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CLASSIFICATION OF AMPLITUDE-MODULATED NOISE PATTERNS WITH EXTENDED PRACTICE

James H. Howard, Jr., and James A. Ballas

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Technical Report ONR-78-7

Human Performance Laboratory
Department of Psychology
The Catholic University of America

December, 1978

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Four listeners were given extended practice in an eight-category classification task (3072 trials). The stimuli were sixteen amplitude-modulated noise patterns that varied in modulation frequency (Tempo) and attack (Quality). Two listeners learned an eight-category partition that was based primarily on stimulus Quality, and two learned a partition that was based primarily on stimulus Tempo. The resulting confusion data were analyzed in terms of the aural classification model proposed by Howard, Ballas, and Burgy (1978). The theoretical analysis enabled us to

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specify the relative emphasis placed on the two stimulus features by each listener on each of the sixteen trial blocks. The results indicated that although large individual differences occurred, all listeners had more difficulty making use of the subtle stimulus differences along the Quality dimension than they did of differences along the Tempo dimension. Three of the four listeners placed a greater emphasis on Tempo than would be optimal. Although one listener only "discovered" the Quality dimension after 750 trials, very few changes occurred for any listener after 1000 trials. It was concluded that extensive practice alone is not likely to improve a listener's ability to use difficult features in aural classification. The role of sensory factors in limiting performance was considered.

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In a recent paper, Howard, Ballas, and Burgy (1978) presented a bottom-up model for the classification of complex, steady-state sounds. The model assumes that listeners undergo several steps in classifying a presented stimulus. First, an initial, low-level measurement representation of the stimulus is constructed by the peripheral auditory system. Second, these measurements are transformed by a feature extraction processor into a vector of higher-order feature elements. Third, a decision processor then estimates the perceptual distance between the stimulus and each of a set of category prototypes to determine the likelihood of each category given that stimulus. Finally, the stimulus is classified into the category having the greatest likelihood.

As in previous models of aural classification (Durlach & Braida, 1969), it is assumed that category likelihoods are represented by Gaussian density functions over the perceptual space. These likelihood functions may be estimated by fitting Gaussian distributions to confusion data obtained in a classification experiment. In the Howard et al model, the estimated variance parameters for the Gaussian distributions are particularly important. Unlike earlier classification models, one parameter is obtained for each dimension in the feature space. These parameters are analogous to uncertainty measures in that they describe the extent to which the categories overlap in the perceptual space.

Previous research with the model (Howard et al, 1978) has shown that listeners improve their classification peformance very quickly with practice, and that this improvement is reflected in a corresponding reduction in the estimated uncertainty parameters. The reduction was described as a fine tuning process that the listeners use to maximize the overall probability of correct classification. This tuning process is selective in that it emphasizes features that are important in the classification task, i.e., greater uncertainty reduction occurs for more relevant dimensions than for less relevant dimensions. However, Howard et al have noted that the tuning process does not continue as long as one would expect for optimal classification. In particular, there appeared to be an overall limit on the amount of uncertainty reduction that could occur. Since this limit could not be attributed to absolute sensitivity limitations, Howard et al (1978) argued that it was determined by a limit on the listener's overall information-processing capacity (e.g., Kahneman, 1973). Given this limit, it was concluded that the listener's feature tuning process apportioned his or her attentional effort between the two perceptual features so as to maximize the average probability correct.

The Howard et al (1978) findings have an alternative explanation which must be explored. It is possible that insufficient practice was provided in the experiment for listeners to fine-tune their sensitivity optimally on <u>both</u> stimulus dimensions. Their listeners peformed 720 classifications over three days which was not sufficient to conclude that asymptotic levels had been reached. In order to study the effects of additional practice, a classification experiment was conducted that provided extensive practice. The stimuli and experimental procedure were similar to those used in the previous study. Listeners were asked to classify sixteen amplitude modulated noise patterns into one of eight categories. The stimuli, which resembled a broad class of passive sonar signals, varied in both modulation frequency and attack. Howard et al (1978) have referred to the perceptual correlate of modulation frequency as sound Tempo, and the perceptual correlate of attack as sound Quality. Some listeners learned a category partition that was based primarily on signal Tempo (the Tempo group), and others learned a partition that was based primarily on signal Quality (the Quality group). The aural classification model was used to analyze and interpret the results.

