the other cry types rarely misidentified as pleasure; (b) cry 2 (pain, cry 8 (pain) and cry 13 (birth) would be classified as hunger; (c) cry 19 (hunger) would be classified as birth/pain; and (d) the pain and birth cries would be confused with each other.

A comparison of Figure 5 with Figure 2 shows these predictions to be quite accurate, with the exceptions that cry 2 (pain) was not in fact classified as hunger whereas cry 3 (birth) was, and cry 19 (hunger) was not classified as pain/birth. And, as in Experiment 1, the results support the suggestion that the pain and birth cries are perceptually similar, and that cries 8, 13 and 19 have features characteristic of cry-types other than their own.

INDSCAL ANALYSIS. The striking similarity between the predictions made from the semantic differential clusters and those made from the similarity clusters raises the possibility that the same perceptual dimensions may be involved in both tasks. To uncover the dimensions underlying the similarity judgements, the 26 subject similarity matrices were subjected to a single INDSCAL analysis. Solutions were obtained in three, four and five dimensions, which accounted for 61, 63 and 65% of the variance respectively. Because of the relatively small increases in variance, and the convenience in terms of plotting and visualising the solution, the three-dimensional solution was selected for further analysis.

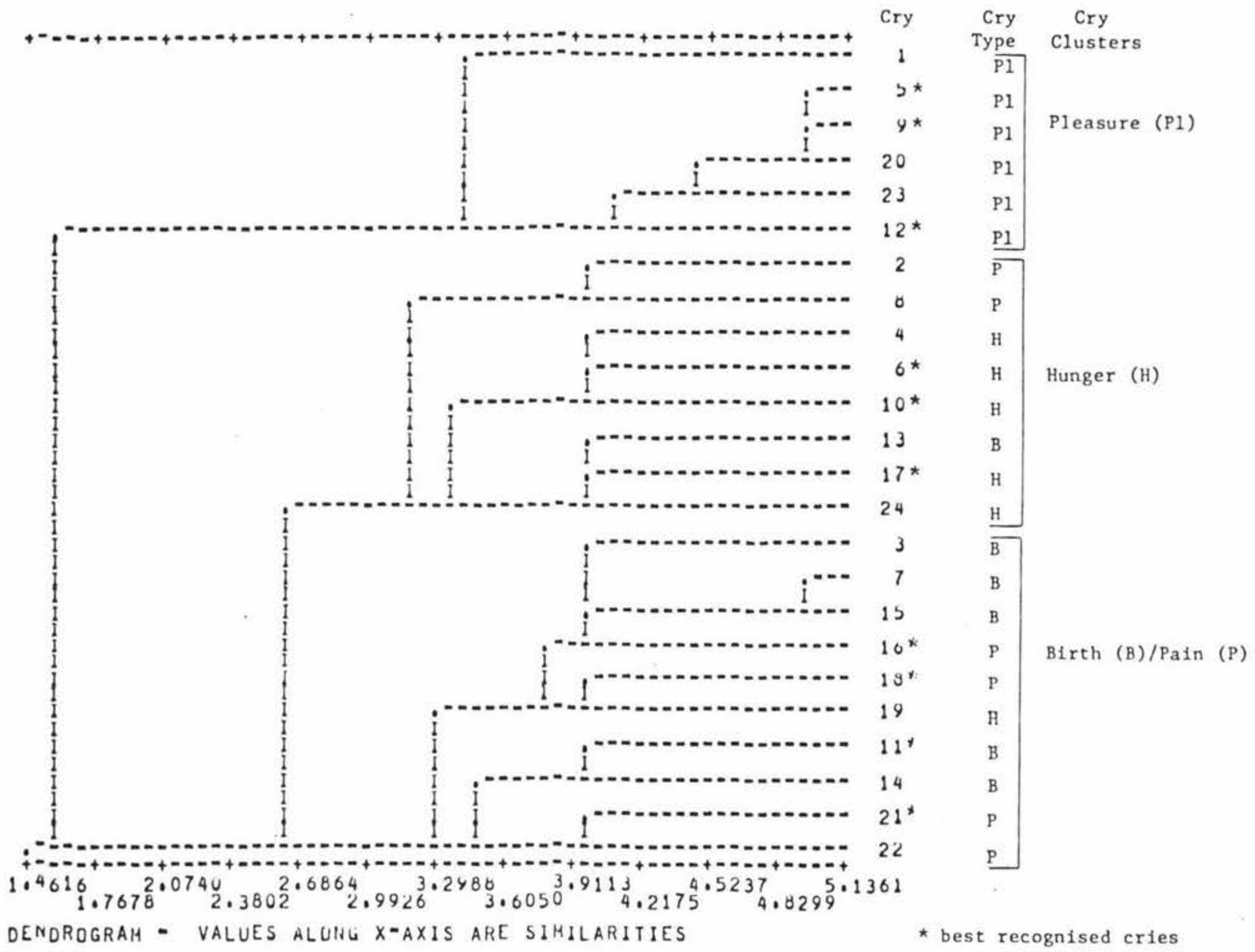


FIGURE 5 Cry clusters using the mean group cry similarity ratings

The normalised A matrix for the cry signals is presented in Table 9. The saliency weights can be treated as distances and were used to produce a dendrogram, presented in Figure 6, and to plot the spacial distribution of the signals, as in Figure 7.

Whilst the internal arrangement of the clusters differs, the three clusters in Figure 6 are identical to those in Figure 5. As the respective similarity matrices were derived from different treatments of the same data, the results suggest that (a) the INDSCAL dimensions are essentially those underlying the clusters in Figure 5, and (b) that the INDSCAL solution does in fact correspond to an absolute optimum rather than merely a local optima (see Shepard, 1972).

From Figure 7 it is apparent that Dimension 1 serves to separate the birth/pain cries from the hunger cries and the pleasure cries; Dimension 2 separates the pleasure cries from the other cry types; and Dimension 3 separates the pain and birth cries.

RELATIONSHIP BETWEEN THE SEMANTIC DIFFERENTIAL AND INDSCAL SOLUTIONS. To examine the relationship between the semantic differential and the INDSCAL solutions, a canonical correlation analysis (SPSS) was performed between the INDSCAL normalised A matrix (Table 9) and the semantic differential factor score matrix (Table 10).

Canonical analysis transforms sets of multidimensional solutions so that the transformations, called canonical variates, have the largest possible correlations between corresponding dimensions, and zero correlations between non-corresponding dimensions. The magnitude of the correlations reflects the degree of similarity between the solutions, whilst the number of statistically significant canonical correlations indicates the number of dimensions common to the two solutions (Cooley & Lohnes, 1971; Nie *et al.*, 1975; Dobson & Young, 1973).

TABLE 9

INDSCAL Normalized A Matrix for the 24 Cry Signals

| Cry | Dimension 1 | Dimension 2 | Dimension 3 |
|---|---|---|---|
| 1 | -0.129 | -0.167 | -0.351 |
| 2 | 0.009 | 0.299 | -0.185 |
| 3 | 0.106 | 0.062 | 0.211 |
| 4 | -0.250 | 0.226 | 0.107 |
| 5 | -0.154 | -0.341 | -0.296 |
| 6 | -0.244 | 0.134 | 0.235 |
| 7 | 0.223 | 0.091 | 0.204 |
| 8 | -0.046 | 0.219 | -0.144 |
| 9 | -0.128 | -0.357 | -0.307 |
| 10 | -0.297 | 0.050 | 0.211 |
| 11 | 0.258 | 0.069 | 0.155 |
| 12 | -0.127 | -0.372 | -0.262 |
| 13 | -0.236 | 0.095 | 0.010 |
| 14 | 0.204 | 0.028 | 0.183 |
| 15 | 0.267 | 0.033 | 0.212 |
| 16 | 0.262 | 0.009 | 0.253 |
| 17 | -0.252 | 0.054 | 0.176 |
| 18 | 0.339 | 0.093 | 0.004 |
| 19 | 0.094 | 0.039 | 0.187 |
| 20 | -0.104 | -0.391 | -0.295 |
| 21 | 0.236 | 0.114 | -0.000 |
| 22 | 0.235 | 0.179 | -0.037 |
| 23 | -0.162 | -0.334 | -0.213 |
| 24 | -0.102 | 0.163 | -0.059 |

