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GENERALITY OF INTERFERENCE BY TONAL STIMULI IN RECOGNITION MEMORY FOR PITCH

DIANA DEUTSCH

Center for Human Information Processing, University of California, San Diego, U.S.A.

An investigation was made into the disruptive effects on pitch recognition produced by tones taken from beyond the octave from which the standard (S) and comparison (C) tones were taken. Pitch recognition was required after a retention interval during which eight other tones were played. Errors were compared for sequences in which the interpolated tones were taken from the same octave as were the S and C tones; in which they were taken from the octave above; in which they were taken from the octave below; and in which half of the intervening tones were taken from the octave above and the other half from the octave below, the order of choice of octave within the sequence being random. Large disruptive effects were produced by interpolated tones drawn from the higher and lower octaves, though these effects were slightly less than those produced by tones drawn from the same octave. The greatest disruptive effect occurred when the intervening tones in any one sequence were drawn from both the higher and the lower octaves. The implications of these findings are discussed.

Introduction

Pitch recognition declines slowly over a silent retention interval (Koester, 1945; Harris, 1952; Bachem, 1954). However, if a sequence of tones is interpolated during this period, considerable disruption in pitch recognition is produced (Deutsch, 1970*a*), even though the subjects are instructed to ignore the intervening tones. This large interference effect appears to be due specifically to the interpolation of tones, since the interpolation by comparison of numbers spoken at equal loudness produces only a minimal decrement in the identical pitch recognition task. The decrement due to interpolated spoken numbers continues to be minimal even when the subjects are required also to recall the numbers. It can be concluded that memory for the pitch of a musical tone is subject to a large interference effect produced by other tones.

A question which arises from the above finding concerns the generality of this interference effect within the range of tonal stimuli. In the study reported by Deutsch (1970*a*) the tones in the interpolated sequence were all taken from the same octave as were the standard (S) and comparison (C) tones; and the effects of including interpolated tones taken from outside this octave range were not investigated. In other experiments, various highly specific interactive effects have been

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demonstrated in memory for pitch. For instance, if there is included in the interpolated tonal sequence a tone of the same pitch as the S tone, memory facilitation is produced (Deutsch, 1970*b*, 1972*a*). This is true both when the S and C tones are identical in pitch and also when they differ. Further, when the S and C tones differ in pitch, including in the intervening sequence a tone at the pitch of the C tone produces a substantial increment in errors (Deutsch, 1970*b*, 1972*a*). In addition, both when the S and C tones are identical in pitch and also when they differ, including in the interpolated sequence a tone which is a semitone removed from the S tone produces an increment in errors (Deutsch, 1973). This latter disruptive effect, however, is significantly less pronounced than the former. Further, it is possible to map in intervals of 1/6 tone separation both facilitatory and disruptive effects on pitch memory as a function of the pitch relationship between the S tone and the critical intervening tone (Deutsch, 1972*b*). These interactive effects appear to return to baseline at approximately a whole tone separation in the equal-tempered scale.

The highly specific phenomena outlined above might lead one to suspect that disruptive effects in pitch memory gradually trail off as the distance between the S tone and the critical intervening tone becomes more remote, and should disappear before the distance of an octave is reached. On the other hand, in the study first quoted (Deutsch, 1970*a*), the interpolated tones were chosen at random from within a whole octave's range. Since a large disruptive effect was obtained under these conditions, it would appear that some powerful interference effect operates throughout this region. The question therefore arises as to whether such interference also takes place with interpolated tones taken from beyond the octave from which the S and C tones are taken. The present experiment was designed to explore this question.

Method

Procedure

The following procedure was used. In all experimental conditions, subjects listened to an S tone, which was followed by eight intervening tones and then, after a pause, by a C tone. They were told to attempt to remember the S tone, to ignore the eight intervening tones, and then to judge whether or not the C tone was the same in pitch as the S tone. Subjects recorded their judgements by writing "S" (same) or "D" (different) on paper. The duration of all the tones was 200 ms. The interval between the S tone and the first intervening tone was 300 ms, as were the intervals between the intervening tones. A 2-s pause was incorporated between the last intervening tone and the C tone. All tones were adjusted to be equal in loudness as judged by the subjects.

Conditions

There were four conditions in the experiment. In Condition S, the tones in the intervening sequence were taken from the same octave as were the S and C tones. In Condition H, they were taken from the octave above. In Condition L, they were taken from the octave below. In Condition HL, half of the tones in each intervening sequence were taken from the octave above, and the other half were taken from the octave below, the order of choice of octave being random.

Each condition consisted of twelve sequences, in half of which the S and C tones were identical in pitch, and in the other half of which they differed by a semitone. Within each condition, when the S and C tones differed, in half of the instances the S tone was higher than the C tone; and in the other half it was lower.