Method

Participants. Four students were recruited by advertisement. Two students were assigned to the Tempo group and two to the Quality group. All four listeners, three females and one male, reported normal hearing. Their pay was determined by a schedule that encouraged high performance.

Apparatus. All experimental events were controlled by a laboratory digital computer. Modulation waveforms were synthesized by the computer and output on a 12-bit digital-to-analog converter at a 5 kHz sampling rate. This signal was applied to the input of a laboratory-constructed transconductance operational amplifier circuit (RCA CA3084). The output gain of the operational amplifier was directly proportional to the amplitude of the modulation signal. These amplitude-modulated signals were delivered to listeners over matched Telephonics TDH-49 headphones with MX-41/AR cushions.

Stimuli. A set of 16 amplitude-modulated noise signals was generated by combining four levels of modulation frequency (4, 4.8, 5.6, 6.4 Hz) and four levels of attack (43%, 57%, 71%, 86% of period). These sounds differed from those used by Howard et al both in modulation frequency and attack. The modulation frequency differences were made smaller in order to increase task demand and to prevent possible ceiling effects. The attack values were chosen to avoid rise times of 20-40 msec. According to Cutting and Rosner (1974), perception of rise times in this interval involves different processes than perception of rise times outside this interval.

The noise carrier was 20 Hz - 20 kHz white noise (B & K type 1402 Random Noise Generator). The modulated signals had sawtooth waveforms with the attack values indicated above. All signals were presented at about 65 dB SPL. As in the Howard et al (1978) study, two partitions of the 16 sounds into eight categories (two sounds per category) were constructed. In the Tempo partition, listeners were required to discriminate four levels of Tempo and only two of Quality (43% and 57% vs 71% and 86%). The second, Quality, partition required four levels of Quality discrimination and two of Tempo discrimination (4 and 4.8 Hz vs 5.6 and 6.4 Hz).

Procedure. The listeners were tested individually in a sound attenuated booth. They were told that their task was to learn to classify 16 sounds into eight categories, two sounds per category. No specific instructions were given about how Tempo and Quality were to be used. Each trial began with a visual warning followed by a 2.5 or 3 sec presentation of one of the sounds. The two signal durations occurred equally often and were included to discourage a simple "peak-counting" strategy. After the signal ended, the listener pressed one of eight keys (labeled with CVC nonsense trigrams of equal association value) to indicate the category for the sound. Feedback was provided after each trial.

All listeners received 192 trials in each of 16 blocks for a total of 3072 trials. This represents a substantial increase over the 720 trials used in our earlier study. Trials were randomized within each block. Listeners normally completed two consecutive blocks a day.

Results and Discussion

Overall performance. Generally, all four listeners achieved asymptotic performance within eight blocks (1536 trials) as may be seen in Figure 1.

Insert Figure 1 here

It is evident from this figure, however, that the four listeners differed widely in their final performance levels. For example, listener SG achieved a final level of 85% correct, whereas listener PD remained at approximately 25% correct throughout the entire experiment. Although in all cases listeners were classifying well above the 12.5% chance level, it is evident that listeners EK and PD had considerable difficulty in using both