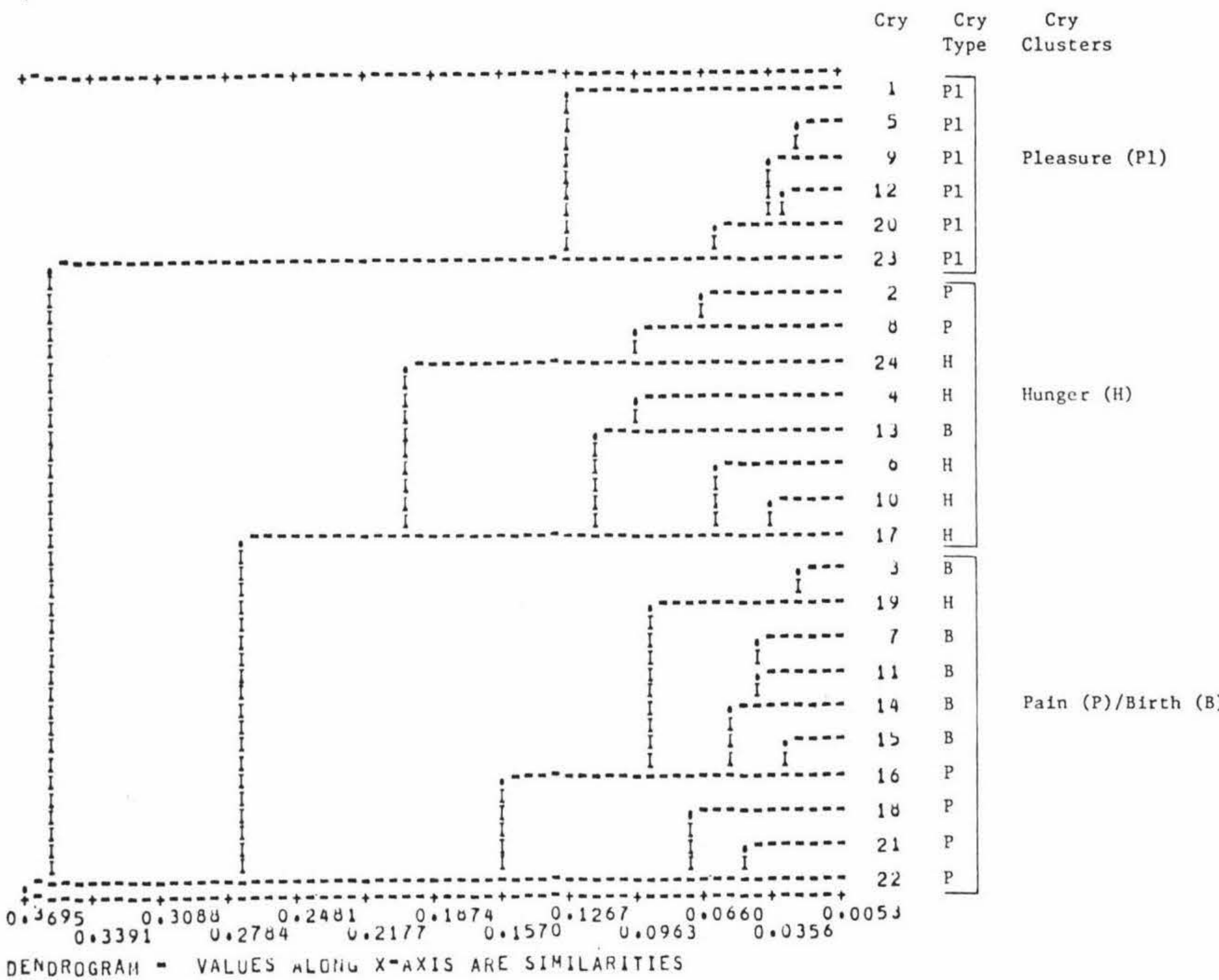


FIGURE 6 Cry clusters from the 3D INDSCAL solution

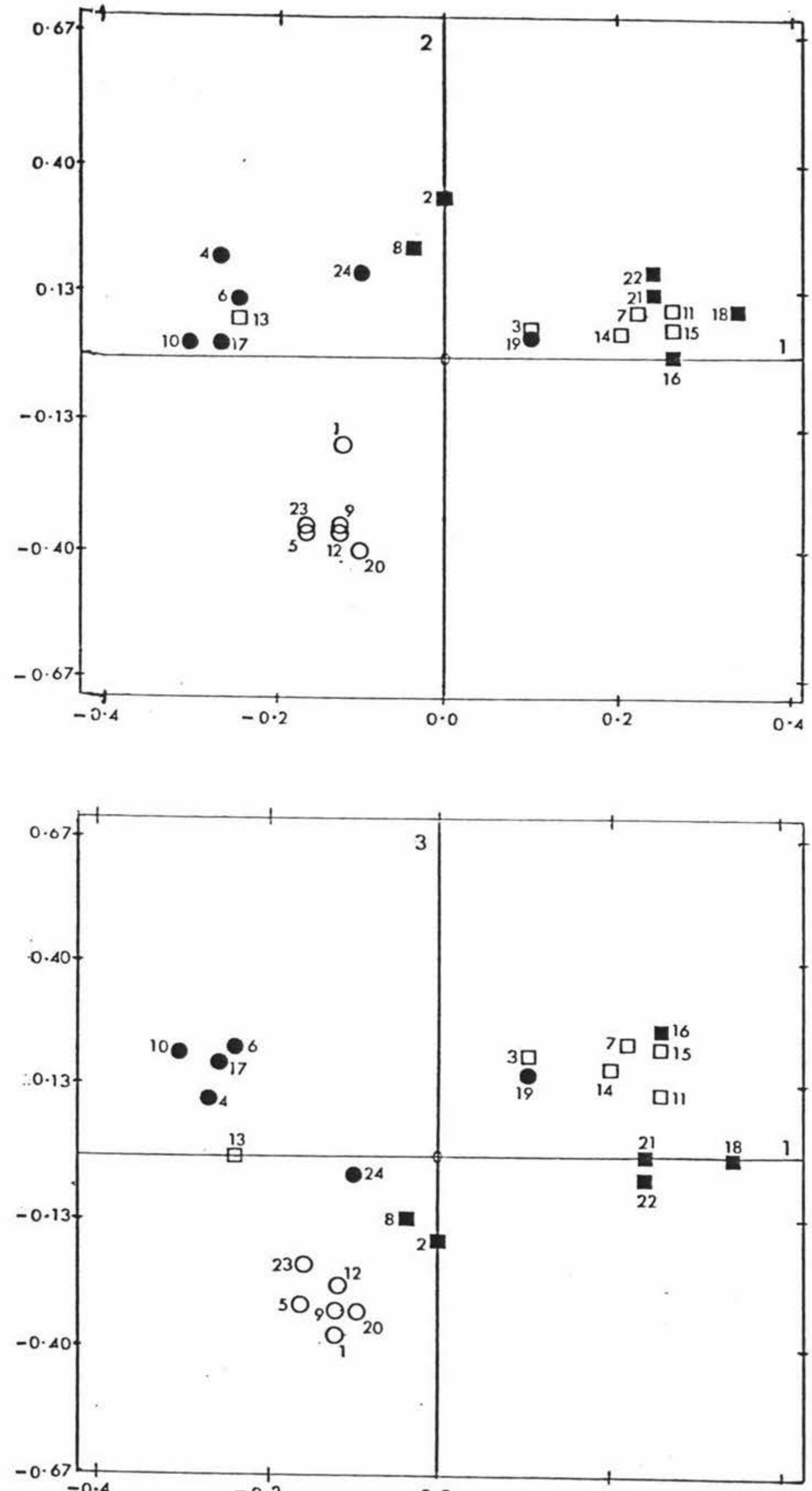


FIGURE 7 Plots of the 24 cry signals on the three INDSCAL dimensions

TABLE 10

Semantic Differential Factor Scores From the Group (N=39) Mean Ratings on the 15 Factor-scales

| Cry | Factor 1 | Factor 2 | Factor 3 |
|---|---|---|---|
| 1 | -0.671 | 1.042 | -1.219 |
| 2 | 0.987 | -0.228 | -0.167 |
| 3 | 0.647 | 1.665 | -0.319 |
| 4 | 0.570 | -1.412 | -0.320 |
| 5 | -2.004 | -0.472 | 0.452 |
| 6 | 0.721 | -0.879 | -0.159 |
| 7 | 0.719 | 0.618 | 0.791 |
| 8 | -0.006 | -0.039 | -1.127 |
| 9 | -1.932 | 0.216 | 0.189 |
| 10 | 0.465 | -1.245 | -0.547 |
| 11 | 0.802 | 0.375 | 0.927 |
| 12 | -1.726 | -0.062 | -0.498 |
| 13 | -0.201 | -1.549 | -1.451 |
| 14 | 0.476 | 0.217 | 0.295 |
| 15 | 0.739 | 0.606 | 1.040 |
| 16 | 0.531 | 1.535 | 1.336 |
| 17 | -0.263 | -0.719 | -01.09 |
| 18 | 0.674 | 0.964 | 1.047 |
| 19 | 0.848 | 1.028 | -0.950 |
| 20 | -1.728 | -0.125 | 0.200 |
| 21 | 0.705 | 0.521 | 1.173 |
| 22 | 0.794 | 0.010 | 1.181 |
| 23 | -1.404 | 0.228 | -0.814 |
| 24 | 0.094 | -1.862 | 0.155 |

The canonical correlations and coefficients are presented in Table 11. The results indicate that the INDSCAL and semantic differential solutions share two of the three possible common dimensions. Furthermore, the canonical coefficients indicate that Dimension 1 corresponds to Factors 2 and 3, whilst Dimension 2 corresponds mainly to Factor 1 but also in part (negatively) to Factors 2 and 3. Dimension 3 does not appear to have a close correspondence to any of the Factors.

