January 5, 1989

Pitch of Complex Tones with Many High-order Harmonics

Adrianus J. M. Houtsma, *Institute for Perception Research IPO*
J. Smurzynski, *University of Connecticut Health Center*

10:50

FFF6. Distinguishable musical dynamics. Blake R. Patterson (Network Management Division, AT&T Bell Laboratories, 480 Red Hill Road, Middletown, NJ 07748)

Loudness changes, which composers specify by musical dynamics *pp, p, mp, mf, f, and ff,* make music exciting. The goal of this study is a usable and rational specification of an "acceptable" dynamic range for musicians. Requiring that a note at one dynamic level be at least s dB more intense than nearby notes at the next-lower dynamic level leads to a minimum solo-instrument per-note dynamic range $(k\text{-}1)(d+s)$, where k is the number of dynamic levels and d is the maximum intensity difference between nearby notes at "constant" dynamic level. For six dynamic levels and the bassoon, for which d is about 5 dB, a 1-dB spacing s between dynamic levels gives a minimum dynamic range of 30 dB ["Musical Dynamics," Sci. Am. **231** (5), 78–95 (November 1974)]. Some related results published by others over the past 14 years are briefly noted. Professional performances having different dynamic ranges are exhibited. A live demonstration of distinguishable dynamics on the bassoon is presented. Much remains to be studied in this rich field, for example, (1) dependence of d on instrument and dynamic level; (2) dependence of (listener-perceived) loudness on musical factors other than intensity, such as pitch, timbre, note duration, and transients; (3) dynamic complexities of ensemble performance: solo levels, heterogeneous ensemble, "chorus" effects, ensemble with soloist, etc.; (4) dependence of musical dynamics on music type, performance environment, and performance objective.

11:10

FFF7. Influence of hammer velocity in piano sound. Caroline Palmer (Pychology Department, Ohio State University, Columbus, OH 43210) and Judith Brown (Physics Department, Wellesley College, Wellesley, MA 02180 and MIT Media Lab E15-483, Cambridge, MA 02139)

Recent models of piano string excitation suggest that string motion is proportional to hammer velocity. Preliminary to measuring dynamics in piano performance, the relationship between radiated piano sound and hammer velocities was studied. A computer-monitored piano allowed reproduction of a range of hammer velocities, and a microphone placed near a pianist's head location recorded radiated sound. The first eperiment indicated that peak amplitude of the waveform was directly proportional to the hammer velocity of individual notes for a wide range of frequencies and hammer velocities. A second experiment investigated the waveforms of notes struck simultaneously and compared these with the waveforms of the individual component notes. The peak amplitude of the dyads was directly proportional (with proportionality close to 1) to the sum of the individual peak amplitudes. A third experiment extended these findings to a wider range of dyadic pitch intervals. These findings suggest linear relationships between hammer velocity, amplitude of string motion, bridge motion, and amplitude of the soundboard vibration for single notes. The additivity of dyads indicates that the principle of superposition is obeyed with a small energy loss. [Work supported by MIT Media Lab, Ohio State University Small Research Grant, and a Wellesley College Brachman Hoffman Fellowship.]

FRIDAY MORNING, 26 MAY 1989 NEWHOUSE I, ROOM A1, 9:00 TO 11:15 A.M.

Session GGG. Psychological Acoustics IX: Complex Stimuli

Arlene E. Carney, Chairman
Boys Town National Institute, 555 North 30th Street, Omaha, Nebraska 68131

Contributed Papers

9:00

GGG1. Pitch of complex tones with many high-order harmonics. Adrianus J. M. Houtsma (Institute for Perception Research IPO, P. O. Box 513, 5600 MB Eindhoven, The Netherlands) and J. Smurzynski (Division of Otolaryngology/Surgery, University of Connecticut Health Center, Farmington, CT 06032)

Pitch identification and pitch discrimination experiments were performed for complex tones with missing fundamentals between 200 and 300 Hz and with many successive harmonics varying from low (below the 10th) to high (above the 25th) harmonic order. Identification performance was found to degrade with increasing harmonic order from an essentially perfect to an asymptotic level that was clearly less than perfect but much better than chance. Just-noticeable differences in (missing) fundamental frequency were found to increase, with increasing harmonic order, from a fraction of 1 Hz to an asymptotic level of about 5 Hz. Influence of phase was found only for tone complexes of high harmonic order. Results support the existence of two separate pitch mechanisms in the auditory system, one based on pattern matching of resolved frequencies, the other on periodicity of nonresolved frequencies.