A procedure and instrumentation for presenting luminous numeric response cues in a nonverbal auditory serial position task

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This report describes the use of a luminous numeric display to generate response cues in a forced-choice recall task for nonverbal auditory (pitch) sequences. A response cue display (RCD) was constructed for this purpose. The RCD is triggered by a 3-bit binary configuration of sine-wave logic tones. The logic tones were recorded on an alternate track of magnetic recording tape synchronous with the sequential audio stimulus events.

The procedure and instrumentation described herein was developed for nonverbal auditory (pitch) memory experimentation at the Systematic Musicology Laboratory, University of Washington, Seattle. Subjects were requested to recall a single tone from a designated serial position within a pitch sequence, and demonstrate that pitch by singing (Williams, 1973). For a typical experimental task, subjects listened to a pitch sequence, waited a variable delay time (0 to 15 sec), and then responded to a cue which indicated the position of the pitch they were to recall from a sequence.

The nature of the task imposed several constraints on designing a response cue device to indicate the appropriate recall position. First, since retention was to be measured over time, the variable timing between offset of the last pitch in a sequence and the presentation of the response cue had to be precisely controlled. Second, the response cue had to be presented visually. Any form of auditory response cue could possibly interfere with the subjects' processing of the pitch sequence. Third, the visual response cue had to be nonsequential. A visual series of cues corresponding to the serial positions of the stimulus would have offered

Figure 1. Response cue display (RCD).

subjects a visual continuum to use as a retention aid. And finally, due to the large number of experimental trials required and the necessity for rigorous control over timing, the instrumentation for presenting the response

Recorded Audio Tape		
TRACK 1	Tone ₁ , T ₂ , . . . T ₇	Delay time (0 to 15 secs)
TRACK 2		*Logic tone(s) to trigger RCD

Figure 2. Recorded pitch events on the audio-stimulus tape (Track 1 is audible to the subject; Track 2 is inaudible to the subject).

Figure 3. Set-up during an experimental session with the RCD device.

cues had to be automated and synchronized with the stimulus events.

The instrumentation devised for the pitch experimentation used a single luminous numeric display indicating the serial position to be recalled—a position between 1 and 7. A response cue display (RCD) was constructed for this purpose (Figure 1). The RCD displayed a luminous number between 1 and 7 when triggered by a three-bit binary configuration of sine-wave logic tones. The three bits were represented by 1,800-, 600-, and 200-Hz logic tones for Bits 1, 2, and 3, respectively. Thus, if the logic tones appeared singularly, then the 1,800-Hz tone would trigger the numeral 1 to appear (binary 0 0 1), the 600-Hz tone, the numeral 2 (0 1 0), and the 200-Hz tone, the numeral 4 (1 0 0). Simultaneous combinations of two logic tones triggered the numerals 3 (600 plus 1,800 Hz or 1 0 1), 6 (200 plus 600 Hz or 1 1 0), and 5 (200 plus 1,800 Hz or 1 0 1). All three logic tones simultaneously triggered the numeral 7 (1 1 1) on the RCD.

The sine-wave logic tones were recorded on Track 2 of the prepared audio-stimulus tape synchronous with the sequential pitch events to be heard by subjects. The relationship of the stimulus audio to the logic tones is

Figure 4. Schematic diagram of the RCD.

illustrated in Figure 2. Up to seven pitches were recorded in sequence on Track 1 of the stimulus magnetic recording tape. Then, after a variable delay time of 0 to 15 sec, the logic tone configuration was recorded on Track 2 of the tape. The logic tones were sounded for 5 sec so that during an experimental session, the luminous number appeared on the RCD for the duration of the response time.

Grason-Stadler 1200 Series programming equipment controlled the preset selection and timing of three sine-wave generators tuned to 200, 600, and 1,800 Hz (details available in Williams, 1973).

Figure 3 illustrates the subject station arrangement during an experimental session. For playback of the audio-stimulus tape, the output of Track 1 went directly to the subject's headphones. Track 2 logic-tone audio was output to the RCD device which would luminate a number when triggered by the logic tones recorded on this track of the tape. Track 2 was inaudible to the subject.

The internal construction of the device is shown in Figure 4. The presence or absence of each of the three sine-wave tones is sensed by a separate tuned filter, rectifier, and threshold circuit. By the time the signals get to the 7447 decoder/driver, the analog tones have been separated and converted to standard digital logic levels. The three bits are then decoded in the binary to seven-segment decoder/driver and the appropriate segments of the seven-segment display turned on. Grounding Pin 5 of the 7447 causes the display to be dark when no tones are present. Leaving this pin open causes the display to indicate zero when no tones are present. The frequencies of the three tones are: 200 Hz for the 4's bit, 600 Hz for the 2's bit, and 1,800 Hz for the 1's bit. Each tone is meant to be presented at a level of -10 dBm (two tones at -7 dBm, three tones at -5 dBm). The actual threshold of each tone detector is

f_c = center frequency

Q = parameter for sharpness of resonance

$$X = \frac{1}{2\pi f_c C}$$

$$R_2 = 2QX$$

$$R_1 = X/2Q$$

$$\text{Gain at } f_c = R_2/2R_1 = 2Q^2$$

$$\text{Input impedance} = R_1 (1 + i/4Q)$$

The circuit must be driven from an impedance small compared to this input impedance.

Figure 5. General schematic diagram of the tuned amplifier circuit used in the RCD.

at -23 dBm, so there is 13 dB of margin for tape dropouts, etc. At this recorded level, there was no audible crosstalk into the other channel of the TEAC 6010 tape recorder.

The tuned amplifier may also be useful in a variety of other situations and is depicted separately in Figure 5, along with equations governing its use.

REFERENCE

- Williams, D. B. Short-term retention of pitch sequence: Effects of sequence length, serial position, and delay in time before recall. (Doctoral dissertation, University of Washington) Ann Arbor, Michigan: University Microfilms, 1974, No. 74-2283.

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