INDSCAL DIMENSION LABELS. To interpret and label the three INDSCAL dimensions, the mean scale ratings from the 50 semantic differential scales were fitted to the three-dimensional INDSCAL solution using standard linear multiple regression (SPSS) in which the mean scale value was the criterion variable and the INDSCAL saliency weights the predictors. The regression weights for each of the scales were normalised so that the sum of their squared values equals one, and thus indicate the relative importance of the dimensions (c.f. Wish & Carroll, 1974; Sherman & Dowdle, 1974). The normalised beta weights are present in Table 12.

For the 15 factor-scales, the multiple correlation coefficients are highly significant (for all but two, $p<.0001$). However, as would be expected from the canonical analysis, many of the partial correlation coefficients are non-significant at the .05 level, particularly for Dimension 3. The factor scales loading most highly on the INDSCAL dimensions (1 & 2) are shown in Table 13. In agreement with the canonical analysis, it is apparent that Dimension 1 is a potency-evaluative dimension and corresponds to Factors 2 and 3, whilst Dimension 2 is an aesthetic-affective dimension corresponding to Factor 1. Dimension 3 is not described by the factor-scales. Furthermore, as both factor analysis and INDSCAL extract the most important dimensions first, there is clearly a difference in the importance of the two common dimensions for the two techniques.

When descriptions of the INDSCAL dimensions are drawn from all 50 semantic differential scales, a different emphasis is

TABLE 11

Canonical Coefficients and Correlations (Rci) Between Semantic Differential (First Set) and INDSCAL (Second Set) Solutions

| | First Set | | Second Set | |
|---|---|---|---|---|
| | Factor | Canonical coef. | Dimension | Canonical coef. |
| | 1 | -1.006 | 1 | -0.158 |
| Canvar 1 | 2 | 0.128 | 2 | -0.730 |
| $R_{c1}$ = .974 | 3 | -0.016 | 3 | -0.300 |
| | 1 | -0.160 | 1 | 1.002 |
| Canvar 2 | 2 | 0.671 | 2 | -0.513 |
| $R_{c2}$ = 931 | 3 | 0.587 | 3 | 0.048 |

Note: $R_{c3}$ = .062 (n.s.)

TABLE 12

Normalized β Weights for the INDSCAL Dimensions and 50 Semantic Differential Scales

| Scale | INDSCAL DIMENSIONS 1 | 2 | 3 | $R^2$ | Scale | INDSCAL DIMENSIONS 1 | 2 | 3 | $R^2$ |
|---|---|---|---|---|---|---|---|---|---|
| V 1 | .680 † | .638 † | .359 † | .911 ** | V26 | .906 † | .373 † | .194 ns | .883 ** |
| V 2 | .587 † | .702 † | .402 * | .840 † | V27 | .908 † | .307 ns | .282 ns | .823 ** |
| V 3 | -.912 ns | -.085 ns | -.401 ns | .103 ns | V28 | -.911 † | -.378 ns | -.160 ns | .708 ** |
| V 4 | .897 † | .411 * | .156 ns | .785 ** | V29 | .855 † | .498 * | .142 ns | .737 ** |
| V 5 | .769 † | .574 † | .279 ns | .849 ** | V30 | .602 † | -.793 * | -.088 ns | .575 ** |
| V 6 | .462 † | .859 † | -.312 † | .871 ** | V31 | .608 † | .720 † | .332 † | .929 ** |
| V 7 | -.976 † | .062 ns | .205 ns | .698 ** | V32 | -.995 † | .066 ns | .064 ns | .548 ** |
| V 8 | .875 † | .465 † | -.127 ns | .761 ** | V33 | .740 † | -.670 ns | .049 ns | .643 ** |
| V 9 | .242 ns | .948 † | .205 ns | .497 † | V34 | -.105 ns | .703 * | .703 * | .518 † |
| V10 | .599 † | .745 † | .291 ns | .850 ** | V35 | .937 † | -.061 ns | .341 ns | .694 ** |
| V11 | -.652 † | .734 † | .186 ns | .655 ** | V36 | .410 ns | .848 † | .333 ns | .782 ** |
| V12 | .937 † | -.334 ns | .096 ns | .535 † | V37 | -.215 ns | -.740 † | -.636 † | .810 ** |
| V13 | -.575 ns | .170 ns | .799 † | .574 ** | V38 | -.928 † | -.377 ns | -.193 ns | .796 ** |
| V14 | -.923 † | .379 * | -.059 ns | .740 ** | V39 | .885 † | .444 † | .136 ns | .831 ** |
| V15 | -.912 † | .029 ns | -.408 * | .756 ** | V40 | .438 † | -.667 ns | -.601 ns | .649 ** |
| V16 | .799 † | .594 ns | .083 ns | .494 † | V41 | -.607 † | -.663 † | -.437 † | .887 ** |
| V17 | -.484 † | -.830 † | -.294 ns | .832 ** | V42 | -.499 † | -.818 † | -.282 † | .964 ** |
| V18 | .773 † | 0.36 ns | .632 † | .817 ** | V43 | .720 † | .590 † | .363 † | .917 ** |
| V19 | .485 † | .713 † | .504 † | .906 ** | V44 | -.506 † | -.715 † | -.480 † | .886 ** |
| V20 | .800 † | -.596 † | .048 ns | .539 † | V45 | -.236 ns | -.902 † | -.359 * | .841 ** |
| V21 | -.604 † | .769 † | .206 ns | .506 † | V46 | .885 † | -.061 ns | .459 * | .765 ** |
| V22 | .678 † | -.632 † | .374 * | .716 ** | V47 | -.454 † | .866 † | -.205 ns | .703 ** |
| V23 | .503 † | .637 † | .583 † | .879 ** | V48 | .482 ns | .859 ns | -.168 ns | .193 ns |
| V24 | .955 † | .194 ns | -.220 ns | .576 ** | V49 | .632 † | .625 † | .456 † | .940 ** |
| V25 | .468 † | .776 † | .421 † | .941 † | V50 | .386 † | .921 ns | .045 ns | .865 ** |

* P <.05
† P <.01
** P <.001

Partial correlation coefficients d.f. = 1,20
Multiple correlation coefficients d.f = 3,20

TABLE 13

Semantic Differential Factor-scale Descriptions of INDSCAL Dimensions 1 and 2

| Dimension 1 | | | Dimension 2 | | |
|---|---|---|---|---|---|
| Scale | Label | Factor | Scale | Label | Factor |
| -V 7 | weak - strong | 2 | V25 | happy - sad | 1 |
| V24 | unintentional - intentional | 3 | V21 | colourful - colourless | 3 |
| V35 | meaningless - meaningful | 3 | V10 | soothing - arousing | 1 |
| V12 | small - large | 1 | V31 | beautiful - ugly | 1 |
| -V38 | unimportant - important | 3 | V19 | relaxed - tense | 1 |
| -V14 | shallow - deep | 2 | -V33 | sincere - insincere | 3 |
| -V15 | light - heavy | 2 | V 1 | pleasant - unpleasant | 1 |

apparent, as shown in Table 14. Both Dimensions 1 and 2 have an evaluative element, and Dimension 1 clearly suits the label Potency. However Dimension 2 could be better described as Form rather than Effect, and Dimension 3 appears to represent Clarity. Thus it would appear that the similarity analysis tends to emphasise the physical aspects of the signals whereas the semantic differential emphasises the emotional aspects.

