Synchronization of Cinefluorography and Speech Observations

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In recent years, the utilization of cinefluorography has provided useful information for the study of speech mechanism. There is a need, however, to develop suitable methods for synchronous observation of articulation skills and of the velopharyngeal mechanism.

Synchronization systems may be divided into two groups: a) direct methods, by which the sound being produced is recorded on the cinefilm as the sound track, and b) indirect methods, in which the sound is recorded separately on other recording apparatus.

Moll (*3*) has applied a direct method by using the Auricon cinecamera and obtained the synchronization between articulatory movements and sound. In an indirect method, such as when the speed of the cinecamera and that of the recording apparatus (tape-recorder or electromyograph recorder) are different, exact synchronization cannot be expected without any correlated time axis, particularly if the speed of each of them may vary slightly. To solve this problem, Lubker and Moll (*2*) have reported the use of a spike signal generator for synchronization between articulatory movements and the oral-nasal air flow measurements. In their work, one spike signal per second is the correlated time axis between the cinefluorographic film and the air flow records. Björk (*1*) and Nylén (*4*) have reported a synchronization device which delivers marking pulses on both the cinefilm and the sound tape for the synchronization between articulatory movements and the sound which is produced. This pulse is generated at every tenth frame by the frame signals derived from the driving shaft of cinecamera. This method is one of the most suitable ways in synchronizing the cinefluorogram with sound.

There have been attempts at measuring time, notably that by Umeno (*5*), but in all the attempts there is the methodological difficulty in the measurement of correct time.

The present study was designed for the purposes of a) synchronizing the articulatory movements with sounds being produced and b) obtaining correct time relationships between the movements and the sounds for evaluating the articulatory mechanism in a quantitative form.

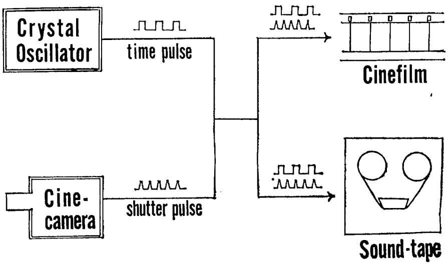

FIGURE 1. Pulse marking method.

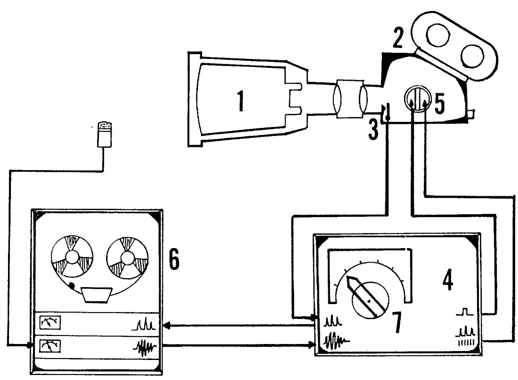

FIGURE 2. Block diagram: (1) image intensifier, (2) cinecamera, (3) a shutter switch, (4) a crystal oscillator, (5) double-neon marking apparatus, (6) tape recorder, (7) pulse amplifier unit.

Equipment

Two signals are necessary; a synchronizing pulse and a time pulse. The time pulse from a crystal oscillator and the shutter pulse from the cinecamera are fed into both cinefilm and sound tape simultaneously. By corresponding the shutter marks of both cinefilm and sound tape, exact synchronization is expected, and the measurement of correct time can be made (Figure 1). Thus, the articulatory movements and their related phenomena can be analyzed simultaneously and quantitatively as a function of time.

Figure 2 shows the block diagram of this apparatus. It consists of a pulse generator, a double-neon marking apparatus, a shutter pulse switch in the cinecamera, and a two-channel magnetic tape recorder.

The pulse generator consists of a crystal oscillator and a pulse amplifier unit for a light power supply to mark on the cinefilm. The crystal oscillator generates the time pulse of 60 Hz. From it, pulses of 5, 10, 15, 30 Hz can be produced by dividing the circuit.