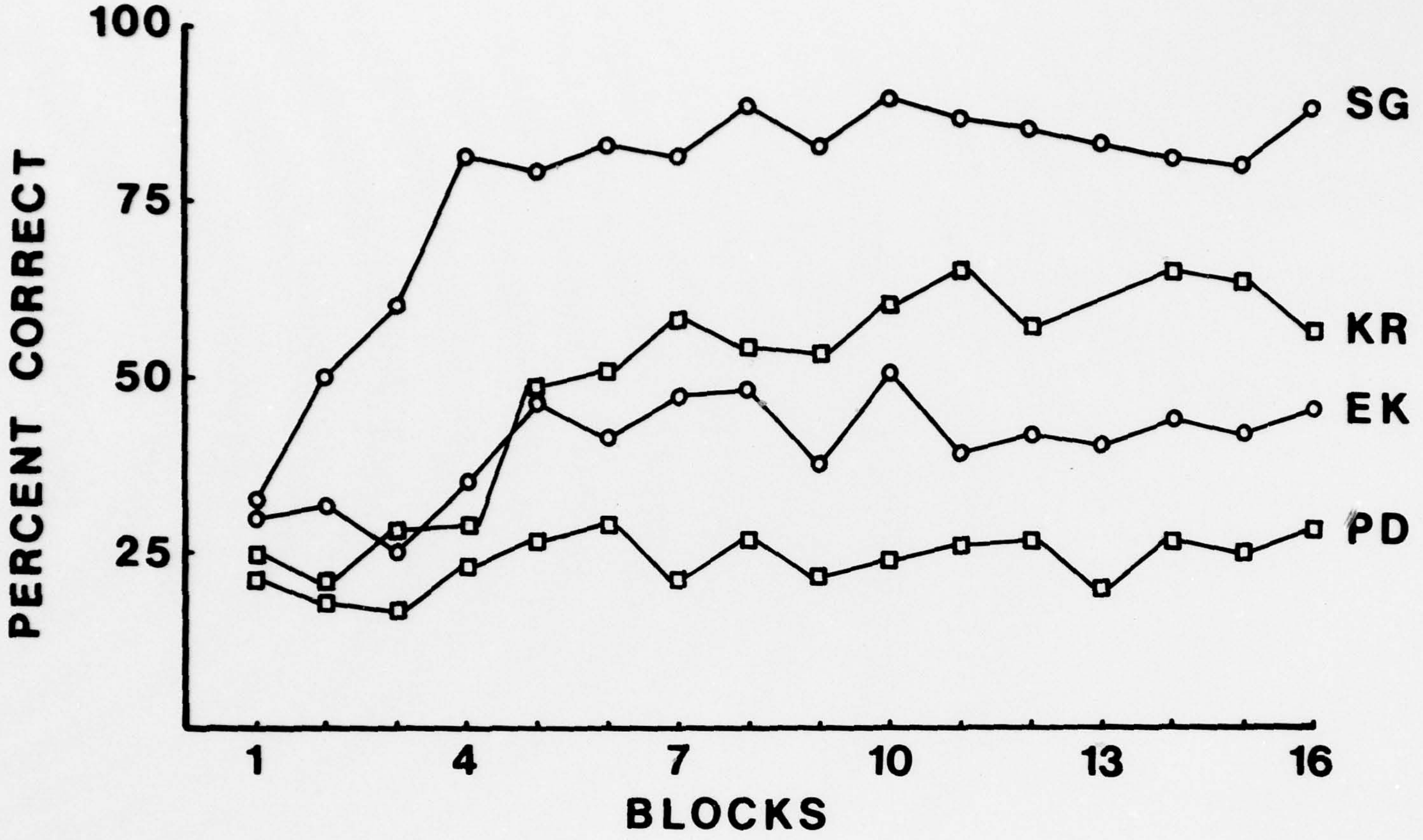

Figure 1. Overall percent correct by block for each of the four listeners.

dimensions. In particular, PD's 25% performance level suggests that he was totally insensitive to differences in signal Quality. Individual listener performance will be considered in more detail below.

The data also reveal higher overall performance levels for the Tempo partition than for the Quality partition (59% and 36% correct for the Tempo and Quality groups, respectively). Although this finding is consistent with the results reported by Howard et al (1978), in the present study even larger within group differences were observed.

Theoretical analysis. The Gaussian classification model was used to estimate theoretical confusion matrices for each listener on each block. The theoretical matrices were determined by selecting standard deviation parameters for each feature that minimized the discrepancy between the theoretical and observed matrices in a least squares sense. A standard, quasi-Newton gradient algorithm was used to perform the fits (subroutine ZXMIN in the IMSL statistical library). The reciprocals of the standard deviation parameters were used to estimate a subjective weight for each feature, and the two weights were summed to estimate the total attentional effort. The predicted confusion matrices were correlated with the observed matrices to judge the accuracy of the estimation. These correlations, averaged across blocks (using Fisher's z transformation), were .96, .89, .78 and .63 for listeners SG, EK, KR and PD, respectively. Thus, the fits ranged from very good for listener SG, to very poor for listener PD.

The estimated parameters for each listener are plotted as a function of block in Figures 2 to 5.

