Publications of Dr. Martin Rothenberg:

Interpolating Subglottal Pressure from Oral Pressure

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Journal of Speech and hearing Disorders, No. 47, pp. 218-224, May 1982
(Received August 28, 1981; Accepted September 17, 1981)

Smitheran and Hixon (1981) recently used intraoral pressure during an unvoiced stop as a measure of the subglottal pressure in adjoining vowels. I would commend the authors for testing the applicability of this method in a clinical situation, though I have a few suggestions that potential users might want to keep in mind.

When using this technique in a previous study (Rothenberg, 1973), I suggested that the consonant used be a geminated unvoiced-voiced pair, as /pb/ in the sequence b V p b V p b V pb - - - for bilabial consonants and a vowel V. An English-speaking subject can be instructed to repeat the syllable /b V p/. Because of the added /b/, the vocal folds are adducted again at or just before the articulatory release. This greatly reduces the drop in subglottal pressure that would be caused by the aspiration of the /p/ release; and thus makes the peak intraoral pressure during the closure more nearly equal to the subglottal pressure during the following vowel. The error caused by the aspiration would naturally vary with the degree of aspiration. This error may be small with the short periods of aspiration shown in the example of their Figure 1, but could be appreciable in other cases.

A potential user of this method should also be cautioned that the response time of the entire pressure measurement system (the time required to respond to a sudden change in pressure) including the pressure transducer. sholild be less than the shortest oral closure time expected. For example, long catheters of very narrow diameter can greatly lengthen this response time, especially if there is a large air volume between the catheter and the transducer diaphragm. The response time of the total system can be measured by recording the system's response to a sudden change of pressure. The simplest methods for accomplishing this usually involve the release, or driving quickly to zero, of a constant pressure at the probe tip. For example, one can hold a pressure in the catheter by means of a finger over the tip, and then quickly remove the finger, or the syllable /pa/ can be produced with the probe tip between the lips, and the decay in the system output after the release of the /p/ measured. The resulting response can be recorded on a chart recorder or storage oscilloscope.

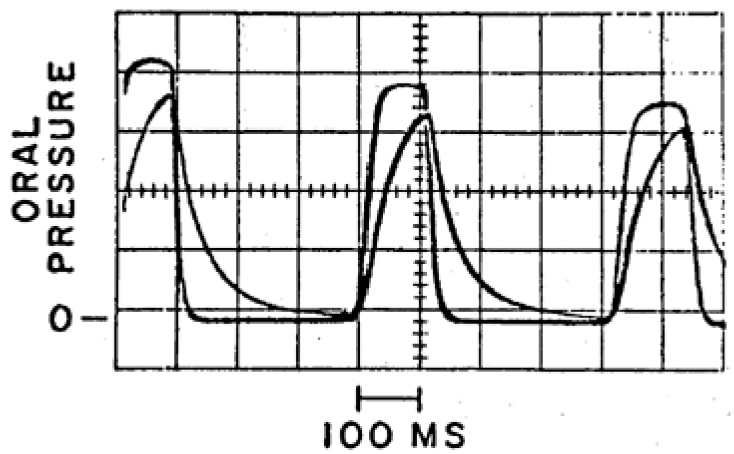

FIGURE 1. Intraoral pressure during contiguous repetitions of the syllable /pa/ as measured by two transducer systems having different response times.

To illustrate the effect of too slow a response time, the oscilloscope traces below show the simultaneous response of two transducers to a repetition of /pa/, when each was connected to a catheter between the lips. The amplitude calibration was the same for both transducers; however, because of different catheters, one had a total response time, defined here as the time required for attaining 95% of a sudden change, of roughly 40 msec, while the other required about 1.80 msec. The slower system only attained 85-90% of the true oral pressure before the release occurred for closure periods of 100 to 150 msec. The response of the fast-responding transducer shows a flat or slightly rounded peak, that approximates the subglottal pressure during the lip closure, while the slow-responding system shows a sharp peak at the instant of articulatory release.