The cinecamera is an Arriflex 16 mm, in which a shutter switch and a double-neon marking apparatus are fixed. The shutter pulse is generated from this shutter switch at the moment the camera shutter begins to open. The double-neon marking apparatus, which can mark various sig-

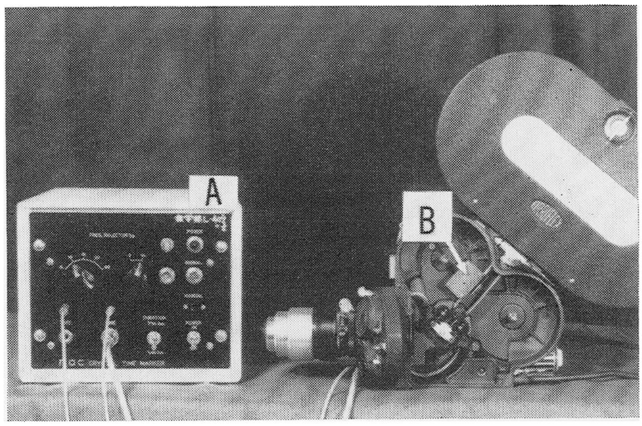

FIGURE 3. A, pulse generator and B, double-neon marking apparatus.

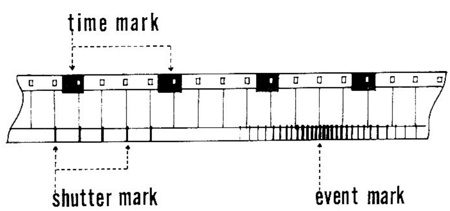

FIGURE 4. Marks on the cinefilm.

nals on the cinefilm, is 20 frames ahead of the camera aperture (Figure 3). This apparatus marks the time pulse on one side of cinefilm and the shutter pulse and the event mark (acoustic signal) on the other side of it. A two-channel magnetic tape recorder (Sony 777 4JS) is used. The film motion analyzer has a frame counter; articulatory movements are analyzed quantitatively. The image intensifier is a Siemens 7-inch tube.

Procedure

The subjects were two groups of men: five normal adults (aged 24 years) who showed normal articulation and five postoperative cleft palate patients (aged 16 to 24 years) who exhibited abnormal speech patterns. All subjects were instructed to demonstrate normal pitch and intensity in all phonations; the films were exposed at a speed of 64 frames per second.

Since a shutter pulse is marked on the same position of each frame, a continuous marking on the cinefilm is unnecessary. Instead, it is desired that sound or other phenomena are recorded on the cinefilm as the event mark, after switching off the shutter pulse (Figures 4 and 5). In practice, the shutter pulse is switched on after the cinecamera starts and switched off just before phonation begins.

The shutter pulse is recorded in one channel of the tape recorder, and

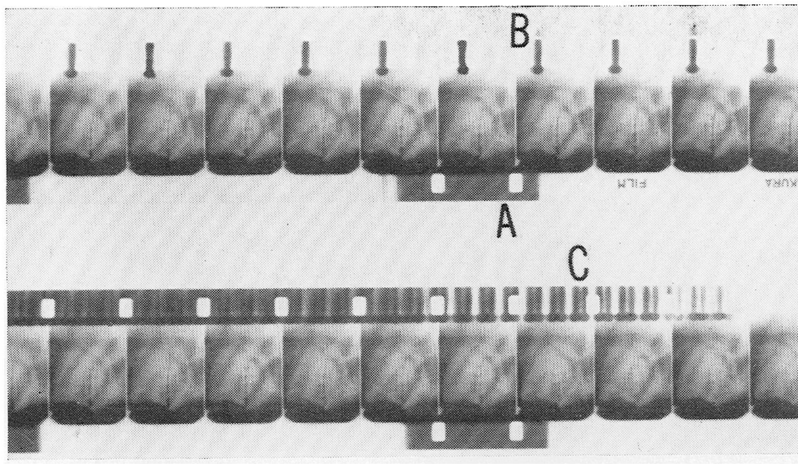

FIGURE 5. Actual 16 mm cinefluorographic film. A, time mark; B, shutter mark; and C, event mark as an acoustic signal. Time pulse: 10 Hz. Shutter pulse: 64 f/s.

