Memory for Musical Intervals: Cognitive Differences for Consonance and Dissonance

Susan E. Rogers and Daniel J. Levitin
Dept. of Psychology, McGill University, 1205 Dr. Penfield Avenue, Montréal, Québec, Canada, H3A 1B1

1. INTRODUCTION

When two tones are produced simultaneously, the resulting sound – a *dyad* – may be judged along several continua such as from smooth to rough, pleasant to unpleasant, and *consonant* to its opposite – *dissonant* [1]. Infants and adults display heightened sensitivity to and a preference for consonant over dissonant musical intervals, leading to speculation that consonant intervals are inherently easier to process than dissonant [2]. Regardless of whether consonance and dissonance are learned or innate distinctions, the contrast is reflected in two independent measures – one based on the frequency separation between two tones (sensory consonance/dissonance); the other based on the frequency ratio between two tones (musical consonance/dissonance). The present study used a short-term memory (STM) paradigm to examine the influence of frequency separation versus frequency ratio on the processing of pure-tone dyads presented outside of a musical (tonal) context.

When the frequency separation between a dyad's two tones is less than a single critical bandwidth (auditory filter) the physical interaction produces a sensation termed *beating* when the separation is less than 15 Hz, and *roughness* when the two tones are separated by roughly 25% to 40% of the bandwidth [3]. Models of *sensory* consonance/dissonance (C/D) predict that all pure-tone dyads with frequency differences greater than a critical bandwidth should be judged consonant [4]. *Musical* C/D, on the other hand, is a term used by music theorists and relates C/D to the size of the integers defining the frequency ratio relationship between two tones. Most adults describe small-integer ratio dyads such as octaves (1:2) as consonant compared with large-integer ratio dyads such as tritones (32:45), described as dissonant [5, 6].

The representation of musical C/D typically reflects an integration of the sensory properties of a *complex-tone* signal, the musical context, and the listener's exposure to intervals. The perception of musical C/D is thus a "knowledge-driven" process [7]. Subjective evaluations, however, of the "beauty" and "pleasantness" of pure-tone dyads show that frequency ratio size influences C/D judgments in the absence of tonal context [8, 9]. An outstanding question is the extent to which distinctions between sensory and musical C/D are reflected in higher-level cognitive processes. We recruited musicians and nonmusicians to explore these distinctions in a novel/familiar recognition memory task.

2. METHOD

Seventy-two dyads of 500 ms duration each were created by summing two sine tones. Root notes ranged from C3 (130 Hz) to B4 (494 Hz). The 12 musical intervals of the chromatic scale (m2, M2, m3, M3, p4, tritone, p5, m6, M6, m7, M7, octave) were assigned to each of the root notes by random number table. Each musical interval was represented at 6 different root notes; each pitch chroma was represented by 6 different musical intervals. The stimulus set was partitioned into four levels of musical C/D by integer-ratio size, labeled from most to least consonant as follows: MC, mc, md, and MD. The same stimulus set was also partitioned into four levels of sensory C/D by frequency separation and critical bandwidth, labeled from most to least consonant as follows: SC, sc, sd, and SD.

Eight musicians ($\geq$ 5 years training) and eight nonmusicians ($\leq$ 2 years training) heard each dyad twice, first as a novel and later as a familiar stimulus. Novel/familiar pairs were separated by as few as 0 or as many as 6 intervening dyads, corresponding to memory retention periods ranging from 7.75 to 48.00 s. At each trial participants judged whether a dyad was novel or familiar by responding with a keystroke ("yes" or "no" – the "1" and "3" keys, respectively) to the question "Have you heard this before?," displayed on a computer screen. Dyads were presented at 55 dB(A) through stereo headphones in a soundproof booth.

3. RESULTS

At long retention periods (40.75 s and 48.00 s) nonmusicians recognized MD and md, but not MC or mc, dyads significantly better than chance [MC: $\chi2(1, N = 48) = 0.75$, $p = 0.39$; mc: $\chi2(1, N = 40) = 2.50$, $p = 0.11$; md: $\chi2(1, N = 40) = 10.00$, $p < 0.01$; MD: $\chi2(1, N = 56) = 23.14$, $p < 0.001$] (see Fig. 1a). Nonmusicians recognized only two levels of sensory C/D dyads (SD and SC) significantly better than chance at the longest retention periods [SC: $\chi2(1, N = 40) = 10.00$, $p < 0.01$; sc: $\chi2(1, N = 48) = 2.08$, $p = 0.15$; sd: $\chi2(1, N = 56) = 1.14$, $p = 0.29$; SD: $\chi2(1, N = 40) = 8.10$, $p < 0.01$] (see Fig. 2a).

Musicians recognized all levels of musical and sensory C/D dyads significantly better than chance at 40.75 and 48.00 s [MC: $\chi2(1, N = 48) = 6.75, p < 0.01$; mc: $\chi2(1, N = 40) = 12.10, p = 0.001$; md: $\chi2(1, N = 40) = 16.90, p < 0.001$; MD: $\chi2(1, N = 56) = 16.07, p < 0.001$; SC: $\chi2(1, N = 40) = 10.00, p < 0.01$; sc: $\chi2(1, N = 48) = 5.33, p < 0.03$; sd: $\chi2(1, N =56) = 25.79, p < 0.001$; SD: $\chi2(1, N = 40) = 12.10, p = 0.001$] (see Figs. 1b and 2b).

