Journal of Experimental Psychology
1973, Vol. 100, No. 2, 228–231

INTERFERENCE IN MEMORY BETWEEN TONES ADJACENT IN THE MUSICAL SCALE[1]

DIANA DEUTSCH[2]

University of California, San Diego

Pitch recognition was required after a 4-sec. delay during which 4 other tones were played. When the standard (S) and comparison (C) tones were identical in pitch, the inclusion of a tone in the intervening sequence that was a semitone higher or lower than the S tone produced an increase in errors. Including tones both a semitone higher and a semitone lower in the same intervening sequence produced a further increase in errors. Analogous results were obtained when the S and C tones differed in pitch. However, when the critical intervening tone was identical in pitch to the C tone, errors were further increased.

This paper is concerned with interference effects in memory between tones of similar pitch. Studies of long-term verbal memory have repeatedly demonstrated similarity-based interference. However, the existence of such effects in short-term verbal memory has been the subject of considerable controversy (Brown, 1958; Conrad, 1964; Wickelgren, 1965). It has been shown that short-term recognition memory for tonal pitch is subject to interference produced specifically by the interpolation of tones in the retention interval and not by the interpolation of numbers presented acoustically at equal loudness (Deutsch, 1970). Since tones are more similar acoustically to each other than they are to spoken numbers, this finding demonstrates a general effect of similarity. A more specific effect has also been found in a study in which pitch recognition was required after an interval during which other tones were played (Deutsch, 1972a). The standard (S) and comparison (C) tones were either identical in pitch or differed by a semitone. It was found that when S and C tones differed in pitch, the inclusion of a tone at the pitch of the C tone in the interpolated sequence produced an increment in errors. It was hypothesized that this effect was due to loss of order information, i.e., *S* recognized correctly that the tone had occurred, but assumed incorrectly that it was the S tone. This effect has recently been mapped in detail (Deutsch, 1972b) as a function of the difference in pitch between the S tone and the critical interpolated tone. In that experiment, a function of similar shape but lesser magnitude was also demonstrated for those sequences in which the S and C tones were identical in pitch. It is not clear from the experiment, however, whether the increased errors occurring when the S and C tones were identical in pitch were based on an independent disruptive effect or were due to an artifact of the experimental design. A further unanswered question concerns the effect of placing in the intervening sequence a tone that is a semitone removed from the S tone, but on the opposite side of the pitch continuum from the C tone, when the S and C tones differ in pitch. The following 2 experiments represent a systematic investigation into the effects on recognition and discrimination of tonal pitch of including in an intervening tonal sequence a tone that is a semitone removed from the S tone.

EXPERIMENT I

Method

Procedure. In all experimental conditions *Ss* listened to an S tone, which was followed by 4 intervening tones and then by a C tone. They were asked to remember the S tone, to ignore the 4 intervening tones, and then to judge whether or not

[1] This work was supported by U.S. Public Health Service Grant MH-21001-01 from the National Institute of Mental Health and by Grant 655 from the University of California, San Diego Academic Senate.

[2] Requests for reprints should be sent to Diana Deutsch, Department of Psychology, University of California, San Diego, P.O. Box 109, La Jolla, California 92037.

the C tone was the same in pitch as the S tone. All tones were 200 msec. in duration. The interval between the S tone and the first intervening tone was 300 msec., and the intervals between the intervening tones were also 300 msec. The interval between the last intervening tone and the C tone was 2 sec. All tones were of equal loudness.

Conditions. There were 5 conditions in this experiment. In Conditions 1–4, the S and C tones were identical in pitch. In Condition 1, a tone a semitone higher in pitch than the S (and C) tone was included in the intervening sequence. In Condition 2, a tone a semitone lower was included in the intervening sequence. In Condition 3, one tone a semitone higher and another a semitone lower were both included in the same sequence. Within each of Conditions 1–3, the placement of these critical tones was systematically varied between the second and third serial positions, so that the effect of including 2 critical tones rather than 1 in the same sequence (Condition 3 compared with Conditions 1 and 2) could be evaluated without the complication of employing another serial position to accommodate the extra critical tone. In Condition 4, no tone a semitone higher or lower than the S (and C) tone was included in the intervening sequence. In Condition 5, the S and C tones differed in pitch by a semitone. There was no systematic inclusion or exclusion of tones on the basis of a semitone separation from the S or C tone in this condition.

The entire tape consisted of 96 sequences; in half the S and C tones were the same in pitch and in the other half they differed. The *S*s listened to the entire tape on 2 separate occasions, and the results were averaged.