TABLE 14

Semantic Differential Scale Descriptions of the INDSCAL Dimensions

| Dimension 1 (Potency) | | Dimension 2 (Form) | | Dimension 3 (Clarity) | |
|---|---|---|---|---|---|
| Scale | Label | Scale | Label | Scale | Label |
| -V 32 | short - long | V 9 | even - uneven | V 13 | clear - hazy |
| -V 7 | weak - strong | V 50 | rounded - angular | V 34 | near - far |
| V 24 | unintentional - intentional | -V 45 | yielding - clinging | -V 37 | intimate - remote |
| V 35 | meaningless - meaningful | V 47 | formed - formless | V 18 | fine - coarse |
| V 12 | small - large | V 6 | low - high | -V 40 | open - closed |
| -V 38 | unimportant - important | V 36 | healthy - sick | V 23 | clean - dirty |

## DISCUSSION

The method of pair-comparisons appears to be an effective means of obtaining measures of perceived similarity between cry signals. The cry clusters produced from these measures accurately predicted the cry recognition results, which suggests that the listeners attended to the same cry features in both tasks. The cry clusters also corresponded closely to those produced from the semantic differential factor-scale ratings in Experiment 1, suggesting that the two techniques uncovered the same perceptual dimensions.

Three perceptual dimensions were uncovered from the similarity data by INDSCAL. The cry clusters produced from the INDSCAL dimension saliency weights matched those produced from the pair-comparison similarity matrix, indicating that the INDSCAL dimensions are those underlying the pair-comparison task. A canonical analysis of the semantic differential and the INDSCAL data confirmed that the two solutions describe essentially the same perceptual space, as did the standard multiple regression analysis, by which the INDSCAL dimensions were labelled (Potency, Form and Clarity) in terms of the 50 semantic differential scales.

To obtain similarity measures, all possible cry-pairs were rated on a five point scale by listeners. The presentation of the cry-pairs was not randomly ordered, but followed a systematic pattern, with the first 24 pairs beginning with cry 1, the second 23 pair beginning with cry 2, and so on. In contrast, in an earlier study (Brennan, 1978) using the same signals, the cries were presented in sequences of 10 with short pauses between each cry. Listeners compared each cry with the cry immediately preceding it in the sequence and judged them as "same" or "different". These similarity judgements were recorded by the experimenter, and the cry similarity matrix computed by summing the number of "same" responses for each cry-pair.

Whilst the present method of cry-pair presentation may seem to invite systematic errors in fact there is a very close correspondence between the cry clusters produced by Brennan (1978) and those from the present study, which suggests that the method is reliable. The present method simplifies considerably the task of producing the cry-pair sequences and tabulating the responses, when compared to either the method used by Brennan (1978) or the method of pair-comparisons when a randomly ordered sequence is used. Furthermore, it is far easier to introduce new signals into the analysis. The new signal is paired with each of the existing signals in turn and the new set of cry-pairs added to the beginning of the existing cry-pair tape.

Thus the method of pair-comparisons, coupled to INDSCAL, effectively uncovered perceptual dimensions of infants' cry signals. However, a further analysis was required to identify and label these dimensions. In the present study, the semantic differential scale labels were used for this purpose, although the dimensions could also have been described in terms of the acoustic or "distinctive" features of the cries.

# GENERAL DISCUSSION

The present results indicate that both the semantic differential technique and the method of pair-comparisons are effective means for identifying perceptually similar cries. The cry similarity clusters resulting from these techniques corresponded closely to the clusters computed from cry recognition data, suggesting that the listeners attended to the same features when comparing or rating the 24 cries as they used to identify the cries in the recognition task. Furthermore, the perceptual dimensions uncovered by factor analysis of the semantic differential data appear to be essentially the same as those uncovered by an INDSCAL analysis of the pair-comparison data, although the semantic differential factors tend to emphasis emotional aspects of the cries, whereas the INDSCAL dimensions emphasise physical characteristics.

Whilst the two techniques produce similar results, there are several advantages to using the semantic differential rather than the method of pair-comparisons to analyse the perceptual features of cry signals. Firstly, to use the method of pair-comparisons it is necessary to restrict both the number of signals in the analysis and their duration, due to the time required for the task of rating all possible cry-pairs. This is a disadvantage when investigating cries as signals, for important information may be contained in the pattern of inspirations and expirations. For example, Wolf (1969) reports that the "natural unit" for a repeated pain cry consists of an inspiratory whistle immediately followed by a long expiratory cry, whereas for a "frustration" cry, the natural unit is a cry followed by an inspiratory whistle. The semantic differential is particularly suitable for such signals. Nordenstreng (1968) used the technique with musical excerpts which each lasted five minutes.

Secondly, the construction of test-tapes for the pair-comparison task is very laborious, especially if a randomly ordered sequence is used. This also creates difficulties for tabulating the responses. With the semantic differential, however, test-tape preparation is straight forward and in fact it would be possible to dispense with a recording all together and rate cries as they were being emitted.

Thirdly, to uncover the perceptual dimensions from the pair comparison data, the similarity matrices must be submitted to a program such as INDSCAL. In contrast, once the semantic differential factor have been uncovered, the perceptual dimensions are subsequently represented by the factor-scales. Whilst INDSCAL is particularly useful because it provides saliency weights for both subjects and signals, thus indicating the relatively importance or salience of the various dimensions to individual listeners, similar information is actually provided by the factor-scale profiles. However the semantic differential data could also be submitted to an INDSCAL analysis by first computing cry similarity matrices using Dendrogram7. In fact, INDSCAL can be used to compare the solutions obtained from different techniques (such as the semantic differential and the method of pair comparisons) by submitting both sets of similarity matrices to a single INDSCAL analysis (see Wish & Carroll, 1974).

And fourthly, whilst the semantic differential dimensions are described by the factor-scale labels themselves, identification of the dimensions uncovered from pair-comparison data requires a further analysis, either in terms of the acoustic features or the "distinctive features" of the signals. In the present study, however, the dimensions common to both the INDSCAL and the semantic differential, as well as the unique INDSCAL dimensions, were all described in terms of semantic differential scales. This procedure raises the possibility of replacing the method of pair-comparisons altogether, by using the appropriate semantic differential scales instead. However, a further study is required to determine whether the cry clusters produced from cry ratings on such scales do in fact correspond to those produced from the INDSCAL saliency weights.

The semantic differential seems particularly applicable for several areas of cry research. Firstly, the present semantic differential scales effectively differentiate the four cry-types of birth, pain, hunger and pleasure, and the classification function coefficients are an effective means of identifying the different cry-types. These same techniques could also be used to investigate other general classes of cries, such as "frustration ", "anger", "boredom" and so on, or to examine the cry repertoires of individual infants. In either case, the semantic differential scale labels provide a means for developing rules to describe specific cry signals which may serve as an aid to help the caregiver "tune in" to the infant and respond appropriately.

Secondly, the semantic differential may provide a means for the early identification of infants with clinical abnormalities. Illingworth (1955) reports that:

> A clinician recognises the hoarse gruff cry of a cretin, the hoarse cry of laryngitis, the shrill cry of hydrocephalus, meningitis, or cerebral irritability, the grunting cry of pneumonia, the feeble cry of amytonia or of a severely debilitated infant, and the whimper of a seriously ill child (p 76).

Clearly, these cries could be described by an appropriate set of descriptive scales. Furthermore, as noted previously, Zeskind & Lester (1978) found that with a set of only eight semantic differential scales it was possible to differentiate between the cries of normal infants and the cries of infants who had experienced prenatal and perinatal complications. This raises the possibility of developing either a set of rules that clinicians could use to identify clinically significant cries, or a set of scales for plotting a cry profile which could be compared to a "normal".

Recently, cry studies have begun to examine the effects that crying can have on the caregiver (Frodie *et al.*, 1987a,b; Zeskind & Lester, 1978; Donovan, Leavitt & Balling, 1978), and it has been suggested that the cry is an aversive stimulus that in some instances may provoke abuse. To date, however, these investigations have used physiological or self report measures of the effects of cries on listeners, and paid little attention to the nature of the signals themselves. Thus a third possible application of the semantic differential technique would be to examine the relationship between the nature of an infant's cry signals and the perception of them by the infant's caregiver.

The first step in such an analysis would be to record a sample of the infant's cries and have them rated on the 50 semantic differential scales by a group of reliable listeners, along with the 24 signals from the present study. The ratings on the Factor 1 scales would indicate the aversiveness of the infant's cries relative to the 24 signals. Also, if the infant had perceptually distinct cries that matched the particular cry eliciting situations, a set of rules could be developed from the scales as in Experiment 1, to help the caregiver identify the different cry types.

The second step would be to have the caregiver rate the same set of cries. Cluster analysis (Dendogram7) should reveal whether or not the caregiver is able to discriminate between different signals, the Factor 1 ratings would indicate the perceived aversivenss of both the infant's cries and the 24 introduced signals, and the ratings on the Factor 3 factor-scales should indicate the importance that the caregiver attaches to the signals. The caregiver's cry-profiles could also be compared with those of other subjects to examine for differences in perception. In addition, the same semantic differential scales could be used by the caregiver to rate concepts, such as "motherhood", "baby", "crying" and so on, in the manner originally intended by Osgood. When the scales are used in this way with caregivers who are abusive, or find cries particularly irritating, it might be possible to gain some insight into the various factors that contribute to the effects of crying.