The entire tape consisted of 48 sequences, which were presented in four groups of 12. Sequences within each group of 12 were separated by 10-s pauses, and there were 2-min pauses between the groups. The sequences were presented in random order, with no separation by condition, except for the following restrictions. First, each group of 12 sequences contained six in which the S and C tones were the same and six in which they were different, in order to minimize the development of response biases. Second, each group of 12 sequences contained the same set of combinations of S and C tones (see below) so as to minimize repetition effects. Subjects listened to the tape on two separate days, for which the results were averaged.

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S and C tones

The S and C tones were taken from an equal-tempered scale (international pitch: A = 435 Hz) and they ranged from the C♯ above middle C to the C an octave above. The frequencies employed (in Hz) were therefore: C♯ = 274; D = 290; D♯ = 308; E = 326; F = 345, F♯ = 366, G = 388, G♯ = 411, A = 435; A♯ = 461; B = 488; and C = 517. The same S and C tone combinations were used in all conditions.

Intervening tones

The intervening tonal pitches were taken from the scale described above, and spanned a three-octave range from the C below middle C to the B almost two octaves above. The frequencies employed (Hz) were therefore: C = 129; C♯ = 137; D = 145; D♯ = 154; E = 163; F = 173; F♯ = 183; G = 194; G♯ = 205; A = 218; A♯ = 230; B = 244; C = 259; C♯ = 274; D = 290; D♯ = 308; E = 326; F = 345; F♯ = 366; G = 388; G♯ = 411; A = 435; A♯ = 461; B = 488; C = 517; C♯ = 548; D = 581; D♯ = 615; E = 652; F = 691; F♯ = 732; G = 775; G♯ = 821; A = 870; A♯ = 923; and B = 977.

No sequence contained a tone of the same pitch as the S or C tone of that sequence, or a tone that was separated by exactly an octave from either of these. Further, no sequence included more than one example of any one tonal pitch, neither did it include any tones which were separated by exactly one octave. Apart from these restrictions and those specified in the Conditions Section, the intervening tonal pitches were chosen randomly from the set designated above.

Subjects

Twenty undergraduates at the University of California at San Diego served as subjects for this experiment. These were selected on the basis of obtaining a score of 100% correct (Selection Condition) on a tape containing the same 12 pairs of S and C tones as were employed in each experimental condition. All S and C tones were separated by blank retention intervals of 6-s duration. When the S and C tones differed in pitch this was always by a semitone (between 15 and 29 Hz in the range employed here), so the required discrimination was well above threshold given the 6-s retention interval (Harris, 1952). Errors on the selection task were therefore due either to an abnormally high threshold, or to a general inaccuracy in performance. The subjects in this experiment were therefore broadly representative of the general population.

Apparatus

The tones were generated by a Wavetek oscillator which was controlled by a PDP9 computer. The output was recorded on high-fidelity tape. The tape was played to subjects on a high-quality Wollensack tape recorder, the output of which was passed through a frequency balance control (Advent Corp.) and a Fisher stereo master control amplifier, with the controls adjusted so that the tones were judged by the subjects to be equal in apparent loudness. The output was played to the subjects through high-quality KLH loudspeakers.

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Results

The results of this experiment are shown in Figure 1. It can be seen that large disruptive effects on tone recognition were produced by interpolated tones in each of the experimental conditions. Errors rose from 0% in the selection condition (silent retention intervals) to 33·5% in condition S; 28·1% in condition H; 25·6% in condition L; and 38·3% in condition HL. Further, a Friedman test comparing errors in conditions S, H, L, and HL displayed an overall effect of varying the intervening tonal pitches ($\chi_r^2 = 10{\cdot}68$, $df = 3$, $P < 0{\cdot}02$). Further analysis showed a significant difference in performance between conditions S and L ($P < 0{\cdot}05$, two-tailed on a Wilcoxon test), but no significant difference between conditions S and H, or between conditions H and L ($P > 0{\cdot}05$, two-tailed, on a Wilcoxon test in both cases). Highly significant differences in performance were found between both conditions H and HL, and conditions L and HL ($P < 0{\cdot}01$, two-tailed, on a Wilcoxon test for both comparisons). However, there was no significant difference between conditions S and HL ($P > 0{\cdot}05$, two-tailed, on a Wilcoxon test).

