Multidimensional scaling of unfamiliar, complex sounds: Age and Context Effects

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In a series of experiments, multidimensional scaling was used to evaluate the encoding of complex sounds by school-aged children (6-11 years) and adults. Listeners rated the similarity of all possible pairs of sounds within a given set. The ratings were used to derive a multidimensional space in which the stimuli were represented as points and the axes represent the perceptual dimensions used in making the judgements. Using a computer procedure listeners heard pairs of sounds and were asked to place two computer images at a distance from one another that reflected their perceived similarity.

Experiment I. Age effects. The stimuli were 17, 430 ms signals including 3 pure tones (250, 1000, and 4000 Hz), 6 harmonic complexes consisting of the low (2-6), high (12-16) or wide (2-16) harmonics of either a 110 or 200 Hz fundamental, 2 AM noises (500 Hz and 2000 Hz noises, 12 dB modulation at 6 Hz), 2 FM tones (500 and 2000 Hz, frequency modulated at 10 Hz), 3 narrow band noises (centred at 500, 1000, and 2000 Hz) and 1 wide band noise (500-2000 Hz). Listeners were 10 children aged 6- to 7-years (mean: 7 yrs, 2 mos) 11 aged 10- to 11-years (mean: 10 yrs,7 mos) and 11 adults (mean: 26 yrs) with normal hearing.

A 3-dimensional space was derived for each age group using INDSCAL (Carrol & Chang, 1970). With increasing age the proportion of the variance accounted for increased. All listeners evaluated the sounds according to both spectral and temporal features but the relative weights assigned to each dimension, the integration of features, and the resolution along the dimensions varied with age. The adults grouped the stimuli into 3 groups representing the tones, noises, and harmonic complexes. Group formation was based on similarities in the first 2 dimensions reflecting temporal structure (number of components per critical band) and spectral shape (number of spectral peaks). Within each group the stimuli were ordered according to frequency which represented the third dimension. The 10-yr-olds formed similar stimulus groups but the groups were more loosely defined and the dimensions did not represent independent acoustic features of the sounds but a combination of both spectral and temporal cues. The 7-year-olds also showed an integration of spectral and temporal features in the individual dimensions and further showed less resolution in the temporal dimension, discriminating stimuli only on the basis of temporal fine structure but not envelope variations.

Experiment II. Stimulus range effects. Increasing the range of a features should increase its salience (e.g. Ashkenasy & Odom, 1982, JECP 34). Given that the adults weighted frequency as the 3rd most salient dimension in Exp. 1, its range was increased to test this hypothesis. Eight adult listeners (7 from Experiment 1) participated. Stimuli were 4 tones (250, 1000, 4000, and 6000 Hz), 6 harmonic complexes (F0=110 or 400 Hz and harmonics 2-6, 12-16 or 2-16), 3 noise bands (centre frequencies of 250, 1500, and 4000 Hz), 2 wide band noises (500-2000 Hz, and 200-4000 Hz), and 2 inharmonic complexes (5 randomly chosen from the 220-660 Hz and 4800-6400 Hz range). The 3-d solution no longer showed a clustering of stimuli as in Experiment 1. Increasing the frequency range increased its salience to dimension 1.

Experiment III. Stimulus distribution effects. It has also been suggested that salience will be determined by the diagnostic value of the feature reflecting the usefulness of the dimension for forming categories (e.g. Tversky, 1977, Psych. Rev. 84). To examine this hypothesis, four groups of adults were each asked to evaluate the similarity of a different stimulus set. Stimuli were complexes that varied either continuously or categorically in frequency and number of components. A low and a high frequency range were used that were adjacent to one another (continuous distribution) or separated by 3 critical bands (categorical distribution). The number of components was varied either continuously (1-9) or categorically (1-2 or 5-9). Results showed that the number of components overall was not a significant factor, but that the number of components per critical band (periodicity) was. When both frequency and periodicity varied continuously, the listeners' solution reflected a trend for categorization of stimuli based upon these two parameters. The clustering was enhanced when the parameters varied categorically. When only one parameter varied categorically, it received the highest salience and was used to classify the stimuli with stimuli evenly distributed along the dimension that was continuously sampled.