JUDGED DIRECTION OF PAIRS OF OCTAVE-RELATED COMPLEXES (SHEPARD TONES): TRAINING EFFECTS AND REVERSAL

Annabel J. Cohen[1], Michael Lamoureux[2], Richard Fleming[3] Debora Dunphy[4]
[1]Department of Psychology, University of Prince Edward Island, Charlottetown, P.E. C1A 4P3,
[2]Department of Mathematics and Statistics, University of Calgary, Calgary
[3]Department of Psychology, University of Prince Edward Island, Charlottetown, P.E.
[4]Enigma Animations Productions, Vancouver

1. Introduction

Shepard (1964) constructed a set of octave-related sinusoids whose amplitudes were scaled by a bell-shaped envelope which removed the usual cues to pitch height but preserved chroma (e.g., A, A#). For simplicity, he divided an octave into 10 rather than 12 equal units to produce a "chromatic" scale of 10 complex tones. When pairs of these tones were presented, listeners, who had previously demonstrated good frequency directional sensitivity, judged the direction of the second tone to be higher than the first when the chroma of the second tone was 1or 2 semitones higher than that of the first tone. Conversely, when the chroma of the second tone was 8 or 9 semitones higher than that of the first, it was judged as lower. The results were consistent with a proximity principle. Judgements by this group of listeners were consistent for the tones separated by intermediate distances. A group of listeners who had poorer pitch directional judgment ability in the pretest produced less consistency for the smaller and larger intervals as well.

Although typically the direction of octave-complex intervals around 5 to 7 semitones is inconsistent, we noted in our laboratory, that presentation of a particular series of intervals overrode this inconsistency. In such a series, each interval began on the same note and the second note of successive intervals increased or decreased by one semitone. For example, an increasing series would be C-C#, C-D, C-D#, C-E, C-F, C-F#, C-G... For this increasing pattern, we typically observed consistent ascending judgments for intervals of 7 and 8 semitones, although violation to the proximity principle. The descending series led to systematically descending judgments. A similar phenomenon was reported by Tuller and Giangrande (1991). This phenomenon resembles biases induced with the psychophysical method of limits (Fechner, 1860) when the ascending series produces the opposite bias in judgment from the descending series. To explain the phenomena, we considered the possibility that hearing an interval in one direction establishes a propensity to hear the interval in the same direction. Such a proposal has also been made in the context of music perception by Narmour (1990), however only for small intervals. Large intervals, he claims, bias expectations in the other direction.

In the present study, examples of each of the intervals from 1 to 11 semitones were presented to two groups of listeners, differing in level of musical training, who were asked to judge the direction of a second tone of each interval relative to the first. Percentage of judgments in each direction was measured for each interval. In order to determine whether interval direction biassed successive directional judgments, the second order statistics of directional responses were investigated.

2. Method

Stimuli. All 12 tones consisted of 10 sinusoidal components that were related by octaves with amplitudes governed by a fixed, bell-shaped spectral envelope (cf., Shepard, 1964). The lowest component of the lowest tone was 20 Hz. Successive fundamentals were separated by one equal-tempered semitone. Thus, the fundamental of the 12th tone of the set was separated by 11 semitones from the fundamental of the first tone. Each tone was .5 sec in duration, and a .5 sec silence preceded the second tone of the interval.

Procedure. Testing was performed in a quiet room. On each trial the subject indicated whether the two tones ascended or descended by positioning a cursor on a 1 inch square up or down button displayed on a 17" computer screen. The up button was above the down button.

There were 132 different tone pairs resulting from the combination of all possible pairs of the 12 different tones with the exception of repetitions. Each pair was selected in a random order without replacement. This resulted in 12 examples of each of 11 interval sizes of from 1 to 11 semitones.

Apparatus. Tones were generated on a NeXT computer system at a sampling rate of 44.1 kHz and 16-bit resolution (13-bits linearity, Lamoureux & Cohen, 1993). Playback was accomplished through ADS loudspeakers on either side of the listener.