To measure the system response time, it is not sufficient to measure the response to the electronics alone, as Smitheran and Hixon appear to have done. They are not clear on this point, but the pressure curve in their Figure 1. indicates a frequency restriction on the complete pressure system much lower than the 30 Hz they mentioned. Though the time scale in the figure permits only a very rough estimate, I would judge the time constant τ of the primarily system-determined pressure decay after each release (the time required to reach 1/e of the initial value), to be roughly 25 msec. Using the equation $f_c = 1/2\tau\pi$ which is valid for simple dynamic systems of this type, I would estimate the total system frequency response to be flat to only about 6 Hz. The total response time, as defined above, is about three times the time constant for a simple, exponential response, and so would be about 85 msec. With this restriction, the measurements of peak oral pressure made from Figure 1. would have been about 5% low.

I would also favor a syllable repetition rate somewhat higher than the 1.5 per second that they chose, because of the possibility of the subject making separate respiratory gestures for each syllable at rates slower than about 2 per second. Variations of respiratory activity within a syllable tend to invalidate the continuity assumption on which this method is based. Respiratory gestures within the syllable can usually be detected by a significant variation of oral pressure within the period of articulatory closure, especially a peak at or just before the release, as shown in Figure 2, made by repeating the syllable /b ae p/ with a relatively constant subglottal pressure (top trace), and with separate respiratory gestures for each syllable (bottom trace).

In order to see the true variation of oral pressure in the pressure tracing, the system response time must be no greater than about 1/3 the closure period. Since closure periods of as little as 90-100 msec can be expected, it would be necessary for the pressure system response time to be no greater than about 30 msec, with no insignificant resonances or overshoot due to the transducer diaphragm, the acoustic system formed by the catheter and air chamber over the diaphragm, or the conditioning electronics. A resonance-free response in under 30 msec should be easily attainable with a number of transducers now available. The system response in this case was about 10 msec, as can be verifed by the return-to-zero speed after each release, and so the waveform during the period of complete closure is a fairly good indicator of the subglottal pressure during that period. The primary exception is the occasional small decrease in pressure prior to the sharp drop signaling the articulatory release. This small decrease in pressure is probably caused by the closure of the vocal folds as they come to the position for voicing (for the /b/ during the period of articulatory closure, and momentarily seal the oral cavity. Since the mandible is dropping for the articulatory opening at this time, the volume of the oral cavity is increasing, and so the oral pressure would show a decrease that may not be present in the subglottal pressure. (This artifact does not occur when using only a /p/ for the intervocalic consonant.) To clarify the relationship of oral and subglottal pressures with a fast-responding sensing system, the dashed lines in Figure 2 were sketched to show what the underlying subglottal pressure variation might have been for each case, neglecting the slight decrease in subglottal pressure during the vowel caused by the airflow acting on the subglottal flow resistance.

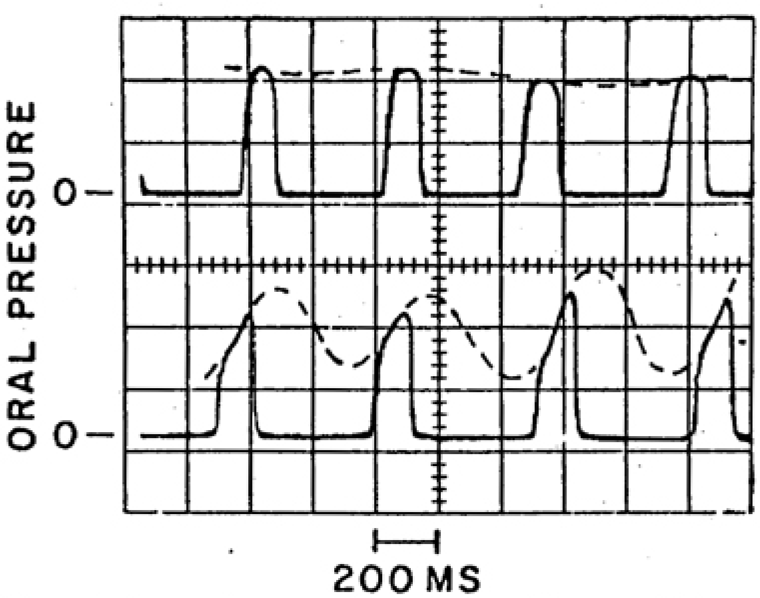

FIGURE 2. Intraoral pressure during two productions of the repeated syllable /bæp/. The top trace was produced with a relatively constant subglottal pressure while the bottom trace was produced with a distinct respiratory gesture during each syllable.

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