In summary, perceptual dimensions underlying a set of infants' cry signals were uncovered by two techniques, the semantic differential and the method of pair-comparisons (coupled to INDSCAL), which appear to describe the same perceptual space. The semantic differential, however, would appear to have wider application in cry research: it is simple to use, it can be used to examine the perceptions of listeners as well as the perceptual characteristics of the signals, and it can also be used to examine a variety of stimuli including concepts. These capabilities suggest that the semantic differential technique is suitable for studies concerned with the signal value of cries, the diagnostic utility of cries, or the effects that crying may have on a caregiver.

APPENDIX A    Semantic Differential Instructions

(MB 79D)

## INSTRUCTIONS

Thank you for agreeing to participate in this study.

The purpose of this study is to find out about the meanings that different baby cries have for different people. Your task is to indicate on a set of descriptive scales, what each of the 24 baby cries means to you.

For each of the 24 cries there are 50 descriptive scales. These scales have been divided into two sets of 25 scales for each. There is one set on each page of this booklet. Pages 1 & 2 contain the scales for Cry 1, pages 3 & 4 contain the scales for Cry 2, and so on.

While you are completing the scales, the cry you are judging will be repeated at short intervals until you have finished.

please read the next page

Please complete these questions

Age ____ (years)

Ages of children (years) ___ ___ ___ ___ ___ ___ ___

Musical experience

sing in choir YES NO
play a musical instrument YES NO
read music YES NO
music exams YES NO(if YES, grade ___)

Maternity nursing experience YES NO (if YES, years ___)

Name: ______________________ ______
last initials

This is how to use the scales :

If you feel that the cry is very closely related to one end of the scale, you should place your check-mark as follows:

fair _X_:___:___:___:___:___:___ unfair

or

fair ___:___:___:___:___:___:_X_ unfair

If you feel that the cry is quite closely related to one or the other end of the scale (but not extremely), you should place your check-mark as follows:

safe ___:_X_:___:___:___:___:___ dangerous

or

safe ___:___:___:___:___:_X_:___ dangerous

If the cry seems only slightly related to one side as opposed to the other side (but not really neutral), the you should check as follows:

good ___:___:_X_:___:___:___:___ bad

or

good ___:___:___:___:_X_:___:___ bad

The direction towards which you check, of course, depends upon which of the two ends of the scale seem most characteristic of the cry you're judging.

If you consider the cry to be neutral on the scale, that both sides of the scale are equally associated with the cry, or if the scale is completely irrelevant and unrelated to the cry, then you should place your checkmark in the middle space:

bitter ___:___:___:_X_:___:___:___ sweet

please read the next page

IMPORTANT: (1) Place your check-marks in the middle of spaces, not on the boundaries:

THIS NOT THIS

___:___: X :___:___X___:___

(2) Be sure you check every scale for every cry - do not omit any.

(3) Never put more than a single check-mark on a single scale.

During the study some of the items may seem similar. It is not necessary to remember what you did previously.
Just make each decision anew.

Please do not puzzle over the scales. Work as fast as you find comfortable. It is your first impressions or feelings that are important.

In summary:

There are 24 cries to rate and two sets of descriptive scales for each cry. While you are judging a cry, it will be replayed at intervals until you have completed the two pages of scales. When you have finished judging a cry, quickly check that you have marked every scale. Then wait quietly for everyone to finish.

Please do not talk during the study.

Do you have any questions?

pleasant ___:___:___:___:___:___:___ unpleasant

smooth ___:___:___:___:___:___:___ rough

repetitive ___:___:___:___:___:___:___ varied

passive ___:___:___:___:___:___:___ active

beautiful ___:___:___:___:___:___:___ ugly

low ___:___:___:___:___:___:___ high

strong ___:___:___:___:___:___:___ weak

soft ___:___:___:___:___:___:___ loud

even ___:___:___:___:___:___:___ uneven

soothing ___:___:___:___:___:___:___ arousing

full ___:___:___:___:___:___:___ empty

small ___:___:___:___:___:___:___ large

clear ___:___:___:___:___:___:___ hazy

deep ___:___:___:___:___:___:___ shallow

heavy ___:___:___:___:___:___:___ light

usual ___:___:___:___:___:___:___ unusual

wet ___:___:___:___:___:___:___ dry

fine ___:___:___:___:___:___:___ coarse

relaxed ___:___:___:___:___:___:___ tense

narrow ___:___:___:___:___:___:___ wide

colourful ___:___:___:___:___:___:___ colourless

thin ___:___:___:___:___:___:___ thick

clean ___:___:___:___:___:___:___ dirty

unintentional ___:___:___:___:___:___:___ intentional

happy ___:___:___:___:___:___:___ sad

| | | |
|---|---|---|
| gentle | ___:___:___:___:___:___:___ | violent |
| slow | ___:___:___:___:___:___:___ | fast |
| rugged | ___:___:___:___:___:___:___ | delicate |
| simple | ___:___:___:___:___:___:___ | complex |
| new | ___:___:___:___:___:___:___ | old |
| calm | ___:___:___:___:___:___:___ | agitated |
| long | ___:___:___:___:___:___:___ | short |
| insincere | ___:___:___:___:___:___:___ | sincere |
| near | ___:___:___:___:___:___:___ | far |
| meaningless | ___:___:___:___:___:___:___ | meaningful |
| healthy | ___:___:___:___:___:___:___ | sick |
| remote | ___:___:___:___:___:___:___ | intimate |
| important | ___:___:___:___:___:___:___ | unimportant |
| soft | ___:___:___:___:___:___:___ | hard |
| closed | ___:___:___:___:___:___:___ | open |
| cold | ___:___:___:___:___:___:___ | warm |
| distressing | ___:___:___:___:___:___:___ | comforting |
| sweet | ___:___:___:___:___:___:___ | bitter |
| awkward | ___:___:___:___:___:___:___ | graceful |
| clinging | ___:___:___:___:___:___:___ | yielding |
| defensive | ___:___:___:___:___:___:___ | aggressive |
| formed | ___:___:___:___:___:___:___ | formless |
| falling | ___:___:___:___:___:___:___ | rising |
| sociable | ___:___:___:___:___:___:___ | unsociable |
| rounded | ___:___:___:___:___:___:___ | angular |