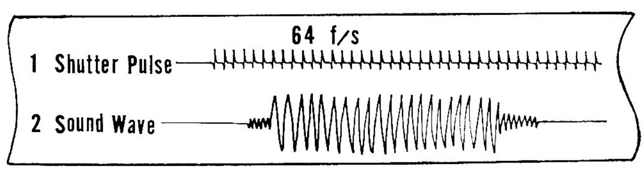

FIGURE 6. Marks on the oscillographic paper.

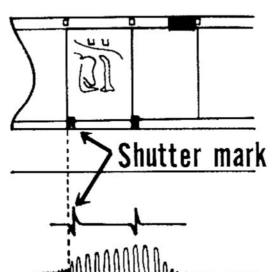

FIGURE 7. Corresponded shutter marks for synchronization.

the sound on the other channel (Figure 6). From the tape, the sound data and shutter pulse are photographed on oscillographic paper at the rate of 75 cm per second.

The two shutter marks are matched by counting the number of the shutter pulses from the beginning. Afterwards, by reducing 20 shutter marks on the cinefilm, the cinefluorographic picture is identified with the oscillographic paper. By this method, good synchronization between the cinefilm and the sound (or other phenomena) is obtained (Figure 7).

Figure 8 shows by an actual photograph the correspondence of the

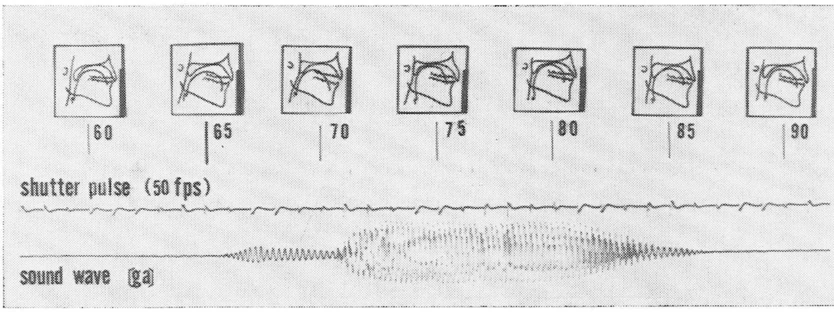

FIGURE 8. Synchronization of cinefluorographic picture with sound being produced. Figure shows the frame number. Shutter pulse is 50 f/s, and the sound is /gɑ/.

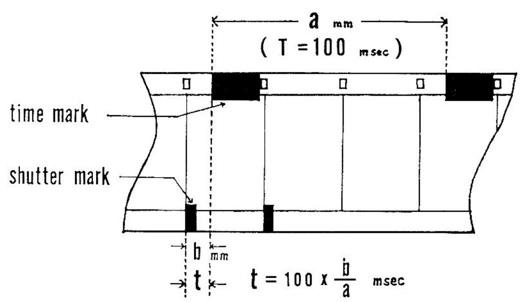

FIGURE 9. Time relationship between shutter and time mark.

tracing of the cinefilm with the oscillographic paper. The measurement of correct time can be made by the relationship between the time and the shutter mark on the cinefilm. The correct time is indicated as the distance between the time pulses. For instance, as Figure 9 shows, if the time mark interval is 100 msec, which is equal to a mm in length, and the length between the time and the shutter mark shows b mm, then the time of b mm, shown as time t, is calculated as $100 \times b/a$ msec. By this relationship between the shutter and the time mark, the time of the shutter mark as well as the starting time of the movement in each frame is determined.

Example 1. Figure 10 demonstrates the quantitative analysis of velopharyngeal closure and the time relationship between the sound and the articulatory movement associated with the Japanese vowel /ɑ/ in a normal subject. The abscissa shows time; the level of velopharyngeal closure is shown as ordinate. Closure of the velopharynx is represented by 100%; total possible opening of velopharynx (when the velum is at the rest position) is shown as 0%. On Figure 10, the time point in this pattern is represented as follows: S, start of palatal movement; C, closure of velopharynx; O, opening of velopharynx; and E, end of palatal movement.

