Proceedings of the Ninth Triennial Conference of the European Society for the Cognitive Sciences of Music, 17-22 August 2015, Manchester, UK
Ginsborg, J., Lamont, A., Phillips, M., Bramley, S. (Editors)

Chord perception and frequency of occurrence: Samples from works by J.S. Bach and The Beatles

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ABSTRACT

Background

Frequency of occurrence of chords may be a contributing factor to the perception of chords in isolation. A tone or chord that appears frequently and at crucial musical moments becomes more important and stable within the underlying system of music (Krumhansl, 1990), and the listener learns and internalizes regularities that organize and constrain the music partly based on the frequency of occurrence of particular musical events (Castelllano, Bharucha, and Krumhansl, 1984; Oram and Cuddy, 1995; Jonaitis and Saffran, 2009).

Previous studies (Budge, 1943; Rohrmeier and Cross, 2008; Bronze and Shanahan, 2013) reveal that functional chords such as I, V, and IV tend to appear more frequently in pieces of music than less functional chords. The frequency of a chord's occurrence was strongly correlated with listeners' ratings of the chord's fitness with the prime scale or chord sequence (Krumhansl, 1985; 1990).

However, how the frequency of occurrence of different types of chord influences the listener's perception of chords has been little studied. Some chords, such as major and minor triads and the dominant seventh, are prevalent in pieces of music, while diminished and augmented triads seldom appear (Rohrmeier and Cross, 2008; Bronze and Shanahan, 2013). From these studies, it can be inferred that listeners will perceive more frequently occurring types of chord more favourably.

Aims

This study aims to investigate the influence of frequency of occurrence and acoustic features on the perception of chords in isolation. In particular, the consonance/dissonance (C/D), pleasantness/unpleasantness, stability/instability, and relaxation/tension of chords will be examined.

Method

We employed 12 different chord types (5 triads and 7 tetrads) as stimuli, all with roots of C or F#, and all played on the piano and organ, making 48 chords in total. In the experiment, three groups of participants (8 musicians, 17 participants with some musical training, and 8 non-musicians, 33 in total) rated C/D, pleasantness/unpleasantness, stability/instability, and relaxation/tension on a 7-point scale. Three contributory factors to listeners' perceptions were examined. Firstly, participants were asked to rate their level of familiarity with each of the two timbres used in the experiment. Secondly, as an estimate of the frequency of the occurrence of each chord type, we counted the number of times each chord type appears in J.S. Bach's Italian Concerto BWV971, and in The Beatles' 30 best-selling UK hits. Thirdly, certain key acoustic features of the 48 chords were extracted using MIR toolbox (Lartillot and Toiviainen, 2007) and Timbre toolbox (Peeters, Giordarno, Susini, Misdariis, and McAdams, 2011). The extracted acoustic features of the 48 chords used, and the frequency of each chord's occurrence, were statistically assessed in order to analyse the relationship between these and the behavioural data.

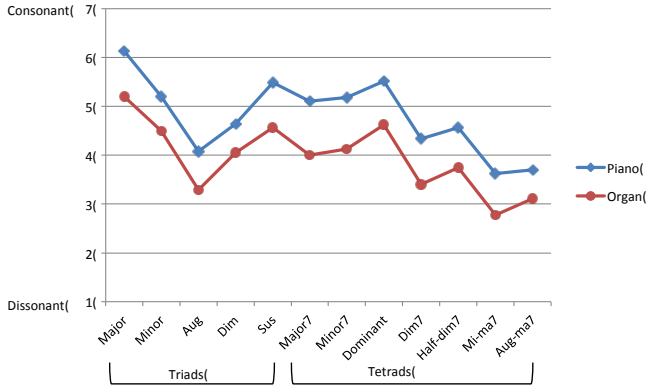

Figure 1. Mean C/D ratings for 12 chords from 33 participants in two timbres.