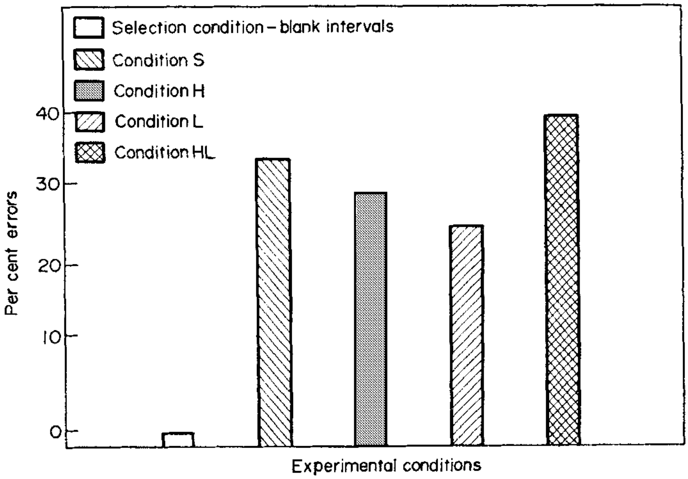

FIGURE 1. Percentage errors in the different conditions of the experiment. Subjects ($n = 20$) were selected on the basis of obtaining a score of 0% errors in the selection condition.

Discussion

The above findings demonstrate that interference in memory for tonal pitch may be produced by a relatively wide range of tonal stimuli. The subjects were selected for displaying an errorless performance in comparing the same S and C tones as were employed in each of the experimental conditions; and these tones were separated by retention intervals of identical duration. The errors obtained in the different conditions are therefore directly attributable to the effect of the intervening tones. This substantial performance decrement contrasts sharply with the

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minimal decrement displayed by subjects when the interpolated stimuli are spoken numbers (Deutsch, 1970*a*).

The generality of interference displayed here stands in contrast to the highly specific disruptive effects demonstrated in other studies employing highly selected subjects (Deutsch, 1972*a*,*b*; Deutsch, 1973). This raises the question of the relationship between the general and specific findings. Direct comparison is very difficult, as the subjects in the two types of experiment were of necessity selected by different criteria. The use of subjects with a virtually errorless baseline performance in the presence of interpolated tones was necessary for the accurate plotting of specific interference effects. However, such a selection procedure would be clearly inappropriate in a study searching for the overall presence of general disruptive effects. It might be suggested, however, that errors produced by tones taken from a different octave are due to a generalization of specific interference effects from one octave to another. That is, interference could be taking place along the dimension of "tone chroma" (Meyer, 1904, 1914; Révész, 1913; Ruckmick, 1929; Bachem, 1948; Shepard, 1964). Alternatively, disruption from other octaves could be based on a simple, nonspecific interference effect operating along the "tone height" dimension. Both these views may be correct, and interference in memory for the pitch of a tone may be due to a variety of factors. Indeed, two separable types of interference have been shown to be produced by tones which are only a semitone removed from the S tone (Deutsch, 1973). Possible specific effects produced by tones separated from the S tone by more than a whole tone but less than an octave have not yet been explored. It would not, therefore, be implausible to assume that disruption produced by the wide range of tonal stimuli employed in this experiment has a complex basis.

Several explanations may be suggested for the weaker interference produced by the lower tones in this experiment. There may be a relatively weak generalization of interference from the lower octave along the "tone height" dimension, or there may be a relatively weak projection from the lower octave onto a "tone chroma" continuum. Alternatively, one may suggest that the lower tones do not compel the attention as well as do the higher tones, and that they are for this reason less disruptive.

It might appear paradoxical that a group of interpolated tones drawn from the same two octaves (i.e. the higher and the lower octaves), should produce different amounts of interference simply depending upon whether they are at any one time drawn from the same octave, or whether their order of presentation is random (conditions H and L compared with condition HL). One might suggest that if the subject knows from what part of the pitch range an intervening tone is about to emanate, he can in some way "filter out" the information coming from that part of the pitch range and so reduce the amount of interference. Alternatively, one may suggest the following hypothesis. When we listen to a sequence of tones, we process not only the individual tones themselves, but also the relationship between them, i.e. the melody. By storing these relationships in memory we should theoretically be able (by working backward) to reconstruct the pitch of the S tone. It is clear that the subjects do not do this to perfection, for otherwise they would always score 100% correct on a tone comparison task such as that employed in the present study. However, the subjects might well be making use of such a process. Now the general study of music would lead one to doubt if much effective use could be made of successive musical intervals if these were large in size. In a previous article (Deutsch, 1972*c*) it was shown that the first half of the tune *Yankee Doodle* was not recognized when its component notes were drawn randomly from any of three octaves, instead of staying in the same octave. It is suggested, therefore, that the greater error rate experienced in condition HL is due to the fact that since the tones in the interpolated sequence bounce back and forth between two octaves (which are themselves separated by an intervening octave) much less use can be made of the successive musical intervals than in the other conditions, in which the intervening tones in any one sequence stay within a single octave.

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