PROGRAM ABSTRACTS FOR DEMONSTRATIONS & TEACHING

Simple apparatus for producing auditory illusions

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Deutsch (1982) and others have described a number of auditory illusions that are much like the visual illusions with which we are all familiar. An example is the so-called "scale illusion." In this illusion, the subject is presented with two musical scales at the same time, one ascending, the other descending; however, the notes of each scale alternate between the right and left ears.

One would expect that a listener would simply hear two scales, but that is often not the case. In the left ear, many people hear notes descending, then ascending, while in the right ear they hear notes ascending, then descending. The effect may occur in opposite ears, and there is evidence showing that the illusion is strongly related to handedness. The illusions, which may be heard through loudspeakers as well as through headphones, make excellent classroom demonstrations.

Deutsch used very expensive equipment in her work. It occurred to me that it might be possible to produce these illusions on the Commodore 64 computer, which contains an excellent sound-generating chip. This paper describes a means of using the Commodore for this purpose, at a total cost of under \$250.

Adding a Second Sound Channel. Many of the auditory illusions are binaural, but the Commodore 64 has only one sound chip, the 6581 Sound Interface Device (SID). Thus, to implement many illusions, a second 6581 must be added to the machine. Such an addition is surprisingly simple. Figure 1 shows the circuit.

The additional 6581 essentially is placed in parallel with the 6581 already in the Commodore 64. The machine differentiates between the two units by the connection of the Chip Select (CS) line of the 6581. This line is set up so that the Commodore 64 regards the new sound chip as the optional Z-80 adapter card, eliminating the need for address decoding in the new unit. This places the second 6581 at addresses 56832 and above. The new sound board can be built in approximately 2 h. The only difficulties are in obtaining the 6581 and the connector used to attach the unit to the cartridge port. An old Apple pro-

totyping board was cut to size for this purpose. The audio transistor can be any NPN transistor with characteristics similar to the PN2222 used in the Commodore 64; such units are available at Radio Shack. The 5- and 12-V supplies may be obtained from the Commodore 64 itself, or from an external supply. The sound outputs from pin 3 of the Commodore 64 audio/video connector and from the new adaptor board may be fed to any quality stereo sound system.

Programming considerations. All programming needed to produce the illusions may be done in BASIC. (Remember that the new sound chip appears beginning at memory location 56832.) A sample program for the scale illusion is provided as Listing 1. Line 30 of the program sets up constants for the durations of the notes and spaces between the notes. Line 40 sets up base addresses for the two sound chips. Lines 100-120 set up parameters for the proper operation of the SIDs. These chips are so complex that their operation cannot be described here.

Figure 1. Auditory illusion circuitry.

The interested reader is referred to Appendix O of the *Commodore 64 Programmer's Reference Guide* (Commodore Business Machines, 1984) for operational details. Line 300 reads in the values needed to set up proper frequencies for each note, and line 400 reads the scrambled scales.

The scales are played 10 times, as determined by the loop beginning at line 710. Each scale is played by the loop starting at line 720. In lines 800-870 the frequencies are set up, the tones started by poking 17 to the base address + 4 of each chip, and the tones stopped by poking 16 to the same address. Lines 6000-6010 contain the values for four octaves of notes, beginning with the A of 110 Hz. The remaining lines contain the scrambled scales.

Discussion. I have successfully implemented many illusions with this system: the octave illusion, the scale illusion, a chromatic scale illusion, the Warren and Warren (1970) confusing sounds, Deutsch's (1972) "Yankee-Doodle" illusion, and many others. Because programming may be done in BASIC, development of new illusions is very simple.

In some ways, the equipment described is inferior to that of Deutsch (1982). The 6581, for example, cannot generate a pure sine wave; a triangular wave was used in our work. There is a slight digital "hash" in the background of the sounds. At the same time, the 6581 offers a bewildering array of waveforms and choices of attack, delay, types of filtering, filter frequency, and so on, that were not easily available to Deutsch in her work.