APPENDIX B   Dendrogram7

```
C      PROGRAM NAME          D E N D R O G R A M 7
C
C      DESIGNED PRIMARILY TO PERFORM WEIGHTED PAIR GROUP AVERAGE CLUSTER-
C      ING ON A SIMILARITY MATRIX (EITHER READ IN DIRECTLY OR COMPUTED
C      FROM RAW DATA) AND TO PLOT A DENDROGRAM DISPLAYING THE CLUSTERS.
C      (IF COMPUTED, THE SIMILARITY MATRIX WILL CONTAIN DISTANCE COEFFS).
C
C      VERSION 7.
C           THIS VERSION PROVIDES OPTIONS ON: INPUT AND OUTPUT FORMATS,
C      SUPPRESSION OF DENDROGRAM,"NORMALISATION" OF DISTANCE COEFFICIENTS
C      AND CREATION OF SIMILARITY AND TRANSPOSED MATRICES ON DISK.
C      SCALING OF DENDROGRAM X-AXIS CONTROLLED BY LHLIM AND RHLIM
C      LINE PRINTER OUTPUT BY THIS VERSION IS LIMITED TO LISTING OF INPUT
C      PARAMETERS AND FORMATS,ROW 1 OF ANY MATRIX READ, AND DENDROGRAMS.
C      ANY NUMBER OF PARAMETER/HEADER/FORMAT SETS MAY BE GIVEN; FOR EACH
C      SET, ANY NUMBER OF MATRICES MAY BE PROCESSED BEFORE READING THE
C      NEXT PARAMETER/HEADING/FORMAT SET.(CONTROLLED BY THE NMTX OPTION)
C
C      INPUT.
C      ******
C           INPUT SUPPLIED VIA THE CARD READER IS:-
C      1.   A PARAMETER LIST (FREE FORMAT INTEGERS - MEANINGS GIVEN BELOW)
C      2.   ONE CARD TO BE USED AS A HEADER FOR LINE PRINTER OUTPUT
C      3.   FORMAT SPECIFICATIONS FOR INPUTTING MATRICES FROM DISK
C      4.   FORMAT SPECIFICATIONS FOR OUTPUT OF SIMILARITY MATRICES
C
C      NOTE:- FORMAT SPECS MUST BE ENCLOSED IN PARENTHESES;TWO CARDS MUST
C      BE PRESENT FOR EACH; COLS 76 AND 80 MUST NOT BE USED; THE LISTS
C      MUST NOT BE LONGER THAN 132 CHARACTERS EACH.
C
C           INPUT FROM DISK (VIA FILE4):-
C      5.   DATA MATRICES OR LOWER HALF SIMILARITY MATRICES MAY BE READ.
C           THE TITLE OF THE FILE CONTAINING THE MATRICES MUST BE GIVEN AT
C           RUNTIME USING A FILE EQUATE OF THE FORM
C
C                FILE FILE4(TITLE =     ...FILE TITLE...     )
C
C           THIS FILE IS ASSUMED TO CONSIST OF 14 WORD RECORDS AND TO HAVE
C           420 WORDS PER BLOCK (KNOWN AS 'CARD IMAGE FORMAT')
C
C      PARAMETERS.
C      ***********
C      THESE MUST BE GIVEN IN THE ORDER SHOWN IN THE FOLLOWING TABLE:-
C
C      PARAMETER  LEGAL       MEANING
C        NAME     VALUES
C
C      ITYPE                  INPUT MATRIX TYPE
C                   1         DATA MATRIX
C                   2         DATA MATRIX, TRANSPOSE BEFORE USE
C                   3         LOWER HALF SIMILARITY MATRIX
C
C      ISIM                   METHOD OF CLUSTERING SIMILARITY VALUES
C                   0         CLUSTER LOW VALUES
C                   1         CLUSTER HIGH VALUES
C
C      N          1-50        NUMBER OF ROWS IN INPUT MATRIX
C
C      M          1-50        NUMBER OF COLUMNS IN INPUT MATRIX
C
C      CUTOFF      >0         IF CUTOFF IS NON ZERO, VALUES IN THE
C                             SIMILARITY MATRIX LESS THAN CUTOFF ARE
C                             REPLACED BY ZEROES
C
C      MTDK                   OPTION ON OUTPUT OF MATRICES TO DISK
C                   0         SUPPRESS DISK OUTPUT OF BOTH MATRICES
C                   1         WRITE SIMILARITY MTX, SUPPRESS TRANSPOSED MTX
C                   2         SUPPRESS SIMILARITY MTX, WRITE TRANSPOSED MTX
C                   3         WRITE BOTH MATRICES TO DISK
C
```

```
C       DGRAM                          OPTION ON CREATION OF DENDROGRAM
C                         0            SUPPRESS
C                         1            CREATE
C       LHLIM                          THESE SET THE LEFT AND RIGHT HAND LIMITS TO
C       RHLIM                          BE USED ON DENDROGRAM X-AXIS.  IF DENDROGRAM
C                                      WILL NOT FIT IN THE RANGE,LHLIM AND RHLIM AR
C                                      IGNORED, AND THE SCALE IS ADJUSTED AS NEEDED
C
C
C       NORM                           OPTION ON NORMALISATION OF DIST COEFFS
C                         0            DO NOT NORMALISE: DIST=SQRT(SUMSQ)
C                         1            NORMALISE: DIST=SQRT(SUMSQ/N)
C
C       NMTX                           NUMBER OF MATRICES TO BE PROCESSED USING THI
C                                      PARAMETER/HEADING/FORMAT SET
C
C       OUTPUT.
C       *******
C       1.  PARAMETERS AND FORMAT CARDS ARE LISTED.
C       2.   THE FIRST ROW OF EACH MATRIX READ IS LISTED (IN 8F10.5)
C       3.  SIMILARITY MATRICES WILL BE WRITTEN TO DISK VIA FILE7 USING
C           THE SPECIFIED FORMAT IF MTDK IS 1 OR 3.  THE DEFAULT TITLE OF
C           THIS FILE IS "DENDRO/SIM" BUT MAY BE CHANGED AT RUNTIME USING
C
C               FILE FILE7(TITLE =     ...FILE TITLE...     )
C
C       4.  TRANSPOSED MATRICES WILL BE WRITTEN TO DISK VIA FILE8 USING
C           F10.5 FORMAT IF MTDK IS 2 OR 3.  THE DEFAULT TITLE OF THIS
C           FILE IS "DENDRO/TRANS" BUT MAY BE CHANGED AT RUNTIME USING :-
C
C               FILE FILE8(TITLE =     ...FILE TITLE...     )
C
C       NOTE:- BOTH FILE7 AND FILE8 ARE 'CARD IMAGE FORMAT' FILES.
C
C       5.  IF A DENDROGRAM IS BEING PRODUCED (DGRAM OPTION IS 1) THE
C           LINKAGE TABLE AND DENDROGRAM ARE DIRECTED TO THE LINE PRINTER
C
C
C
C       ==============================================================
FILE    4(KIND=DISK, MAXRECSIZE=14, BLOCKSIZE=420)
FILE    7(KIND=DISK,MAXRECSIZE=14,BLOCKSIZE=420,PROTECTION=SAVE,
      * TITLE="DENDRO/SIM.")
FILE    8(KIND=DISK,MAXRECSIZE=14,BLOCKSIZE=420,PROTECTION=SAVE,
      * TITLE="DENDRO/TRANS.")
        DIMENSION X(50,50),IPAIR(2,50),XLEV(50),A(50,50)
        REAL INPFMT(22), OUTFMT(22)
        REAL LHLIM, RHLIM
        COMMON HEADER(13)
        MD=50
        ND=50
        MM=50
C
C       READ PARAMETER/HEADING/FORMAT SET
      1 READ(5,/,END=999)
      * ITYPE,
      * ISIM,
      * N,
      * M,
      * CUTOFF,
      * MTDK,
      * DGRAM,
      * LHLIM,
      * RHLIM,
      * NORM,
      * NMTX
        READ(5,1002)(HEADER(INDX),INDX=1,13)
        READ(5,1001)
      *     (INPFMT(INDX),INDX=1,22),
      *     (OUTFMT(INDX),INDX=1,22)
C
C       OUTPUT HEADING, PARAMETERS AND FORMATS
        WRITE(6,2005)(HEADER(INDX),INDX=1,13)
        WRITE(6,2006)
        WRITE(6,*/)
      * ITYPE,
      * ISIM,
      * N,
      * M,
      * CUTOFF,
      * MTDK,
```

```
     * DGRAM,
     * LHLIM,
     * RHLIM,
     * NORM,
     * NMTX
      WRITE(6,2007)
     *      (INPFMT(INDX),INDX=1,22),
     *      (OUTFMT(INDX),INDX=1,22)
   15 CONTINUE
C
C     READ A LOWER HALF SIMILARITY MATRIX USING THE FORMAT SUPPLIED
C
      IF (ITYPE .NE. 3) GO TO 2
      DO 5 I=1,M
       READ(4,INPFMT)(A(I,J),J=1,I)
       DO 51 J=1,I
   51  A(J,I)=A(I,J)
    5 CONTINUE
C
C     PRINT FIRST ROW OF SIMILARITY MATRIX JUST READ
      I=1
      WRITE(6,2001)
      WRITE(6,2004)(A(I,J),J=1,M)
      GO TO 4
C
C     READ A RAW DATA MATRIX USING THE FORMAT SUPPLIED
C
    2 DO 6 I=1,N
    6 READ(4,INPFMT)(X(I,J),J=1,M)
C
C     PRINT FIRST ROW OF DATA MATRIX JUST READ
      I=1
      WRITE(6,2001)
      WRITE(6,2004)(X(I,J),J=1,M)
C
C...  TRANSPOSE DATA MATRIX (IF REQUIRED)
C
      IF (ITYPE .NE. 2) GO TO 3
      MT=M
      IF (N .GT. M) MT=N
      DO 110 I=1,MT
      DO 110 J=1,MT
      XS=X(I,J)