Subjects. There were 34 students, 19 of whom had more than 5 years of musical training.

3. Results

The percentage of ascending judgments as a function of interval size was calculated separately for the two groups of subjects. The pattern of responses was similar for the two groups, but more differentiated for the more musically trained listeners. The second tone was always judged higher when it was from 1 to 3 steps clockwise from the first tone and almost always judged lower when it was 9 to 11 steps clockwise (i.e., 1 to 3 steps counterclockwise). In the vicinity of 6 steps, the judgments were less consistent and the second tone was judged higher about as often as it was judged lower. For the untrained listeners, there also was some inconsistency for the smallest and largest intervals.

Second order statistics. The influence of the direction of a prior interval judgment was investigated by dividing the responses into two classes: those following a preceding "up" response and those following a preceding "down" response. For musically trained listeners, for every interval size, there was a greater tendency to respond up when the preceding interval was judged down, than when the preceding interval was judged up. This reversal effect was largest over the intervals 4 to 6 semitones. The size of the phenomenon at its maximum was over 10%. This tendency was not apparent in the data of the less trained listeners.

The effect was explored in other ways all leading to the same basic result. In one case, only the intervals (1 to 3 and 9 to 11 semitones) which were unambiguous were considered. In another, only the intervals which were unambiguous and also judged "correctly" were considered.

4. Conclusions

The results replicate the original demonstration of Shepard's (1964) circular pitch phenomena. Shepard's conditions differed slightly from those of the present study. In Shepard's study, each tone was presented for only 125 ms followed by 875 ms silence. The results extend to longer tones and shorter ITI's. Shepard also compared different groups of listeners according to a pretest of discrimination of direction of brief sine tone stimuli. In the present study, classifying subjects on the basis of musical experience led to the same pattern of data which had differentiated the extreme groups discussed by Shepard. In the present study, it is likely that the less trained listeners had difficulty in resolving the tones of the smallest intervals and therefore had difficulty in determining their relative direction. In other work, we have shown that scales constructed of adjacent semitone intervals lead to poorer performance of a task of serial order recognition than do scales with wider spacing (Cohen & Frankland, 1990; Parncutt & Cohen, 1995) and that subjects with less musical training perform more poorly.

Finally, our study was motivated by the question, can ambiguity of circular pitch phenomena be overridden by cognitive predispositions to hear successive intervals in the same direction. Observations in our lab, and those reported by Tuller and Giangrande (1991) suggested the possibility that an interval would be judged as rising if the preceding interval was judged as rising. Our results indicate that listeners do not get "caught up in this momentum of the direction of the previous interval". While this might be an adaptation phenomenon, further analyses with third order statistics suggest that it is not, however, too few data points of the type necessary for the analysis prevent drawing any strong conclusions.

The reversal phenomenon demonstrated in this study cannot easily be explained but it rules out the possibility that a rising interval predisposes listeners to hear subsequent intervals as rising. We believe, however, that it should be possible to induce such tendencies through presentation of contour patterns, or macrocontours (Cohen, Trehub & Thorpe, 1989).

Contrary to the notion that a prior direction will prime the same direction, and contrary to Narmour's notion of registral direction, that small intervals imply succeeding intervals in the same direction, the present study showed a bias to hear intervals in the opposite direction to that of the prior interval judged. In relating Narmour's theory to the present study, it should be recognized that Narmour's predictions are for the direction of the interval created by adding a new note N3 to the original interval N1-N2. Instead, the present study looked at the interval between N3 and N4. We might nevertheless have expected the implication of N1-N2 to carry through to N3-N4.

5. References

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6. Acknowledgment and Note

The research was supported by equipment and operating grants from the Natural Sciences and Engineering Research Council made to A. J. Cohen.

Correspondence may be directed to acohen@upei.ca.