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INTERFERENCE IN PITCH MEMORY AS A FUNCTION OF EAR OF INPUT

DIANA DEUTSCH

*Center for Human Processing, University of California, San Diego,
La Jolla, California 92093, U.S.A.*

An experiment was conducted to investigate the effect of spatial separation on interference effects in pitch memory. Subjects compared the pitches of two tones that were separated by a sequence of eight interpolated tones. It was found that error rates were lower in sequences where the test and interpolated tones were presented to different ears, compared with sequences where they were presented to the same ear; however, this effect of spatial separation was not large. It is concluded that differences in spatial location can enable the focusing of attention away from the irrelevant tones and so reduce their disruptive effect, but that this occurs only to a limited extent.

Introduction

When subjects make pitch recognition judgments between two temporally separated tones, the interpolation of an extra sequence of tones during the retention interval produces a substantial decrement in performance. This decrement occurs even when the subjects are told to ignore the intervening tones. Further, if a sequence of spoken digits is interpolated instead, the resultant performance decrement is minimal, even when the subjects are required to focus their attention on these digits (Deutsch, 1970). Such findings raise the possibility that pitch recognition performance under these conditions may be uninfluenced by attentional factors. This hypothesis is strengthened by the results of various studies on the effects of attention on simple auditory processing tasks. Sorkin, Pastore and Pohlmann (1972), Sorkin, Pohlmann and Gilliom (1973), Pastore and Sorkin (1972) and Sorkin and Pohlmann (1973) have found that the detection of an auditory signal which may be presented to either ear is generally unaffected by whether or not attention is focussed on that ear. Analogous findings have been obtained in the visual mode (Shiffrin and Gardner, 1972; Shiffrin, Gardner and Allmeyer, 1973; Gardner, 1973) and the somatosensory mode (Shiffrin, Craig and Cohen, 1973).

The present paradigm, however, involves memory*; and, as Shiffrin (1975) has argued, attentional factors may become important at this level. An experiment was therefore undertaken to determine whether, in the present experimental situation, the channelling of the interpolated tones to a different spatial location might reduce their interference effect. Such a result would be expected if spatial channelling enabled a focusing of attention away from the interpolated tones, and if attentional effects do indeed operate here.

Method

Procedure

Subjects listened to test tone, which was followed by a sequence of eight interpolated tones, and then after a pause, by a second test tone. They were instructed to listen to the first test tone, to ignore the eight interpolated tones, and then to judge whether the second test tone was the same in pitch as the first, or different. They indicated their judgments by writing "S" (Same) or "D" (Different) on paper.

Tonal stimuli

All tones were 200 ms in duration. The pause between the first test tone and the first interpolated tone was always 300 ms, and the interpolated tones were all separated by 300 ms pauses. The pause between the last interpolated tone and the second test tone was 2000 ms.

All tones were taken from an equal tempered scale (International Pitch; A = 435) and ranged from the C# above Middle C to the C an octave above. The frequencies employed (in Hz) were C# = 274; D = 290; D# = 308; E = 326; F = 345; F# = 366; G = 388; G# = 411; A = 435; A# = 461; B = 488; and C = 516. All these frequencies were employed equally often in all conditions, both as test tones and also as interpolated tones. In all conditions, in half of the sequences the first and second test tones were identical in pitch, and in the other half they differed by a semitone. In half of the sequences where the test tones differed, the second test tone was higher than the first, and in the other half the second test tone was lower than the first. The intervening tones were chosen at random from the fre-

* One might argue for an alternative explanation of these interference effects in terms of perception rather than memory. That is, it might be suggested that the interpolated tones here disrupt performance, not by interfering with memory, but rather by disrupting the perceptual encoding of the second test tone. Evidence against this view comes from a recent experiment (in preparation). In all conditions of the experiment a test tone was presented, followed by six interpolated tones, and then by a second test tone. All tones were 200 ms in duration and separated by 300 ms pauses, except as specified by the experimental condition. In condition 1 the pause following the first test tone was 300 ms, and the pause preceding the second test tone was 2000 ms. In condition 2 the pause following the first test tone was 6300 ms, and the pause preceding the second test tone was again 2000 ms. And in condition 3 the pause following the first test tone was 300 ms, and the pause preceding the second test tone was 8000 ms. Thus an identical retention interval separated the two test tones in conditions 2 and 3. However, in condition 2 the interpolated tones occurred late during this time period, and in condition 3 they occurred early.

According to the perceptual encoding hypothesis, the lowest error rate would be predicted to occur in condition 3, where a long blank interval is interposed before the second test tone. However, the error rate here was significantly *higher* than in either conditions 1 or 2. Further, the error rate in condition 2, where a long blank interval was interposed before presentation of the interpolated tones, was lower than in either conditions 1 or 3. It is concluded that the interpolated tones act to degrade a memory trace, which becomes less vulnerable if a blank interval occurs before these interfering stimuli are presented.

quencies listed above, except that no intervening sequence contained repeated tones or tones of the same pitch as either of the test tones. All tones were equal in amplitude.