      X(I,J)=X(J,I)
      X(J,I)=XS
  110 CONTINUE
      MT=M
      M=N
      N=MT
C
C...  CALCULATE SIMILARITY MATRIX
C
    3 CALL DIST(X,N,M,ND,ND,A,MM,NORM)
C
C     APPLY CUTOFF TO SIMILARITY MATRIX
      IF(CUTOFF .LE. 0) GO TO 4
C
      DO 10 I=1,M
      DO 10 J=1,I
      IF(A(I,J).GE.CUTOFF) GO TO 10
      A(I,J) = 0
      A(J,I) = 0
   10 CONTINUE
C
C     PERFORM DISK OUTPUT ACCORDING TO MTDK OPTION
C
    4 IF(MTDK .EQ. 0) GO TO 12
      IF(MTDK .EQ. 1) GO TO 11
      DO 8 I = 1,N
    8 WRITE(8,2008)(X(I,J),J=1,M)
C
   11 IF(MTDK .EQ. 2) GO TO 12
      DO 9 I = 1,M
    9 WRITE(7,OUTFMT) (A(I,J), J=1,M)
   12 CONTINUE
C
C
C     PRODUCE DENDROGRAM (IF REQD)
      IF(DGRAM .NE. 1) GO TO 16
      CALL WPGA(A,M,MM,IPAIR,XLEV,ISIM)
      CALL DENDRO(IPAIR,XLEV,M,MM,ISIM,LHLIM,RHLIM)
```

```
   16 CONTINUE
C
C      DECREMENT AND TEST NMTX COUNTER
       NMTX=NMTX-1
       IF(NMTX .LT. 1) GO TO 1
       IF(ITYPE .NE. 2) GO TO 15
C      "UN-TRANSPOSE" M AND N READY FOR RE READING INPUT MATRIX
       MT=M
       M=N
       N=MT
       GO TO 15
  999  STOP
 1001  FORMAT(13A6/9A6)
 1002  FORMAT(13A6)
 2001  FORMAT('0','FIRST ROW OF MATRIX JUST READ WAS:-')
 2004  FORMAT('0'/(' ',8F10.5))
 2005  FORMAT('1',13A6/)
 2006  FORMAT('0','PARAMETER SETTINGS:-')
 2007  FORMAT('0','INPUT FORMAT:-'/' ',22A6/
     *         '0','OUTPUT FORMAT:-'/' ',22A6/)
 2008  FORMAT(8F10.5)
       END
C
C
C      SUBROUTINE TO PERFORM WEIGHTED PAIR-GROUP AVERAGE CLUSTERING.
C
       SUBROUTINE WPGA(X,M,M1,IPAIR,XLEV,ISIM)
       DIMENSION X(M1,M1),IPAIR(2,M1),XLEV(M1)
       DIMENSION I1(100),I2(100),XSIM(100)
       COMMON HEADER(13)
C
C...   INITIALIZE
C
       WRITE (6,2001)(HEADER(INDX),INDX=1,13)
       WRITE(6,2004)
       DO 110 I=1,M
       I1(I)=I
  110  CONTINUE
       XXINIT=+9.0E35
       IF(ISIM .EQ. 1) XXINIT= -XXINIT
       M3=M-1
       IC=0
       PASS=1
C
C      IF CLUSTERING LOW VALUES, FIND SMALLEST SIMILARITY IN EACH COLUM
C      ELSE FIND HIGHEST SIMILARITY IN EACH COLUMN
C
    1  WRITE(6,1112) PASS
 1112  FORMAT(' ', 'PASS', I3)
       PASS=PASS+1
       DO 100 I=1,M
       IF (I1(I) .LE. 0) GO TO 100
       XX=XXINIT
       IX=0
       DO 101 J=1,M
       IF (I .EQ. J) GO TO 101
       IF (I1(J) .LE. 0) GO TO 101
       XJI=X(J,I)
       GO TO (11,12), ISIM+1
   11  IF (XJI .LT. XX) GO TO 13
       GO TO 101
   12  IF (XJI .GT. XX) GO TO 13
       GO TO 101
   13  XX=XJI
       IX=J
  101  CONTINUE
       I2(I)=IX
       XSIM(I)=XX
  100  CONTINUE
C
C      IF CLUSTERING LOW VALUES, FIND MUTUALLY LOW PAIRS
C      ELSE FIND MUTUALLY HIGH PAIRS
C
       DO 102 I=1,M3
       IF (I1(I) .LE. 0) GO TO 102
       J=I2(I)
       IF (I1(J) .LE. 0) GO TO 102
       IF (J .LE. I) GO TO 102
       IF(I1(J) .EQ. I) GO TO 14
       IF (ABS(XSIM(I)-XSIM(J)) .GT. 0.00001) GO TO 102
C
```

```
C...  SAVE PARAMETERS FOR A CLUSTER
C
   14 IC=IC+1
      IPAIR(1,IC)=I
      IPAIR(2,IC)=J
      XLEV(IC)=XSIM(I)
      WRITE (6,2002) I,J,XSIM(I), I
      I1(I)=J
      I1(J)=0
C
C...  AVERAGE THE TWO COLUMNS
C
      DO 103 K=1,M
      X(K,I)=(X(K,I)+X(K,J))/2.0
  103 CONTINUE
  102 CONTINUE
C
C...  AVERAGE ROWS THAT WERE CLUSTERED ON THIS ITERATION
C
      DO 105 I=1,M3
      IF (I1(I) .LE. 0) GO TO 105
      IF (I1(I) .EQ. I) GO TO 105
      J=I1(I)
C
C...  AVERAGE TWO ROWS IN THE NEW CLUSTER
C
      DO 106 K=1,M
      IF (I1(K) .LE. 0) GO TO 106
      X(I,K)=(X(I,K)+X(J,K))/2.0
  106 CONTINUE
      I1(I)=I
  105 CONTINUE
      IF (IC .LT. M3) GO TO 1
      WRITE (6,2003)
      RETURN
 2001 FORMAT ('1',13A6/)
 2002 FORMAT (6X,2I5,F12.5, I6)
 2003 FORMAT ('0',4X,
     1 'RESULTANT CLUSTER IS AVE. OF OBSERVATIONS (=CLUSTERS)'
     * ' ONE AND TWO'/)
 2004 FORMAT('0LINKAGE TABLE'/' ',T22,'SIMILARITY',T35,'RESULTANT'/
     * ' ', T10, 'ONE  TWO', T24, 'LEVEL', T35, 'CLUSTER'/)
      END
C
C
C     SUBROUTINE TO PRINT A DENDROGRAM
C
      SUBROUTINE DENDRO(IPAIR,XLEV,M,M1,ISIM,XL,XR)
      DIMENSION IPAIR(2,M1),XLEV(M1)
      DIMENSION I1(100),I2(100)
      DIMENSION IOUT(61),XX(13)
      COMMON HEADER(13)
      DATA IBLNK,IC1,ICP,ICM/1H ,1H1,1H.,1H-/
C
C...  DETERMINE ORDER THAT BRANCHES WILL BE PRINTED IN
C
      M2=M-1
      DO 100 I=1,M
      I1(I)=0
      I2(I)=0
  100 CONTINUE
      DO 101 I=1,M2
      J=I-1
   11 IF (J .LE. 0) GO TO 12
      IF (IPAIR(1,I) .EQ. IPAIR(1,J)) GO TO 13
      J=J-1
      GO TO 11
   12 I2(I)=1
      GO TO 15
   13 K=I1(J)
      IF (K .EQ. 0) GO TO 14
      J=K
      GO TO 13
   14 I1(J)=I
   15 DO 102 J=1,I
      K=J
      IF (IPAIR(2,I) .EQ. IPAIR(1,J)) GO TO 16
  102 CONTINUE
      GO TO 101
   16 I2(K)=0
      I1(I)=K
```

```
  101 CONTINUE
C
C...   FIND STARTING CLUSTER
C
      DO 103 I=1,M2
      JS=I
      IF (I2(I) .NE. 0) GO TO 20
  103 CONTINUE
      CALL EXIT
   20 NODE=IPAIR(1,JS)
C
C...   FIND LARGEST AND SMALLEST SIMILARITY COEF.
C
      XMIN=XLEV(1)
      XMAX=XMIN
      DO 104 I=1,M2
      IF (XLEV(I) .LT. XMIN) XMIN=XLEV(I)
      IF (XLEV(I) .GT. XMAX) XMAX=XLEV(I)
  104 CONTINUE
C
C      COMPARE RANGE OF XL/XR WITH ACTUAL RANGE NEEDED
      IF(ABS(XMAX-XMIN) .GT. ABS(XR-XL)) GO TO 9
C      ACTUAL RANGE < SPECIFIED RANGE SO 'STRETCH' TO FIT SPECIFIED RANG
      XMAX=AMAX1(XL,XR)
      XMIN=AMIN1(XL,XR)
    9 CONTINUE
      DX=(XMAX-XMIN)/25.0
      XMIN=XMIN-DX
      XMAX=XMAX+DX
      DX=(XMAX-XMIN)/60.0
      IF (ISIM .NE. 0) GO TO 21
      DX=-DX
      XMIN=XMAX
C
C...   BLANK OUT PRINT LINE ARRAY
C
C
   21 DO 105 I=1,61
      IOUT(I)=IBLNK
  105 CONTINUE
C
C...PRINT DENDROGRAM
C
      X=XMIN
      DO 106 I=1,13
      XX(I)=X
      X=X+DX*5.0
  106 CONTINUE
      WRITE (6,2000)(HEADER(INDX),INDX=1,13)
      WRITE (6,2001) (XX(I),I=2,12,2)
      WRITE (6,2002) (XX(I),I=1,13,2)
      WRITE (6,2003)
   22 X=XMIN
      IF (JS .NE. 0) X=XLEV(JS)
      IS=IFIX((X-XMIN)/DX)+1
      DO 110 I=IS,61
      IOUT(I)=ICM
  110 CONTINUE
      IOUT(IS)=ICP
      IF (JS .NE. 0) WRITE (6,2004) IOUT,NODE,X
      IF (JS .EQ. 0) WRITE (6,2004) IOUT,NODE
      IF (JS .EQ. 0) GO TO 31
      DO 111 I=IS,61
      IOUT(I)=IBLNK
  111 CONTINUE
      IOUT(IS)=ICI
      WRITE (6,2004) (IOUT(I),I=1,IS)
      NODE=IPAIR(2,JS)
      JS=I1(JS)
      GO TO 22
   31 WRITE (6,2003)
      WRITE (6,2002) (XX(I),I=1,13,2)
      WRITE (6,2001) (XX(I),I=2,12,2)
      WRITE (6,2005)
      RETURN
 2000 FORMAT ('1',13A6)
 2001 FORMAT (6X,6F10.4)
 2002 FORMAT (1X,7F10.4)
 2003 FORMAT (6X,'+',12('----+'))
 2004 FORMAT (6X,61A1,1X,I3,F10.4)
 2005 FORMAT (1H0,4X,'DENDROGRAM - ',1X,
```

```
     1 'VALUES ALONG X-AXIS ARE SIMILARITIES')
       END
C
C
C      SUBROUTINE TO CALCULATE THE MATRIX OF DISTANCE COEFFICIENTS
C      BETWEEN COLUMNS OF DATA MATRIX X
C
       SUBROUTINE DIST(X,N,M,N1,M1,A,M2,NORM)
       DIMENSION X(N1,M1),A(M2,M2)
C
C...   CALCULATE DISTANCE COEFFICIENT BETWEEN COLUMNS I AND J
C
       DO 100 I=1,M
       DO 100 J=1,M
C
       SUMSQ=0
       DO 101 K=1,N
       SUMSQ=SUMSQ+(X(K,I)-X(K,J))**2
  101  CONTINUE
C
C...   CALCULATE DISTANCE COEFFICIENT AND STORE IN MATRIX A
C
       IF(NORM .EQ. 1) SUMSQ=SUMSQ/N
       A(I,J)=SQRT(SUMSQ)
       A(J,I)=A(I,J)
  100  CONTINUE
       RETURN
       END
```