Insert Figures 2 - 5 here

Since the overall attentional effort is simply the sum of the Tempo and Quality weights, one can determine which feature a listener emphasized by comparing the Tempo weight to the total attentional effort parameter.

A question of primary interest in the present study concerns the long term stability of the listeners' overall attentional effort. In particular, does this parameter continue to increase after the 720 trials examined in the Howard et al (1978) experiment? To what extent do any increases beyond this point reflect additional tuning of the less important feature? An examination of Figures 2 - 5 reveals that with the exception of listener KR, relatively little improvement occurs after the fourth block (i.e., after 768 trials). However, since interesting individual differences exist, the data of each listener will be characterized in more detail.

Listener SG had the best overall performance. She improved consistently over the first four blocks as is evident in Figure 1. It is important to note, however, that her improved performance resulted from a fine-tuning of both the Tempo and Quality features. This is seen in Figure 2 in the initially diverging plots of the attentional effort and Tempo weight parameters. The more rapid increase in attentional effort

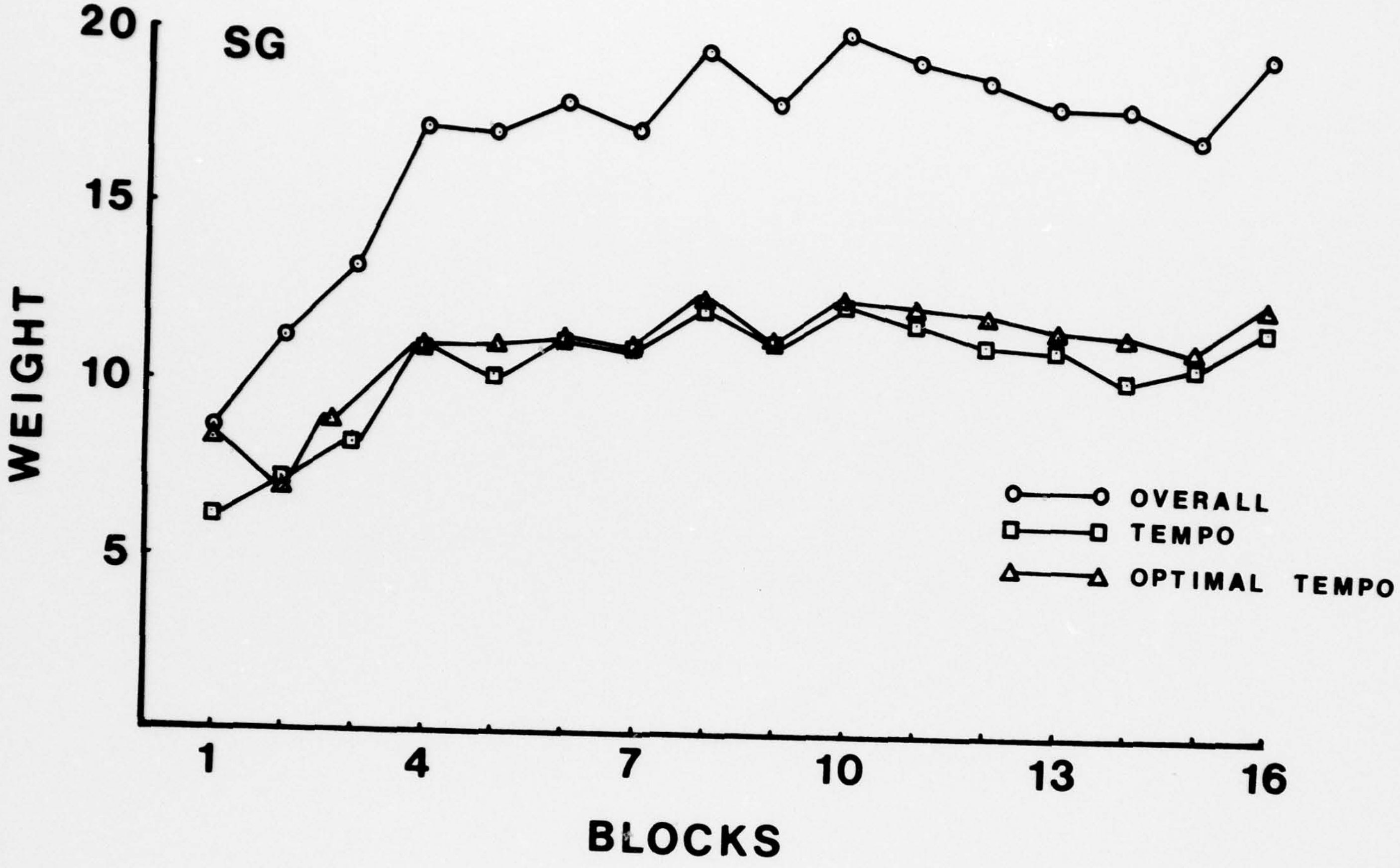

Figure 2. Obtained and optimal weight parameters by block for listener SG.

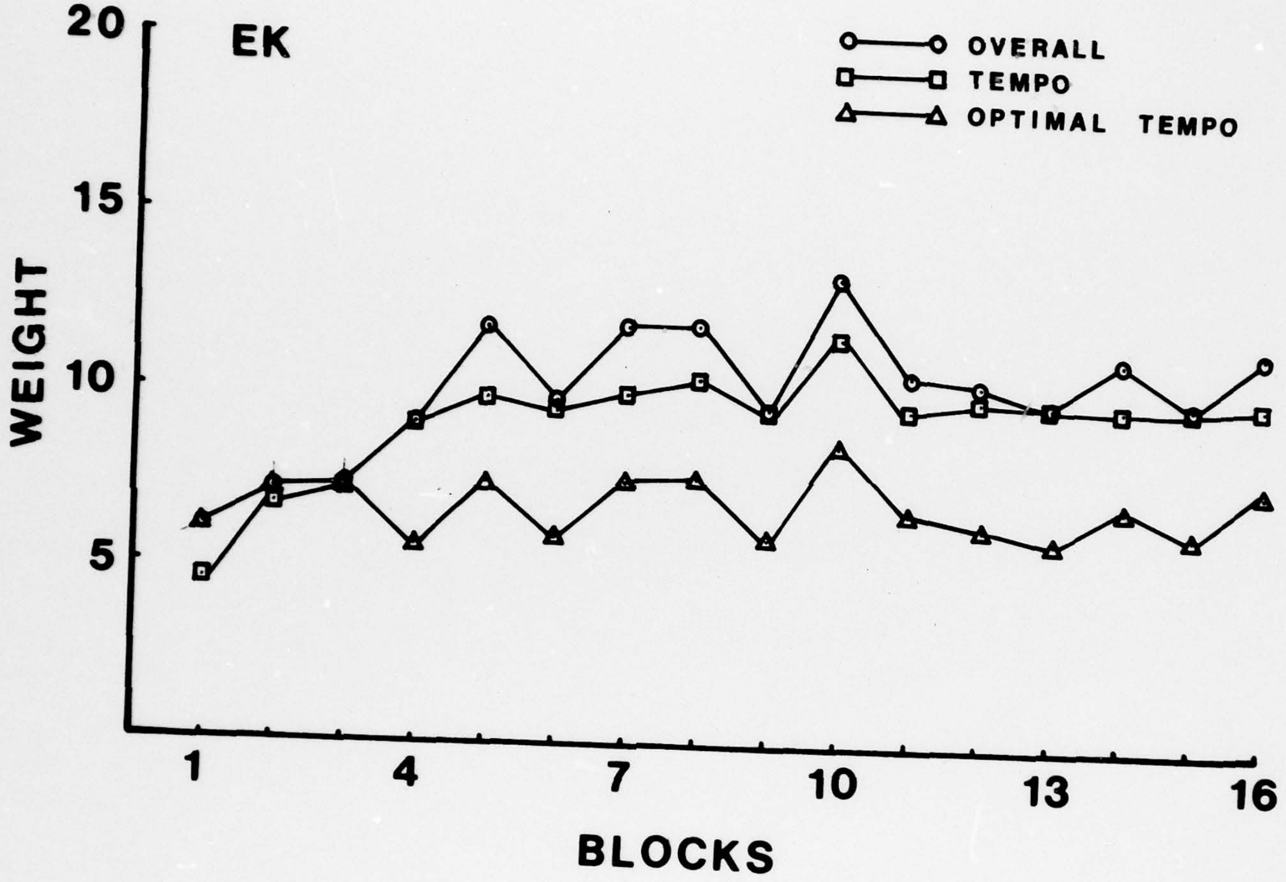

Figure 3. Obtained and optimal weight parameters by block for listener EK.

