The Effect of Overtones on Dissonance Perception

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Introduction

In Western music theory, different musical intervals are connected with perceived consonance or dissonance. Consonant could be described as a pleasant sound, stable sound and "at rest". On the other hand, dissonance could be described as an unstable sound, grief and creating tension. The twelve-tone equal temperament tuning which divides the octave into 12 equal parts is used in most countries today. In twelve-tone equal temperament, consonance and dissonance are defined as 7 consonant intervals and 5 dissonant intervals shown in Table 1. Figure 1 shows consonance and dissonance in music notes. Applying this concept to a psychoacoustic analysis of environmental sounds, however, demands a description of consonance and dissonance which is not limited to distinct musical intervals and equal level ratios. In a previous study, an auditory modelling approach based on envelope fluctuations showed promising results by predicting both known relations from musical theory and findings from a new experiment [1]. The aim of this series of psychoacoustics experiments is to investigate how the relative levels of the harmonic overtones influence the human consonance and dissonance perception because an effect was expected based on the previous modelling approach. The perceived dissonance of 18 different sounds with varying overtone content, interval and decay of the overtone components were adjusted to the same dissonance as a comparison signal by altering the level of one of the two overtones in an adaptive procedure. It showed that for some combinations of overtone content and musical interval, a significantly lower reduction of the second tone was needed to reach the dissonance of the comparison signal. This finding supports the idea of modelling using envelope fluctuations as a measure for perceived dissonance.

Interval	Number of semitones	Consonant/Dissonant
Minor 2nd	1	Dissonant
Major 2nd	2	Dissonant
Minor 3rd	3	Consonant
Major 3rd	4	Consonant
Perfect 4th	5	Consonant
Aug 4th/Dim5th	6	Dissonant
Perfect 5th	7	Consonant
Minor6th/Aug 5th	8	Consonant
Major 6th	9	Consonant
Minor 7th	10	Dissonant
Major 7th	11	Dissonant
Octave	12	Consonant

Table 1: Consonant and dissonant combinations in Twelve-tone equal temperament

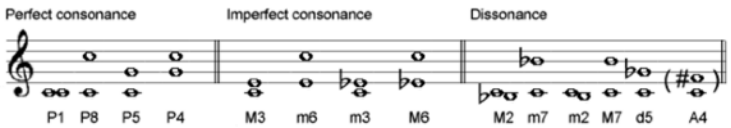

Fig.1 :Consonance and dissonance in music notes

Stimulus/Procedure/Participants

An adaptive procedure implemented in a Matlab program [3] was used in this experiment. First of all, 18 different dissonant sounds with varying overtone content, interval and decay of the overtone components were chosen. There were unlimited numbers of options to decide the dissonant sounds for the listening experiment, however, time and budget have a limit. Thus, 3 different intervals, 4 different patterns of decay of the overtone components and 3 different numbers of the overtone component were chosen. The parameters are shown in Table 2, Table 3. The method of this listening experiment is 2AFC [4] which the subjects listen to a pair of sounds, and choose one which was more dissonant. One of the pair of sounds is the reference sound which is minor 3rd, based on C6(1046Hz), the reference sound is a consonant and always the same. The other is one of 18 dissonant sounds. When a subject chooses one of the pair of sounds as more dissonant compared to the other, the level of the second component is going to be attenuated in the next rials, this process continues until getting a point of subjective equality for the 2 sounds. The convergence points for each of the 18 different patterns (cf. Table 2, Table 3) were collected in random order within the experiment. Pink noise was added by the program in order to simulate car interior sound. In the end, all sounds were adjusted to equal consonance to the reference sound by attenuating the level of the second components of the dissonant sounds. A session of the experiment takes 50-70minutes. 4 males and 5 females, a total of 9 people participated in this hearing experiment. The ages of the participates were between 18 - 27 years old. All participants had experience with playing a musical instrument. All sessions were conducted in a small listening booth, calibrated sound playback system with a pair of headphones was used. Before start every session, the sound playback system was calibrated to 65db.

Case Number	1	2	3	4	5	6	7	8	9
Interval/Semi-tone	1	6	1	1	1	1	6	6	6
Decay 1	0	0	$1/f$	$1/f^2$	$1/f^2$	$1/f$	$1/f$	$1/f^2$	$1/f^2$
Decay 2	0	0	$1/f$	$1/f^2$	$1/f$	$1/f^2$	$1/f$	$1/f^2$	$1/f$
Overtone	1	1	3	3	3	3	3	3	3

Table 2: The parameters of case1 to case9

Case Number	10	11	12	13	14	15	16	17	18
Interval/Semi-tone	6	1	1	1	1	6	6	6	6
Decay 1	$1/f$	$1/f$	$1/f^2$	$1/f^2$	$1/f$	$1/f$	$1/f^2$	$1/f^2$	$1/f$
Decay 2	$1/f^2$	$1/f$	$1/f^2$	$1/f$	$1/f^2$	$1/f$	$1/f^2$	$1/f$	$1/f^2$
Overtone	3	5	5	5	5	5	5	5	3