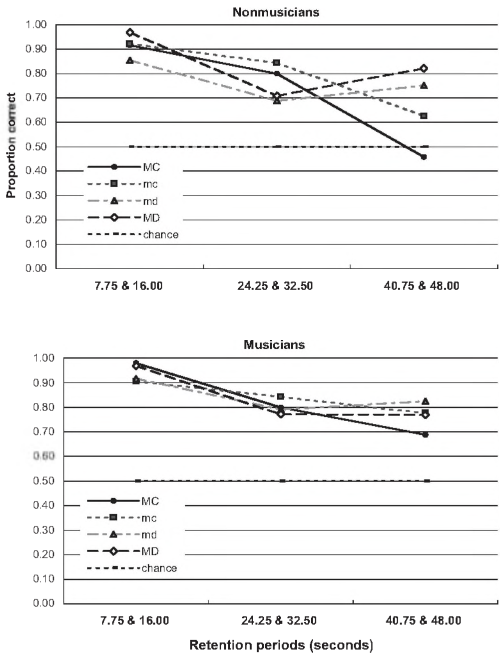

Figure 1. Mean proportion of correct recognitions by nonmusicians (a) and musicians (b) with increasing retention period for dyads categorized by musical consonance/dissonance.

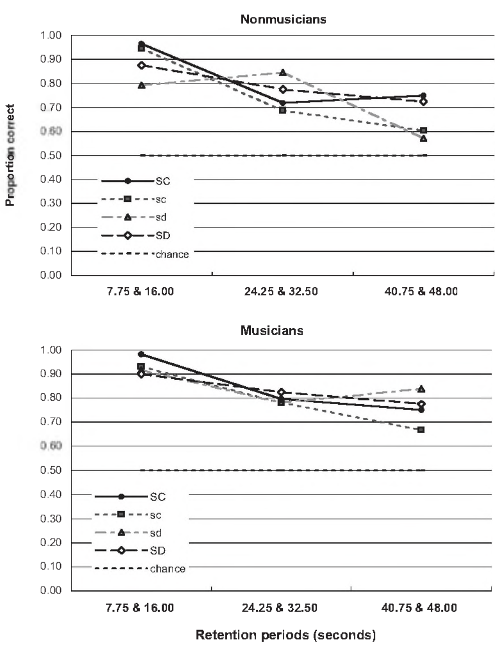

Figure 2. Mean proportion of correct recognitions by nonmusicians (a) and musicians (b) with increasing retention period for dyads categorized by sensory consonance/dissonance.

4. DISCUSSION

The present finding shows auditory STM to be robust and accurate for some dyads beyond the generally understood limit of 30 s retention [10], despite interference from other sounds. Groups of dyads with similar frequency ratio relationships (musical C/D), as opposed to frequency separation (sensory C/D), were processed similarly, particularly by nonmusicians. Nonmusicians displayed more accurate memory for large-integer compared with small-integer ratio dyads. Musicians showed slightly better memory performance overall than did nonmusicians, and less variation between categories of dyads.

Musicians' scores may have reflected a higher degree of explicit music knowledge and familiarity with musical intervals, while nonmusicians' scores may have been driven more by interval distinctiveness [7]. Exposure to musical intervals and their frequency of occurrence allows nonmusicians to internalize the rules of harmonic relationships between notes and chords [1, 7]. Early passive exposure to complex-tone intervals present in speech and music may account for the privileged position of consonance over dissonance and the influence of integer-ratio size on the processing of pure-tone dyads [2,9]. Differential memory for consonance and dissonance implies processing differences in the computation of musical intervals and suggests that certain auditory features are particularly salient.

REFERENCES

[1] Krumhansl, C. L. (1991). "Music psychology: Tonal structures in perception and memory," Ann. Rev. Psychol., 42, 277-303.
[2] Schellenberg, E.G., & Trainor, L. (1996). "Sensory consonance and the perceptual similarity of complex-tone harmonic intervals: Tests of infant and adult listeners," J. Acoust. Soc. Am., 100, 3321-3328.
[3] Zwicker, E. & Fastl, H. (1990). *Psychoacoustics: Facts and Models.* (Springer-Verlag: Berlin).
[4] Plomp, R., & Levelt, W.J.M. (1965). "Tonal consonance and critical bandwidth," J. Acoust. Soc. Am., 38, 548-560.
[5] Cazden, N. (1980). "The definition of consonance and dissonance," Int. Rev. Aesthet. Sociol. Music, 11, 123-168.
[6] Helmholtz, H.L.F. von (1954). *On the Sensations of Tone as a Physiological Basis for the Theory of Music*, A.J. Ellis, ed., trans. (Dover: New York), 2nd ed. (Originally published 1885).
[7] Bigand, E. & Tillman, B. (2005). "Effect of context on the perception of pitch structures," in *Pitch: Neural Coding and Perception,* C. Plack, A. Oxenham, R. Fay, and A. Popper, eds. (Springer: NY).
[8] Van de Geer, J., Levelt, W. & Plomp, R. (1962). "The connotation of musical consonance," Acta Psychol. 20, 308-319.
[9] Tramo, M., Cariani, P., Delgutte, B., & Braida, L. (2003). "Neurobiology of harmony perception," in *The Cognitive Neuroscience of Music*, I. Peretz and R. Zatorre, eds. (Oxford: NY)
[10] Winker, I. *et al.* (2002). "Temporary and longer-term retention of acoustic information," Psychophys. 39, 530-534.