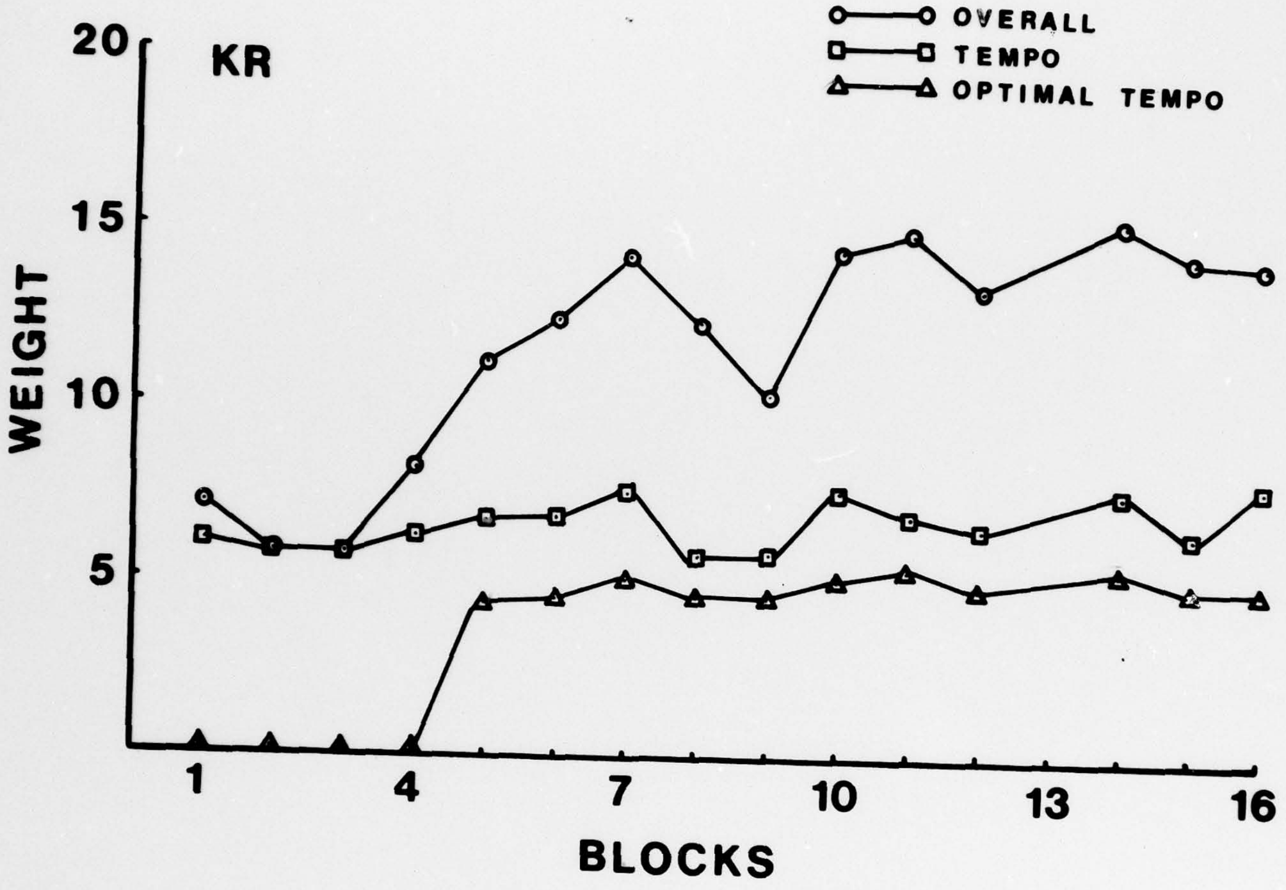

Figure 4. Obtained and optimal weight parameters by block for listener KR.

