AUDITORY ILLUSIONS
&
LAB REPORT FORM

NAME: _____ DATE: _____

PARTNER(S): _____

The objective of this experiment is:

- To understand concepts such as beats, localization, masking, and musical effects.

APPARATUS: Stereo tape player, headphones, Auditory Illusions Tape.

INTRODUCTION

We are all familiar with some common optical illusions, such as seeing what looks like water on the road ahead of us on hot summer days when there is actually nothing there. Less frequently noticed are a number of auditory illusions, which fool our ears instead of our eyes. In this experiment you will study a number of different binaural and monaural phenomena and illusions.

For monaural effects the same signal is presented to both ears, while for binaural effects each ear is presented with a different signal. The differences between binaural and monaural signals are often quite striking and are responsible for our ability to locate the direction of a sound source or to hold a conversation in a noisy environment.

Auditory illusions depend on monaural or binaural effects to make you think you hear something that is not really there. The illusions can occur at the ear, which can be made to detect a signal which is not there, or in the brain, which processes the signals sent to it from the ear, and can be fooled into interpreting the signals incorrectly. As is true in the case of optical illusions, not all people perceive the same effect. In fact, in some of the experiments the effect you will perceive (or even if you will perceive any effect at all) may depend on such factors as whether you a right- or left-handed and whether you are male or female. Thus there are no right or wrong perceptions. In your lab report, report what you perceive and not what you expected to perceive.

The audio signals you will study are recorded on a cassette "Auditory Illusions". prepared by Weston A. Anderson.

A. SET-UP

When you listen to the tape make sure that the right and left channels of your headphones are adjusted to approximately the same level. For many of the illusions it will be necessary to rewind the tape and replay it several time to be sure of the effect that you are

hearing. As you listen, you will also be able to observe the signals on a dual trace oscilloscope to help you interpret what you are hearing.

B. BEATS

The phenomenon of beats occurs when two signals of slightly different frequencies are mixed together and are perceived as a low note with a frequency equal to the difference between the frequencies of the two signals. There are two types of beats that we will look at in this lab.

1) Monaural beats occur when two signals of slightly different frequency occupy the same physical space. The interference of the two signals produces a variation in amplitude of the total signal at a frequency equal to the difference in frequency of the two signals. The ear detects this amplitude variation. In the first segment on the tape you will hear a 440 Hz A in the left channel of the headphones. Next you will hear a tone of 443 Hz (approximately 1/8 of a semitone higher than the A) in the right channel. After you hear these two separate notes they will be combined and their combination will be presented to both ears to produce a monaural beat pattern.

QUESTION #1: Describe what the monaural beat pattern sounds like. (Try timing the pattern.)

2) Binaural beats occur when two different frequencies are heard simultaneously, but do not occupy the same space, thus any effect that you hear will be due to the processing that your brain does to the signals. In this segment of the tape the left channel will receive only the 440 Hz signal, while the right channel will be receiving the 443 Hz signal. This will produce binaural beats. Some people, especially women, do not hear binaural beats.

QUESTION #2: Describe what the binaural beat pattern sounds like. (Try timing the pattern.)

QUESTION #3: What differences did you hear between the two patterns?

The next segment of the tape keeps the binaural setup but slowly varies the frequency of the right channel from 440 Hz - 450 Hz while keeping the left channel fixed at 440 Hz.

QUESTION #4: Describe what this new binaural beat pattern sounds like.

3) Intensity dependence of monaural and binaural beats

Now that you have heard beats and know what to expect, we are going to look at the effect that sound intensities have on monaural and binaural hearing. We will do tests at four different intensity levels. First you will hear a 440 Hz tone in the left channel for 3 seconds followed by a 443 Hz tone in the right channel. After this, for each test, you will first hear the binaural beat pattern, followed by the monaural beat pattern. In the first test the two tones have approximately the same intensity. In the second test the intensity of the right channel will be reduced by a factor of 100 (i.e. 20 dB). In the third test the intensity of the right channel will be reduced by another factor of 10 thus giving it a total reduction of 1000 times (i.e. 30 dB). The last test in the series again reduces the intensity of the 443 Hz tone by another factor of 10 (i.e. 10,000 times weaker than originally, 40 dB).

QUESTION #5: Describe the monaural and binaural beat patterns for each case. Pay special attention to which beat pattern sounds louder in each test.

QUESTION #6: In the last test could you still hear the 443 Hz signal? How about the binaural beat pattern?

C. MASKING EFFECTS OF NOISE

In this section we will look at how noise affects our perceptions of hearing and in particular how our binaural hearing permits us to pick out a particular sound from a background (the cocktail party effect). The tape combines pure 440 and 443 Hz tones and presents it with noise monaurally. After this segment, the tape combines a pure 440 Hz tone with noise and plays it in the left channel while the right channel plays the 443 Hz tone with noise. In both the monaural and binaural cases the intensities of the tones and the noise are the same.

QUESTION #6: Which set (monaural or binaural) of beats and tones could you hear more clearly?