If the onset of the phonation is represented as 0 msec, the beginning of palatal movement is calculated −503 msec and the velopharyngeal closure is −15 msec.

Example 2. In Figure 11, the Japanese vowel /ɑ/ and the syllable /kɑ/ are com-

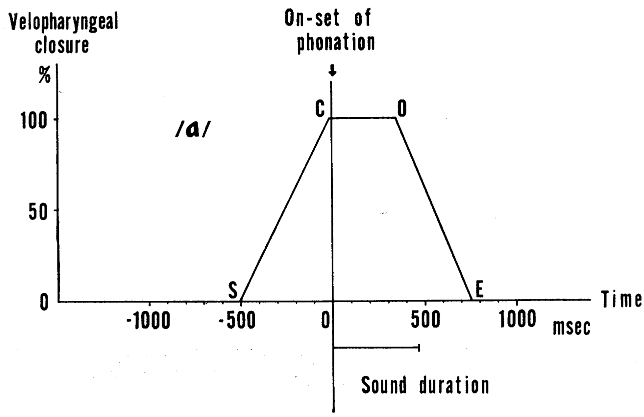

FIGURE 10. Time relationship between the sound and articulatory movement in a normal subject: S, start of palatal movement; C, closure of velopharynx; O, opening of velopharynx; E, end of palatal movement.

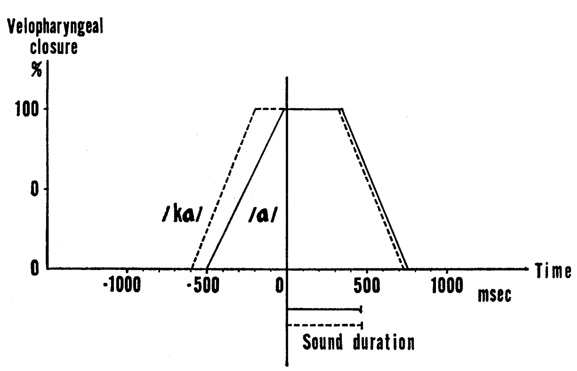

FIGURE 11. Time relationship for the differences between speech tasks.

pared for the same subject. The figure reveals that the palatal movement in phonating /kɑ/ requires more time before the onset of phonation than /ɑ/ but that the process of palatal movement shows almost the same pattern for the two tasks.

Example 3. The abnormal articulation of a postoperative cleft palate subject is compared with a normal subject in Figure 12. Speech samples are Japanese vowels /ɑ/ and /i/, and consonants /kɑ/ and /ki/. In each speech sample, velopharyngeal closure is incomplete for the cleft palate subject and the palatal movement for closure requires much more time for the cleft palate subject than for the normal subject. In addition, the time ratio between closure duration and sound duration is very low: 0.53 for /i/ and 0.26 for /ki/ for the cleft palate subject. The normal subject shows 1.27 and 1.23, respectively. The following minimum openings of the velopharynx were observed after the onset of phonation: /ɑ/, 163 msec; /kɑ/, 77 msec; /i/, 91 msec; and /ki/, 141 msec. The closure level is 80%, 88%, 44%, and 43% respectively. The cleft palate subject shown in Figure 12 exhibits lower closure level and time delay for closing in /ki/ than in /kɑ/. This relationship is also observed between /ɑ/ and /i/, suggesting that this patient has incompetency of palatal movement and difficulty in preparing for such articulation as /i/ or /ki/.