Apparatus

Tones were generated by two Wavetek oscillators controlled by a PDP-8 computer, and the output was recorded on high fidelity tape. The tape was played to subjects on a high quality tape recorder through earphones at a level of 75 dB SPL at each ear.

Conditions

There were four conditions in the experiment. In condition RR, both the test tones and the intervening tones were presented to the right ear. In condition LL they were both presented to the left ear. In condition RL the test tones were presented to the right ear and the intervening tones to the left. And in condition LR the test tones were presented to the left ear and the intervening tones to the right.

There were 24 sequences in each condition, making 96 sequences in all. The sequences were presented in groups of twelve, with 10 s pauses between sequences within a group, and 2-min pauses between groups. The order of presentation of the sequences was random with respect to condition. However, no two adjacent sequences contained test tones of the same pitch, so that repetition effects would be minimized.

Each subject heard the tape twice on separate days, with earphones positioned differently on each day. Thus a sequence which was in the RR condition on the first day was in the LL condition on the second day and vice versa. Similarly, a sequence that was in the RL condition on the first day was in the LR condition on the second day, and vice versa. The order of earphone placement was strictly counterbalanced across subjects.

Subjects

Eighteen undergraduates at the University of California at San Diego served as subjects in this experiment. They were all righthanded and had normal hearing in both ears. They were further selected on the basis of obtaining a score of at least 80% correct on a short tape containing sequences designed as in this experiment, but presented through a single loudspeaker instead of earphones.

Results

The results of the experiment are plotted on Figure 1. It can be seen that error rates were indeed lower in sequences where the test and intervening tones were presented to different ears, compared with sequences where they were presented to the same

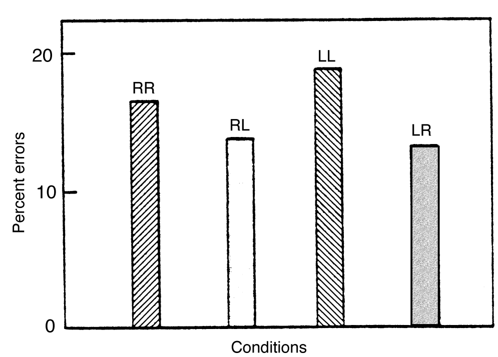

Figure 1. Percentage errors in the different conditions of the experiment.

ear. This difference was statistically significant when the test tones were presented to the right ear (conditions RR vs. RL; $P < 0.05$, two-tailed on a Wilcoxon test) and also when they were presented to the left ear (conditions LL vs. LR; $P < 0.01$, two-tailed on a Wilcoxon test).

There were no significant differences in error rate depending on ear of input, either when the test and intervening tones were presented to the same ear, or when they were presented to different ears (conditions RR vs. LL; conditions RL vs. LR; $P > 0.05$, two-tailed, on Wilcoxon tests, in both cases.

Discussion

It must be concluded from this experiment that disruptive interactions between tones in memory can be reduced by channelling the irrelevant information to a different spatial location. It is hypothesized that this effect operates by enabling the subject to focus attention away from the interpolated tones. This is interesting, however, since in all conditions of the experiment the subjects are asked to ignore the interpolated tones; and there is always a clear and distinct temporal separation between the interpolated tones and the test tones. Thus this effect of spatial separation does not operate by helping to unscramble the relevant from the irrelevant information at a perceptual level, as is the case with certain simultaneously presented auditory materials (Moray, 1969). Rather, the effect acts on elements which are clearly separated in time, and where the task itself imposes only minimal processing load. So it appears that an attention-focusing mechanism acts over time to produce a perceptual integration of the successive tones; and that inhibitory interactions result from this perceptual integration.

The present findings form an interesting analogy with those obtained by Morton, Crowder and Prussin (1972) on the suffix effect. When subjects are required to recall a sequence of acoustically presented digits, there is generally an advantage for the terminal digit in the sequence. However, when a redundant suffix, which the subject is not required to recall, is added to the end of the sequence, there results a considerable disruption of this recency effect (Crowder and Morton, 1969). Morton *et al.* (1971) found that when the test sequence and the suffix were presented to the same ear, the suffix effect was greater than when they were presented to different ears, or when a binaural suffix followed a monaural stimulus list. However, a significant suffix effect was obtained under all conditions. The authors also interpret these findings in terms of an attention focusing mechanism. In support of their interpretation they found that this effect of spatial location was reduced if the subjects were required to pay attention to the suffix; or if they were uncertain as to where it would be coming from.

A further interesting point of similarity between the findings from the present paradigm and the suffix effect concerns the interactions between different types of stimulus material. Just as interpolating spoken digits produces only a minimal interference effect on recognition of the pitch of a tone (Deutsch, 1970) so presenting a nonspeech stimulus at the end of a sequence of digits does not produce a suffix effect (Morton *et al.*, 1971). In both cases, the effect of presenting different types of stimulus material is considerably stronger than the effect of presenting the interfering stimuli to different spatial locations. Thus differences in spatial location can enable the focusing of attention away from interfering stimuli under such sequential conditions, but only to a limited extent.

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