Table 3: The parameters of case10 to case18

Results

Figure 2 shows the dissonance level evaluation depending on numbers of the overtones. The blue bars are minor seconds(1 semitone), red bars are tritone (6 semitones). The Y-axis shows the attenuated sound level needed in order to get the same dissonance as the reference sound. When the amount of level change is higher, it means the dissonance level of the sound is higher. we observe lower dissonance level for the tritone with no overtone, whereas for all other conditions we find the same dissonance level. Figure 3 shows the dissonance level evaluation depending on the decay of the overtones. We observe lower dissonance level for the tritone with 2 or 4 overtones had both components decaying with factor of $1/f^2$. Minor second, however, were not able to decrease dissonance level even though the overtones adjusted to high decay. Those effects are observed in a lower octave band when based on C5(523Hz) as well.

Conclusion

From the results, we observed that components of the harmonic overtones influence human dissonance perception, but also discovered an exception. When the interval of dissonance sound is 6 semitones, the harmonic overtones influence human dissonance perception. Nevertheless, when the interval of dissonance sound is 1 semitone, the harmonic overtones don't influence human dissonance perception. This can be explained by auditory frequency resolution [6]. In this experiment, C6(1146.50Hz) and C#6(1108.73Hz) were used when semitone is 1, when frequencies of 2sounds are too close, it perceived as a strong dissonance. The intervals of 1 semitone and 6 semitones were converted into Bark scale[5] by the equation (1). The interval between the prime sound and 1 semitone is 0.36 Bark, between the prime sound and 6 semitones are 2.2 Bark. Thus when the interval is 1 semitone, it is considered that the 2 tones are perceived in the same critical band. On the other hand, 6 semitones, the 2 tones are perceived in different critical bands. These observations support the concept, that dissonance perception is caused by fluctuations within a critical band.

$$Bark = 13\arctan(0.00076f) + 3.5\arctan((f/7500)^2) \quad (1)$$

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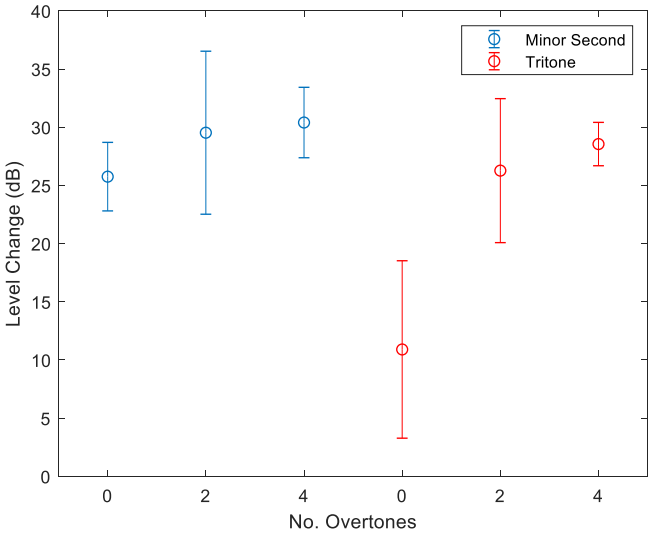

Fig. 2: Dissonance level evaluation depending on numbers of the overtones

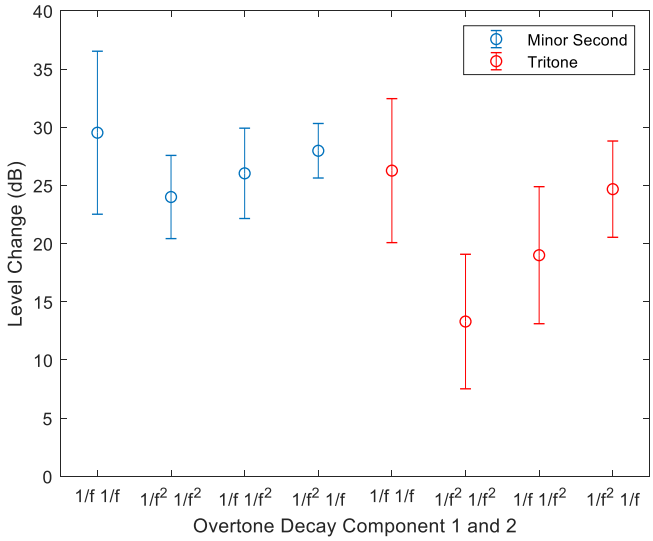

Fig. 3: Dissonance level evaluation depending on decay of the overtones