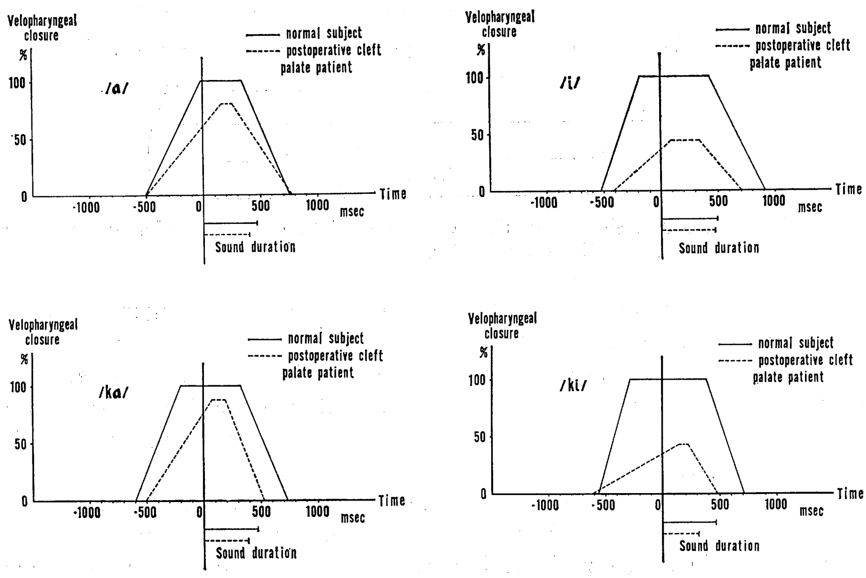

FIGURE 12. Time relationship for the difference between subjects.

Discussion

Since this study was concerned with methodology, the examples were few and the analysis of the speech structure was limited only to the velopharyngeal mechanism. Other data reduction procedures indicate that the cinefluorographic investigation combined with the time axis can provide means for evaluating the function of velar movement in a variety of speech samples and types of subjects.

In the analysis of the time element in cinefluorography, the minimum component or unit is the frame; therefore, the accuracy of the analysis depends on the number of frames per second. In the ordinary cinecamera with a dc variable motor, constant speed with no fluctuation is difficult to be obtained. Therefore, each frame does not always have the same correct time duration. By the method used here, however, it is possible to calculate exactly the time of shutter opening through the positioning of both shutter and time marks, even if the camera speed is not constant. Consequently, the time analysis of the movement can be performed for each frame unit. If the duration between the two frames is $\frac{1}{64}$ second (15.6 msec; 64 frames per second), the movement shown in one frame is sected by the time interval of $\frac{1}{128}$ second (7.8 msec) because the camera shutter sector is 180° in the Arriflex 16 cinecamera (at least for the one which we use). For detailed analysis of movement, high camera speeds should be used. Thus, the time relationship between the cinefluorographic picture and another phenomenon, synchronized through the shutter pulse, is analyzed with ease and accuracy.

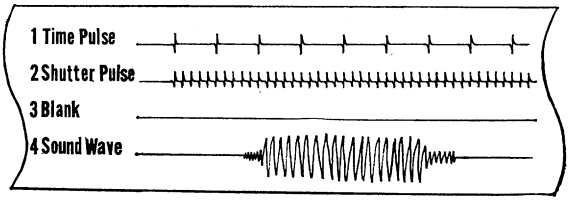

FIGURE 13. Time, shutter marks, and sound data on the oscillographic paper from a four-channel magnetic tape recorder.

If a four-channel magnetic tape recorder is used, as in Figure 13, time pulse, shutter pulse, and sound wave are all recorded simultaneously. This is a more suitable way of analyzing the data easily. If a tape recorder is not used, however, these three signals may be led directly to a four-channel oscilloscope and photographed on paper through the oscillograph camera.

In the further investigation of articulatory mechanism, this apparatus makes it possible to synchronize the articulatory movements not only with sound, but also with such measures as oral and nasal air flow and rate, pressure, and electromyography.

In other fields (for example, in cineangiocardiography) the synchronization of cardiac sound and pressure with electrocardiography is valuable for the analysis of its function.

Summary

A method was designed to synchronize the cinefluorographic picture with sound and to measure the correct time for the articulation. In the synchronization system used here, a shutter pulse from the cinecamera is delivered to both cinefilm and sound tape simultaneously. By corresponding shutter marks of both cinefilm and oscillographic paper, the identification is made. For the measurement of correct time, a time pulse from the crystal oscillator is marked on the cinefilm; the time is calculated from the positioning of both time and shutter marks. Thus, the time relationship between the articulatory movements and sound is obtained. By this method, physiological characteristics of articulation were evaluated.

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