3.7.1.5: Timbre (the first time)

If a trumpet and a clarinet play the same note we can still tell the difference between the two instruments. Likewise, different voices sound different even when singing the same note. Why? We now know that if they are playing or singing the same pitch the fundamental frequency is the same for both so it is not the pitch that enables us to tell the difference. These differences in the quality of the pitch are called ***timbre*** and depend on the actual shape of the wave which in turn depends on the other frequencies present and their phases. Pure tones such as from a tuning fork have a pure sine wave shape and a single frequency. However the notes from musical instruments and voices are more complex and normally contain many frequencies, as we will see in the next chapter. We will also come back to other aspects of the human perception of sounds in Chapter 10 on Perception. For now the main point is that the subjective perception of pitch, loudness and timbre are each related to more than one quantity that can be measured in the laboratory. The following diagram shows some of the connections between objective (laboratory) measurements and subjective perception.

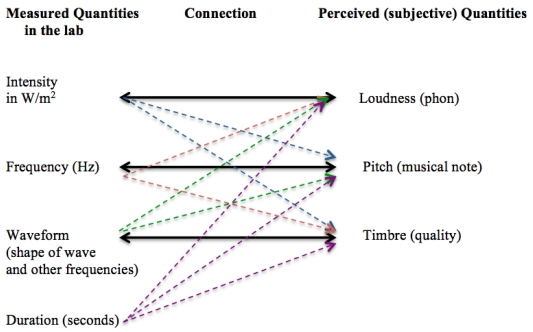

Figure 3.7.1.5.1

Notice that our perception of loudness is mainly determined by the intensity of the sound (energy per second per square meter) but also is influenced by frequency and waveform of the sound. Likewise our perception of pitch is mainly determined by the fundamental frequency but also influenced by intensity and waveform. Finally, timbre is determined by waveform (which is determined by the other frequencies present and their phases) with influences from intensity and the fundamental frequency. As we will see later (in a demo in class) the duration of a sound also affects how we perceive its pitch, loudness and timbre.

Summary

Pitch is primarily determined by the fundamental frequency of a note. Perceived loudness is related to the intensity or energy per time per area arriving at the ear. Timbre is the quality of a musical note and is related to the other frequencies present. Laboratory instruments measure the fundamental frequency in Hz and sound intensity in $\mathrm{W/m^2}$ of a sound wave as independent properties. As we will see we can also measure the other frequencies present which determines the waveform. Our hearing mechanisms, on the other hand, perceive the subjective qualities of timbre, pitch and loudness of a musical note. The objectively measured quantities are related to the subjective perceptions but the relationship is not precise. For example we perceive loudness differently for different frequencies. Our ears are better at distinguishing differences in frequency ($\mathrm{JND\ Hz}$) at low frequencies than high. And we distinguish loudness differences better for loud sounds ($\mathrm{JND\ dB}$). As we will see there are several other interesting features of our hearing system that make the perception of sound different from measurements made in the lab.

Questions on Pitch, Loudness, Timbre:

1. What does the fundamental frequency of an instrument determine?
2. What is the difference between pitch and fundamental frequency?
3. What subjective quantity corresponds to the scientific measurement of the fundamental frequency?
4. What is the typical range of frequencies that a human can hear if they have perfect hearing?
5. Although human hearing has a theoretical range, this isn't always the case in practice. Why is that?
6. How are the frequency ranges of animals different from the range humans can hear? (Look at the chart in Chapter 10.)
7. What is ultrasound?
8. How do we measure sound intensity in the laboratory?
9. What subjective quantity corresponds to the scientific measurement of sound intensity?

10. What is the difference between sound intensity and sound intensity level? What units are used for each?
11. The energy per second per area in $\mathrm{W/m^2}$ is one way to measure sound intensity. What other scale is used?
12. What is the threshold for pain in terms of sound intensity?
13. What is the difference between the phon measurement and the decibel measurement?
14. Suppose one clarinet has a measured loudness of 30 dB. How loud will five identical clarinets together be?
15. What is the sound intensity level in dB for a sound with intensity of $1\ \mathrm{W/m^2}$?
16. A vacuum cleaner is about 100 times as loud as ordinary conversation as measured in $\mathrm{W/m^2}$. How much of a difference is this in dB?
17. How loud are rustling leaves in dB? In $\mathrm{W/m^2}$?
18. In the graph of phons compared to SIL and sound intensity at different frequencies, why does the phon curve take a dip between 3000 Hz and 5000 Hz?
19. What is just noticeable difference in frequency?
20. According to the chart in this chapter, what is the normal JND (in Hz) at 1000 Hz? At 4000 Hz?
21. What is just noticeable difference in loudness?
22. For a 1000 Hz sound, what is the normal JND (in dB) at 20 dB? At 50 dB?
23. What is timbre and what causes it?
24. Pitch is mainly related to the fundamental frequency. But what other factors affect perceived pitch (what else affects the pitch that we think we hear)?
25. Loudness is mainly related to the sound intensity. But what other factors affect perceived loudness (what else affects the loudness that we think we hear)?
26. Explain the difference between subjective measures of pitch, loudness and timbre as compared to the objective measurements of fundamental frequency, sound intensity and waveform.