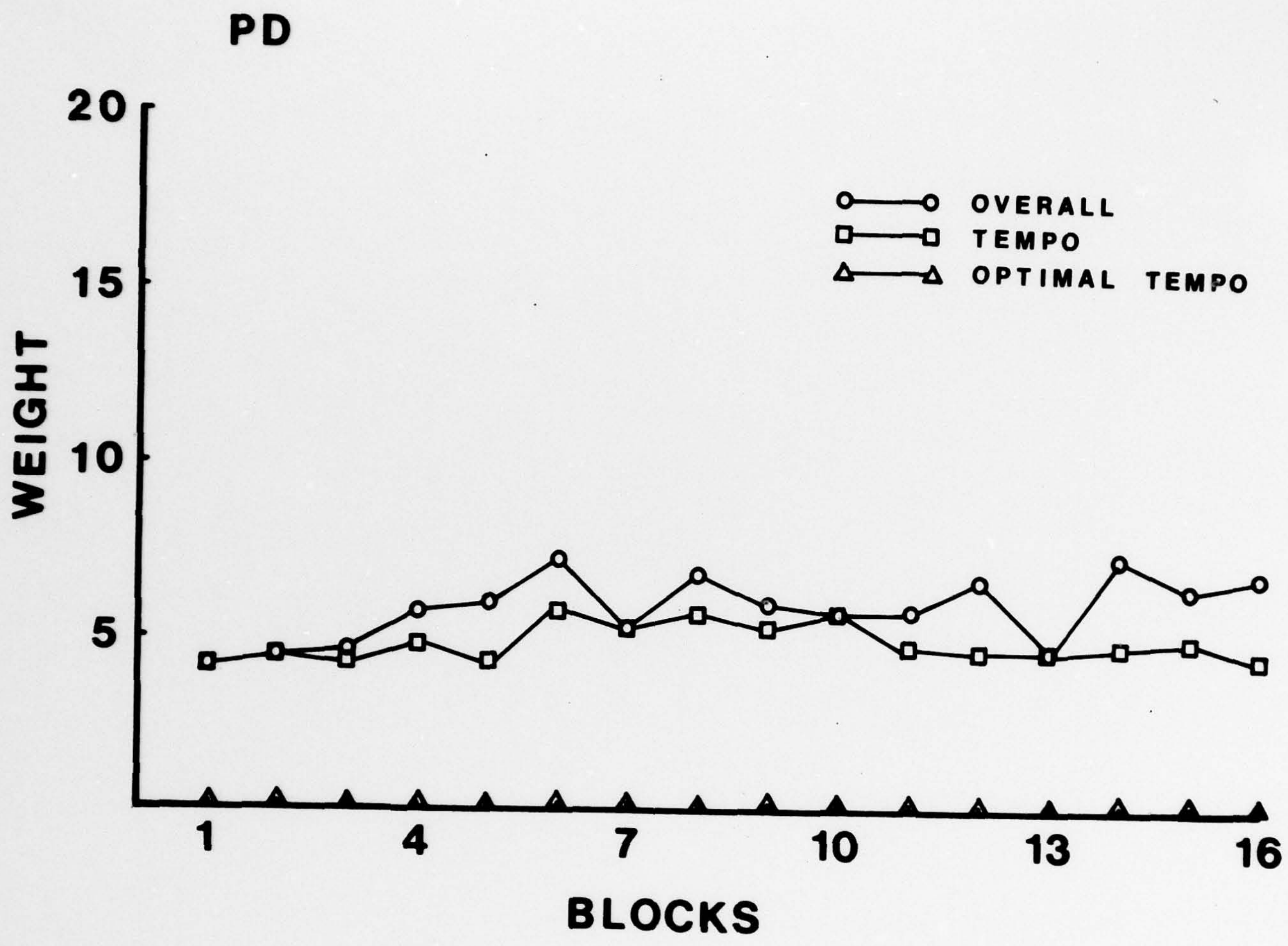

Figure 5. Obtained and optimal weight parameters by block for listener PD.

reveals that Quality, as well as Tempo, is becoming increasingly important. It is also interesting to note that this listener achieved a nearly optimal division of attention between the two features. Beyond the second trial block, her estimated Tempo weight is nearly identical to that required for optimal classification performance (a Tempo to Quality ratio of 60:40). The stability of the attentional effort and Tempo weight curves suggests that this listener was doing about as well as she could. This raises the possibility that sensory limitations contributed to the peformance ceiling observed in this case.