# APPENDIX C Recognition Task Instructions

## Cry recognition

### Instructions

A tape recording of 24 baby cries will be played to you, one cry at a time. These are the same cries you have just been listening to.

As soon as you have heard each cry you are to indicate whether the cry was one of birth, pleasure, hunger or pain. You should do this by circling the appropriate word. There is a five-second silence between each cry. You may do your circling during this time.

At the same time, please indicate how sure you are of your judgement by circling one of the numbers in the same row. Circling '1' would mean that you are NOT sure. whilst circling '5' would mean that you are VERY sure.

For example, if you were 'quite' sure that the cry was one of 'hunger', you might circle like this:

| | | | | not sure | | | | very sure |
|---|---|---|---|---|---|---|---|---|
| BIRTH | PLEASURE | (HUNGER) | PAIN | 1 | 2 | 3 | (4) | 5 |

The first three cries will be played as a trial run using the three practice scales at the top of the next page.

ANY QUESTIONS?

Cry recognition

Practice

| CRY | | | | | not sure | | | | very sure |
|---|---|---|---|---|---|---|---|---|---|
| 1 | birth | pleasure | hunger | pain | 1 | 2 | 3 | 4 | 5 |
| 2 | birth | pleasure | hunger | pain | 1 | 2 | 3 | 4 | 5 |
| 3 | birth | pleasure | hunger | pain | 1 | 2 | 3 | 4 | 5 |

Actual

| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| 1 | birth | pleasure | hunger | pain | 1 | 2 | 3 | 4 | 5 |
| 2 | birth | pleasure | hunger | pain | 1 | 2 | 3 | 4 | 5 |
| 3 | birth | pleasure | hunger | pain | 1 | 2 | 3 | 4 | 5 |
| 4 | birth | pleasure | hunger | pain | 1 | 2 | 3 | 4 | 5 |
| 5 | birth | pleasure | hunger | pain | 1 | 2 | 3 | 4 | 5 |
| 6 | birth | pleasure | hunger | pain | 1 | 2 | 3 | 4 | 5 |
| 7 | birth | pleasure | hunger | pain | 1 | 2 | 3 | 4 | 5 |
| 8 | birth | pleasure | hunger | pain | 1 | 2 | 3 | 4 | 5 |
| 9 | birth | pleasure | hunger | pain | 1 | 2 | 3 | 4 | 5 |
| 10 | birth | pleasure | hunger | pain | 1 | 2 | 3 | 4 | 5 |
| 11 | birth | pleasure | hunger | pain | 1 | 2 | 3 | 4 | 5 |
| 12 | birth | pleasure | hunger | pain | 1 | 2 | 3 | 4 | 5 |
| 13 | birth | pleasure | hunger | pain | 1 | 2 | 3 | 4 | 5 |
| 14 | birth | pleasure | hunger | pain | 1 | 2 | 3 | 4 | 5 |
| 15 | birth | pleasure | hunger | pain | 1 | 2 | 3 | 4 | 5 |
| 16 | birth | pleasure | hunger | pain | 1 | 2 | 3 | 4 | 5 |
| 17 | birth | pleasure | hunger | pain | 1 | 2 | 3 | 4 | 5 |
| 18 | birth | pleasure | hunger | pain | 1 | 2 | 3 | 4 | 5 |
| 19 | birth | pleasure | hunger | pain | 1 | 2 | 3 | 4 | 5 |
| 20 | birth | pleasure | hunger | pain | 1 | 2 | 3 | 4 | 5 |
| 21 | birth | pleasure | hunger | pain | 1 | 2 | 3 | 4 | 5 |
| 22 | birth | pleasure | hunger | pain | 1 | 2 | 3 | 4 | 5 |
| 23 | birth | pleasure | hunger | pain | 1 | 2 | 3 | 4 | 5 |
| 24 | birth | pleasure | hunger | pain | 1 | 2 | 3 | 4 | 5 |

APPENDIX D Cry Pair - Comparison Task Instructions

## INSTRUCTIONS

Thank you for agreeing to participate in this study.

The purpose of this study is to examine the similarities and differences of 24 baby cries. Each of the 24 cries has been paired with every other cry, to give 300 cry-pairs.

Your task is to compare the members of each cry-pair, and indicate on a corresponding five-point scale just how similar or different you consider the cries to be.
Very dissimilar cries should be assigned a rating of "1", while very similar cries should be assigned a rating of "5". The remaining scale values should be used for cries of intermediate similarity or dissimilarity. Just circle the appropriate number on the scale.

The cries in each cry-pair are separated by a two-second pause, and each cry-pair is followed by a seven-second pause during which you should rate their similarity or difference. After every tenth cry-pair there is a 10-second pause to enable you to check that you are still in step: IT IS MOST IMPORTANT that each cry-pair is rated on the scale assigned to it. Therefore, if you cannot decide how to rate a cry-pair in the time available, cross out that scale and carry on, using the next scale for the next cry-pair.

Before beginning the rating, the 24 cries will be played twice, then there will be a practice run with 10 cry-pairs.

Any questions?

| very dissimilar | | | | very similar |
|---|---|---|---|---|
| 1 | 2 | 3 | 4 | 5 |
| 1 | 2 | 3 | 4 | 5 |
| 1 | 2 | 3 | 4 | 5 |
| 1 | 2 | 3 | 4 | 5 |
| 1 | 2 | 3 | 4 | 5 |
| 1 | 2 | 3 | 4 | 5 |
| 1 | 2 | 3 | 4 | 5 |
| 1 | 2 | 3 | 4 | 5 |
| 1 | 2 | 3 | 4 | 5 |
| 1 | 2 | 3 | 4 | 5 |

| | | | | |
|---|---|---|---|---|
| 1 | 2 | 3 | 4 | 5 |
| 1 | 2 | 3 | 4 | 5 |
| 1 | 2 | 3 | 4 | 5 |
| 1 | 2 | 3 | 4 | 5 |
| 1 | 2 | 3 | 4 | 5 |
| 1 | 2 | 3 | 4 | 5 |
| 1 | 2 | 3 | 4 | 5 |
| 1 | 2 | 3 | 4 | 5 |
| 1 | 2 | 3 | 4 | 5 |
| 1 | 2 | 3 | 4 | 5 |

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