S and C tones. The S and C tones were taken from an equal-tempered scale (international pitch: A = 435 cps) and ranged from C# a semitone above middle C to the C an octave above. The frequencies (in cps) employed 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 = 517. In all conditions, each of the above pitches was used equally often, either as an S or C tone or both. In Condition 5, in which the S and C tones differed in pitch, the S tone was a semitone higher than the C tone in half of the sequences and a semitone lower in the other half.

Intervening tones. The intervening tonal pitches were taken from the scale described above and ranged from middle C to the C# an octave above. The following frequencies (in cps) were therefore employed: 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, and C# = 548. No sequence contained a tone of the same pitch as the S or C tone of that sequence or separated by exactly 1 octave from either of these. Further, no sequence included more than 1 example of any tonal pitch or tones separated by exactly 1 octave. In Conditions 1–4, no tone either a semitone higher or a semitone lower than the S tone or separated by exactly 1 octave from one of these was included in the intervening sequence (unless specified by the experimental condition). With these restrictions, the intervening tones were chosen randomly from the set specified above.

TABLE 1

PERCENTAGE ERRORS IN CONDITIONS OF EXPERIMENT I

Condition	% errors
1–4: S and C tones same	
Tone a semitone higher included in intervening sequence	7.9
Tone a semitone lower included in intervening sequence	6.9
2 tones, one a semitone higher and the other a semitone lower, included in intervening sequence	18.5
No tone a semitone higher or lower included in intervening sequence	2.8
5: S and C tones different	7.5

Note. Standard (S) tone presented first, followed by 4 intervening tones and then by the comparison (C) tone.

Subjects. Eighteen undergraduates at the University of California at San Diego served as *S*s. They were selected on the basis of obtaining a score of at least 95% correct on a small tape in which no tone a semitone removed from the S or C tone was included in the intervening sequence.

Apparatus. The tones were generated by a Wavetek oscillator which was controlled by a PDP9 computer, and the output was recorded on high-fidelity tape. The tape was played to *S*s on a high-quality tape recorder through loudspeakers.

Results

The results of the experiment are shown in Table 1. It can be seen upon comparison of Conditions 1 and 4 that when the S and C tones are identical in pitch, inclusion of a tone a semitone higher in the intervening sequence causes an increase in errors. This effect is significant on a Wilcoxon test ($p < .01$, 2-tailed). Comparison of Conditions 2 and 4 demonstrates a similar increase in errors produced by the incorporation of a tone a semitone lower. This is also significant on a Wilcoxon test ($p < .01$, 2-tailed). There is no significant difference between Conditions 1 and 2 ($p > .05$, Wilcoxon test). The error rate is therefore not related to whether the critical included tone is a semitone higher or a semitone lower than the S (and C) tone. Comparisons of Conditions 1 and 2 with Condition 3 demonstrate that a further increase in errors is produced when 2 tones,

TABLE 2

PERCENTAGE ERRORS IN CONDITIONS OF EXPERIMENT II

Condition	% errors
1–4: S and C tones different	
Tone of the same pitch as the C tone included in intervening sequence	20.1
Tone a semitone from S tone, but on the opposite side of pitch continuum than C tone, included in intervening sequence	7.4
2 tones, one as in Condition 1 and the other as in Condition 2, included in intervening sequence	25.2
No tone a semitone removed from S tone included in intervening sequence	3.2
5: S and C tones same	6.6

Note. Standard (S) tone presented first, followed by 4 intervening tones and then by the comparison (C) tone.

one a semitone higher than the S (and C) tone and the other a semitone lower, are both included in the intervening sequence (compared with the inclusion of just one of these). Both these comparisons are significant on Wilcoxon tests ($p < .01$ level, 2-tailed). Serial position effects within conditions were tested and no significant effects were found ($p > .05$, Wilcoxon test, in all cases).

EXPERIMENT II

Method

Procedure. The procedure in Experiment II was the same as in Experiment I.

Conditions. There were 5 conditions in this experiment. In Conditions 1–4, the S and C tones differed in pitch by a semitone. In Condition 1, a tone of the same pitch as the C tone was included in the intervening sequence. In Condition 2, a tone a semitone removed from the S tone, but on the opposite side of the pitch continuum from the C tone, was included in the intervening sequence. In Condition 3, 2 tones, one at the pitch of the C tone and the other a semitone removed from the S tone on the other side of the pitch continuum, were both included in the same intervening sequence. As in Experiment I, and for the same reason, the placement of the critical included tones in Conditions 1–3 was systematically varied between the second and third serial positions. In Condition 4, no tone a semitone higher or lower than the S tone was included in the intervening sequence. In Condition 5, the S and C tones were identical in pitch, and there was no systematic inclusion or exclusion of tones in the intervening sequence on the basis of a semitone separation. In all other respects, the conditions were the same as in Experiment I.