Now let us look at noise masking again, only this time using just one tone. You will hear a three part sequence repeated several times with a silent interval for separation:

1) a 440 Hz tone and noise signal in both channels, 2) a 440 Hz tone in the left channel only with the same noise in both channels, 3) a 440 Hz tone in both channels with the phase reversed in the right channel and the same noise in both channels. Notice that the

first part is a monaural presentation, while the second and third parts are binaural presentations. Now reverse your headsets and listen to this section of the tape again.

QUESTION #7: In which part was it easiest to hear the tone? In which one was it the hardest? What effect did reversing the headphones have?

D. Localization

The sense of localization of a sound source is a result of binaural hearing. At low frequencies (below 1kHz) localization occurs mainly through detection of the phase difference (for steady sounds) or difference in arrival times (for clicks) of sounds arriving at the two ears. In this section the tape presents a series of .15ms long clicks at 40 Hz. The pulses are first applied to the left channel, then to the right channel. Then the clicks are applied to both channels, however they are timed so that the individual clicks alternate between the two channels. Finally the two channels are played together with the clicks timed so that you hear them simultaneously.

QUESTION #8: What differences did you hear between two different binaural presentations?

In the next segment the click rate of the left channel is slowed slightly compared to the right channel. After thirty seconds of the binaural presentation the two channels are combined to produce a monaural presentation.

The two clicks initially occur together but then the left click falls behind the right and the perceived location of the sound changes from straight ahead to closer to the right ear (since the click arrives first). Eventually the left click fails so far behind that it is closer to following right click and the sound source is perceived top be closer to the left ear.

Question #9: Describe what you heard in the binaural presentation and the monaural presentation.

QUESTION #10: Do humans usually hear in a binaural or monaural way? How do you know?

E. LATERALIZATION

You have now finished the section on monaural and binaural hearing, and now you will look at some common musical illusions.

Often the sound you hear and the sound pattern received by your ear are not the same. As we have seen above, whether you receive the sound pattern binaurally or monaurally can effect what you hear. The next segment you will hear three sequences consisting of two tones alternating between two ears so that when the high pitch tone is in one ear the low pitch tone is in the other.

QUESTION #11 : What do you hear for each sequence?

Separate mechanisms appear to exist for determining the pitch we hear and the lateralization (I.e. which ear we hear the pitch with). Indeed, it appears that there exist several mechanisms for each Below we will list some of the more prominent mechanisms proposed.

Lateralization is toward the ear with

A. The highest pitched sound. B. The greatest sound intensity. C. The ear that receives the sound first.

Perceived pitch determined by

a. The tone in the right ear (Right ear dominant) b. The tone in the left ear (Left ear dominant) c. The tone in either ear (no dominance) d. The ear with the greatest sound intensity. e. Both ears

Question #12: Which combination of these explains your answer to #11? For example if you heard the alternating pitches as they were produced then C and e explain what you heard.

Interesting note: In the first sequence the tones were played at a faster rate than in the second sequence. In the first two sequences the tones were an octave apart, while in the third sequence they were not exactly an octave apart. You might find it interesting to see if your descriptions in #11 show these results.

F. DIPLACUSIS

Some listeners perceive a pure tone as having a different pitch when played in different ears. The next segment of the tape alternates a single high tone between the channels and then a low tone between the channels. If either of these tones sounded different in

different ears you may want to reverse the headphones and listen again to make sure that the recorded tones in the two channels are the same.

G. TWO-TONE SEQUENCE

This experiment permits a more thorough testing of the pitch perception and lateralization hypotheses. A high pitch tone is played three times in the right channel while a low pitched tone is played in the left channel. Then the tones are reversed and played twice in each channel. This sequence is repeated several times and then played at a slower rate. After listening once, reverse the headset and listen to the sequence again.

QUESTION #13: Does the sound always appear to come from the earphone with the high or low pitch tone? Does the pitch that you perceive always come from the same ear?

This five step pattern allows a unique identification of the high and low pitches with the right and left channels.

QUESTION #14: With what you've just done answer question #12 again. Has your answer changed?

H. A SIMPLE MUSICAL SEQUENCE

The next segment of the tape plays a simple C-Major scale. At first an ascending musical scale is played in the right channel while a descending scale is played in the left channel. This is repeated several times, then the rate at which the notes is played is cut down from 1/4 seconds per note to 1/2 second per note. In the second test the notes in sequence are the same as in the first test, but the successive notes in each scale are played in alternate ears. The final test combines the notes from the right and left channels and presents them monaurally.

QUESTION #15: Describe what you hear in each of the three tests.

QUESTION #16: Does your description match your answers for question #14?

I. PERCEPTION OF DISSONANCE

In this section you will hear a guitar duet of ~O Susannah. played when the guitars were slightly out of tune. First you will hear the duet presented monaurally, then you will here it again presented binaurally.

QUESTION #16: Did both versions sound equally dissonant? If not which one sounded less dissonant?

For comparison the songs will again be played first monaurally then binaurally but this time the guitars will be in tune. Notice any changes that this makes.

J. THE MUSICAL STAIRCASE (OPTIONAL)

In this last section you will listen to the rest of the tape. Record on a separate sheet of paper what you think you hear for each of the segments you will hear on the tape. In class, we will hand out an explanation of what was actually on the tape.