Availability. Listings of all programs mentioned in this paper may be obtained from the author at no charge. If the reader supplies a disk, it will be returned with the programs, at no charge.

REFERENCES

- COMMODORE BUSINESS MACHINES. (1984). *Commodore 64 programmer's reference guide*. Wayne, PA: Author.
- DEUTSCH, D. (1972). Octave generalization and tune recognition. *Perception & Psychophysics*, 11, 411-412.
- DEUTSCH, D. (Ed.). (1982). *The psychology of music*. New York: Academic Press.
- WARREN, R. M., & WARREN, R. P. (1970). Auditory illusions and confusions. *Scientific American*, 223, 30-36.

LISTING 1 BASIC Program for the Scale Illusion

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10 REM SCALE ILLUSION PROGRAM FOR O'DELL PAPER
20 DIM HI(48),LO(48),NO(50),SC(8),RH(10),LH(10)
30 D1=300: D2=50                                :REM DELAY CONSTANTS
40 S=54272: T=56832                               :REM LOCAT OF 6581'S
50 FOR K= S TO S+24: POKE K,0: NEXT              :REM CLEAR LH CHIP
60 FOR K= T TO T+24: POKE K,0: NEXT              :REM CLEAR RH CHIP
100 POKE S+5, 0: POKE T+5, 0                     :REM NO ATTACK, DELAY
110 POKE S+6, 240: POKE T+6, 240                 :REM MAXIMUM SUSTAIN
120 POKE S+24, 15: POKE T+24, 15                 :REM MAXIMUM VOLUME
300 FOR K=1 TO 48: READ HI(K),LO(K): NEXT        :REM READ NOTE TABLE
400 FOR J=1 TO 8: READ LH(J),RH(J): NEXT        :REM READ SCALES
700 REM NOW PLAY TONES
710 FOR MM=1 TO 10                               :REM PLAY 10 TIMES
720 FOR K=1 TO 8                                 :REM SCALE = 8 NOTES
800 POKE S+0,LO(LH(K)): POKE S+1,HI(LH(K))       :REM SET UP LH TONES
820 POKE T+0,LO(RH(K)): POKE T+1,HI(RH(K))       :REM SET UP RH TONES
840 POKE S+4,17: POKE T+4,17                     :REM TURN ON TONES
850 FOR I=1 TO D1: NEXT                          :REM DURATION OF TONE
860 POKE S+4,16: POKE T+4,16                     :REM TURN OFF TONES
870 FOR I=1 TO D2: NEXT                          :REM DURATION BET TONES
880 NEXT K                                         :REM END OF SCALE
890 FOR I=1 TO 500: NEXT                         :REM DELAY BET SCALES
900 NEXT MM                                       :REM END OF 10X LOOP
5000 REM NOTE TABLE FOLLOWS
6000 DATA 7,12,7,119,7,233,8,97,8,225          :REM OSCILLATOR FREQ VALUES
6010 DATA 9,104,9,247,10,143,11,48              :REM BEGINNING AT A-2
6020 DATA 11,218,12,143,13,78                   :REM SEE PROGRAMMER'S REFERENCE
6030 DATA 14,24,14,239,15,210,16,195            :REM MANUAL P 385 FF.
6040 DATA 17,195,18,209,19,239,21,31
6050 DATA 22,96,23,181,25,30,26,156
6060 DATA 28,49,29,233,31,165,33,135
6070 DATA 35,134,37,162,39,223,42,62
6080 DATA 44,193,47,107,50,60,53,57
6090 DATA 56,99,59,190,63,75,67,15
6100 DATA 71,12,75,69,79,191,84,125
6110 DATA 89,131,94,214,100,121,106,115
7000 REM SCALE ILLUSION TONES FOLLOW
7010 DATA 4,16,15,6,8,13,11,9                  :REM SCRAMBLED SCALE VALUES
7020 DATA 11,9,8,13,15,6,4,16

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