Results

A two-way ANOVA was undertaken, with Timbre and Chord Type as within-subjects factors and multiple dependent measures including listener ratings for C/D, Pleasantness, Stability, and Tension/Relaxation. Significant main effects of Timbre were found in the ratings for C/D: $F(1, 30)= 17.463$, $p < .001$, for Pleasantness: $F(1, 30)=32.824$, $p< .001$, and for Relaxation: $F(1, 30)=25.108$, $p< .001$. There were significant main effects of Chord Type for all ratings, C/D: $F(5.59, 167.69)=32.512$, $p< .001$, Pleasantness: $F(3.92, 117.80)=20.397$, $p< .001$, Stability: $F(5.268, 158.04)=18.411$, $p< .001$, and Relaxation: $F(4.99, 149.95)=24.830$, $p< .001$. Chords with Piano timbre were consistently judged as being more consonant, pleasant, and relaxed than those with Organ timbre, as can be seen in Figure 1.

There was also a significant interaction between the effect of Timbre and Chord for Tension/Relaxation ratings: $F(11, 330)=2.145$, $p= .017$. A one-way ANOVA was carried out in

order to further investigate the effect of Chord on the Tension/Relaxation ratings of stimuli played with Organ and with Piano. There was a significant main effect of Chord on Tension/Relaxation ratings for Organ: (5.56, 178.17)=21.350, p= .001, r= .63, and for Piano (5.05, 161.720)=15.663, p= .001, r= .57, which shows the slightly larger effect size for Organ than for Piano.

As for the difference between participant groups, the musicians' chord ratings were more varied than non-musicians. Musicians tended to perceive 'dissonant' chords (such as augmented, augmented major seventh, and minor-major seventh chords) as more dissonant, unstable and tense than non-musicians; conversely, they perceived major chords as more consonant and pleasant than other groups.

Pearson's product-moment coefficient was used to assess the relationship between ratings for each chord across all four variables. Ratings for Consonance were strongly correlated with ratings for the other three variables (r< .923, df=48, p< .001), which means that more consonant chords were also judged to be more pleasant, stable and relaxed. However, analysis per group revealed that musicians' ratings of Consonance were not significantly correlated with the other three variables, although all other combinations were positively correlated.

Figure 2 shows the percentage occurrence of each chord in works by Bach and The Beatles. Major triads were the most prevalent, followed by the dominant seventh and minor triads, while the half-diminished seventh, the minor-major seventh, and the augmented major seventh appeared rarely.

Acoustic features of each chord, such as dynamics, spectral centroid, irregularity, spectral flux, roughness, key strength, were extracted. Principle Component Analysis extracted three components from variables including both acoustic features and frequency of occurrence. The first component is highly correlated with spectral flux, spectral centroid, and dynamics, and accounts for 70.13% of variance. The second component is highly correlated with the frequency of occurrence with 13.49% of variance, and the third one is correlated with irregularity with 7.23% of variance.

Regression Analysis assessed how these components predict listener ratings for four variables. As for C/D, three predictors explained 60% of variance: R^2= .607, F(3, 44)= 22.608, p= .001. Acoustic features significantly predicted C/D ratings: β= .510, p= .001, and the frequency of occurrence did too: β= .587, p= .001. However, the irregularity did not predict the ratings: β= -.039, p= .682. The standard coefficient values of acoustic features were higher for pleasantness and relaxation than for C/D and stability. This indicates that acoustic features had a larger influence on perceptions of pleasantness and relaxation than they did on perceptions of C/D and stability.

Conclusions

The findings show that the frequency of the occurrence of different types of chord is an important contributory factor to their perception. They also show that musical training enhances and changes a listener's sensitivity to C/D and stability. In addition, the findings revealed that consonance was not always pleasant, especially for listeners with musical training. This suggests that our perception of isolated chords is diverse and multidimensional, and our complex and subtle relationship with chords points to the need for varied approaches to future research.

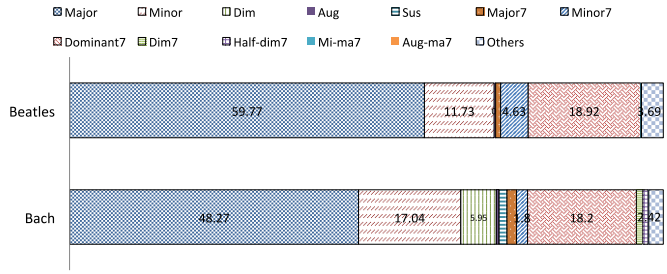

Figure 2. Percentage occurrence of each chord, from pieces by Bach and The Beatles.

Keywords

Chord perception, frequency of occurrence, C/D, pleasantness

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