S and C tones. The S and C tones were taken from the same set as in Experiment I, and in all conditions each of these tonal pitches was used equally often, either as an S or C tone or both. In each of Conditions 1–4, in which the S and C tones differed in pitch, the S tone was a semitone higher than the C tone in half of the sequences and a semitone lower in the other half.

Intervening tones. The intervening tonal pitches were taken from the same set as in Experiment I. They were chosen randomly from this set with the following restrictions: No sequence contained a tone of the same pitch as the S or C tone of that sequence or separated by exactly 1 octave from either of these. No sequence included more than 1 example of any tonal pitch or tones separated by exactly 1 octave. In Conditions 1–4, no tone a semitone removed from either the S or C tone or separated by exactly 1 octave from one of these was included in the intervening sequence (unless this was specified by the experimental condition).

Subjects. Twenty-two undergraduates at the University of California at San Diego served as *S*s. They were selected as in Experiment I.

Apparatus. The apparatus was the same as in Experiment I.

Results

The results of this experiment are shown in Table 2. Comparison of Condition 1 with Condition 4 shows that when the S and C tones differ in pitch by a semitone, inclusion of a tone at the pitch of the C tone in the intervening sequence produces an increase in errors. This effect is significant ($p < .01$ level, Wilcoxon test) and has already been demonstrated (Deutsch, 1972a). Comparison of Condition 2 with Condition 4 shows further that when the S and C tones differ in pitch, inclusion of a tone a semitone removed from the S tone in the intervening sequence, but on the opposite side of the pitch continuum from the C tone, also produces an increase in errors. This effect is significant on a Wilcoxon test ($p < .01$, 2-tailed). However, a significant increase in errors in Condition 1 compared with Condition 2 is also manifest ($p < .01$, 2-tailed Wilcoxon test). Finally, comparisons of Conditions 1 and 2 with Condition 3 demonstrate that a further increase in errors occurs when both (*a*) a tone at the same pitch as the C tone and (*b*) a tone that is a semitone removed from the S tone in the opposite direction are included in the same intervening sequence. This increase in errors is significant on Wilcoxon tests comparing Conditions 1 and 3 ($p < .05$, 2-tailed) and comparing Conditions 2 and 3 ($p < .01$, 2-tailed). As in Experiment I, no significant serial position effects were found within any of the conditions ($p > .05$, Wilcoxon test, in all cases).

General Discussion

Experiment I demonstrates that recognition of the pitch of a tone, after an interval during which other tones are played, is disrupted by incorporating in the intervening sequence a tone that is a semitone removed from the tone to be recognized. An even greater increase in errors is produced by incorporating 2 such tones, one a semitone higher and the other a semitone lower. Experiment II demonstrates an effect on discrimination of one tonal pitch from another, an analogous effect to that found for recognition of the same tonal pitch in Experiment I. The ability of *S* to judge correctly that the S and C tones differ in pitch by a semitone is impaired by incorporating in the intervening sequence a tone a semitone removed from the S tone. And as in Experiment I, including 2 such tones produces significantly more errors than including just 1 tone. However, errors are substantially greater when the critical included tone is identical in pitch to the C tone than when it is not. It would appear, therefore, that there is more than 1 disruptive factor operating in this experiment. One interference effect appears to depend upon identity in pitch between the critical included tone and the C tone. A theoretical basis for such a phenomenon has been described earlier (Deutsch, 1972a). The basis for the other, substantially smaller, disruptive effects remains to be investigated. However, since these effects do not depend on identity in pitch between the critical intervening tone and the C tone, they provide more general evidence that short-term memory for pitch is subject to similarity-based interference.

References

Brown, J. Some tests of the decay theory of immediate memory. *Quarterly Journal of Experimental Psychology*, 1958, **10**, 12–21.

Conrad, R. Acoustic confusions in immediate memory. *British Journal of Psychology*, 1964, **55**, 75–84.

Deutsch, D. Tones and numbers: Specificity of interference in immediate memory. *Science*, 1970, **168**, 1604–1605.

Deutsch, D. Effect of repetition of standard and comparison tones on recognition memory for pitch. *Journal of Experimental Psychology*, 1972, **93**, 156–162. (a)

Deutsch, D. Mapping of interactions in the pitch memory store. *Science*, 1972, **175**, 1020–1022. (b)

Wickelgren, W. A. Acoustic similarity and retroactive interference in short-term memory. *Journal of Verbal Learning and Verbal Behavior*, 1965, **4**, 53–61.

(Received August 19, 1972)