The second listener in the Tempo group, listener EK, achieved little improvement after the fifth block. In contrast to SG, EK concentrated almost exclusively on the Tempo dimension. This is clearly seen in the overlapping attentional effort and Tempo weight curves in Figure 3. It is important to note that an optimal allocation of attention in this case would result in a 60:40 split between the Tempo and Quality dimensions. Since EK generally allocated between 80% and 100% of her attention to the Tempo dimension, her 40% correct performance level fell well below that observed for listener SG. Of particular interest in this case, however, are several instances when EK increased her overall attentional effort by increasing her Quality weight. This occurred on blocks 5, 7, 8, 10, 14 and 16. On these occasions her performance improved, and her division of attention was more nearly optimal. This suggests that for EK, the performance ceiling reflected by the attentional effort parameter is not attributable to sensory limitations. It appears, rather, that this listener was able to distinguish important differences in signal quality, but did not do so in any consistent fashion. This interpretation is consistent with her post-experimental interview in which she expressed little awareness of signal Quality as an independent cue.

Although listener KR was the better of the two in the Quality group, she did not begin to improve significantly until the fifth block. The amount of overlap between the overall attentional effort and Tempo weight curves over the first three days for this listener (Figure 4) indicates that she initially concentrated almost exclusively on Tempo, the less important feature. At block 4, however, KR "discovered" the Quality dimension as is evidenced by the diverging overall effort and Tempo weight curves. From blocks 5 to 16, her attention was allocated primarily to the more important Quality dimension. The consistently higher peformance during this interval is obvious in Figure 1. Despite this, however, KR focused more attention on Tempo than would have been optimal (see Figure 4). This observation, together with the relatively stable performance after block 5, suggests that KR could not do any better with the Quality dimension. As in the case of listener SG, this implies that sensory factors are playing an important role in limiting her performance.

Listener PD showed little improvement during the experiment. Most of his effort was allocated to Tempo, the less relevant dimension. In fact, his 25% correct peformance level would be expected if he were accurately discriminating the two levels of

Tempo and responding randomly with regard to Quality. The slight fluctuations in performance that are observed in Figure 1 are attributable to small increments in the Quality weight since the Tempo weight remained constant over the 16 blocks. These observations were confirmed by PD's self-reported inability to distinguish the Quality differences. Since PD was familiar with the two-dimensional structure of the stimuli before beginning the experiment, his data clearly indicate a sensory limitation.

Summary and conclusions. The present findings clearly indicate that extended practice alone is not likely to lead to any significant improvements in a listener's ability to use less important, difficult signal features in aural classification. Although one listener (KR) only "discovered" the Quality dimension on block 4, very few changes occurred in the overall attentional effort parameter for any listener after block 5. The present findings also emphasize, however, that the "attentional effort" parameter reflects sensory as well as cognitive factors. Two of our listeners, EK and PD, found it extremely difficult to discriminate differences in signal Quality. On the other hand, listeners SG and KR could make use of this feature, albeit to a limited degree. There was no doubt, however, that Tempo was the easier of the two dimensions for all four listeners. Further research with Howard et al's (1978) aural classification model should address the issue of how sensory and cognitive factors contribute to the attentional effort parameter. Similar work along these lines by Gravetter and Lockhead (1973) suggests that such an approach may prove fruitful.

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References

Cutting, J.E. & Rosner, B.S. Categories and boundaries in speech and music. *Perception & Psychophysics*, 1974, *16*, 564-570.

Durlach, N.I. & Braida, L.D. Intensity peception I. Preliminary theory of intensity resolution. *Journal of the Acoustical Society of America*, 1969, *46*, 372-383.

Gravetter, F. & Lockhead, G.R. Criterial range as a frame of reference for stimulus judgment. *Psychological Review*, 1973, *80*, 203-216.

Howard, J.H., Jr., Ballas, J.A., & Burgy, D.C. Feature extraction and decision processes in the classification of amplitude-modulated noise patterns (Technical Report ONR-78-4). Washington, D.C.: The Catholic University of America Human Performance Laboratory, July, 1978.

Kahneman, D. *Attention and effort*, New York: Prentice Hall, 1973.

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