Electromyographic study of lip activity in Swedish CV:C and CVC: syllables

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The present study is an extension of a previous EMG experiment concerning Swedish bisyllabic nonsense words (to be published). In the previous study surface electrodes were placed at the vermilion border of the upper lip, some 5 mm below the vermilion border of the lower lip, and on the tip and blade[1] of the tongue. Six front vowels and one central vowel were investigated, the vowels being in the frame [t ___ tən]. There were four long and three short vowels. Since in Swedish short vowels are always followed by either a long consonant or a consonant cluster, the utterances would be either [tV:tən] or [tVt:ən].

The earlier study provided the following data pertinent to the present study: (1) the five rounded vowels [y:, ø:, ʉ:, œ, ŭ][2] showed a consist-

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1 The term "blade" is used in the sense of Abercrombie and Ladefoged (more fronted than "middle" and "back").

2 The symbols ʉ and ŭ are taken from the Swedish dialectal alphabet. The vowel [ʉ] can be described with reference to the IPA vowel [ʉ], which is a close, central rounded vowel. The Swedish sound is less close and, at least in the dialect investigated, more fronted. It has a characteristic rounding, similar to that for whistling. The vowel [ŭ] is a central, half-open, less rounded vowel. It is sometimes transcribed with the IPA symbol θ.

ent difference between the EMG activity recorded from the upper lip, sufficiently characteristic to make a distinction between them possible; (2) the electrode placed on the blade of the tongue showed, in most instances, a double peak of activity for the [t:] following a short vowel. This double peak was preliminarily interpreted as a gemination phenomenon; (3) it was not clear which muscle was being recorded by the electrode placed below the vermilion border of the lower lip. In most respects the EMG data from this electrode did not agree with those taken from the upper lip. It was assumed that the lower lip electrode was picking up activity from more than one muscle, presumably mainly from the depressor labii inferioris. It is difficult to interpret EMG recordings made with surface electrodes for this very reason. In the present experiment, an attempt was made to clarify some of these earlier data.

One subject was used in this pilot study (the same subject as in the earlier experiment). Nine long and eight short vowels were investigated. They were produced in the frame dɪ'd ___ d(:)ɪn. In addition, four long and four short vowels were investigated in the context dɪ'p ___ p(:)ɪn. All the utterances are nonsense words in Swedish, and all were pronounced with the "acute" word tone (accent 1). The frame dɪ'd ___ d(:)ɪn was chosen to provide a neutral context for the lip articulation of the vowels. The frame dɪ'p ___ p(:)ɪn, on the other hand, was chosen in order to test whether the articulation of the second [p] as indicated by the lip electrodes, would show some indication of gemination following short vowels, similar to that suggested by the articulation of [t:] in the earlier study.

The Swedish vowels used in this study are shown below, with key words given in Swedish orthography.

Symbol	Key Word	Symbol	Key Word
i:	rita (to write)	ɪ	ritt (ride)
e:	reta (to tease)	–[3]	
ɛ:	räta (to straighten)	ɛ	rätt (right)
y:	ryta (to roar)	ʏ	rytt- (rid- as in "rider")
ø:	röta (to rot)	œ	rött (red)
ʉ:	ruta (square)	ŭ	rutt (route)
u:	rota (to poke about)	ʊ	rott (rowed)
o:	Rota (a Norn)	ɔ	rått (raw)
ɑ:	rata (to refuse)	a	ratt (steering-wheel)

[y:, ʏ, ø:, œ, u:, ʊ, ʉ:, ŭ, o:, ɔ] and perhaps [ɑ:] are considered to be articulated with some degree of lip-rounding.

Electromyographic data for these utterances were recorded from three points: the upper and lower parts of the orbicularis oris muscle and the depressor labii inferioris. Bipolar thin wire electrodes were used, a technique reported among others by Basmajian and Stecko (1962) but modified for speech research by Hirano et al. This technique in-

3 Swedish is often said to have 18 vowel phonemes, 9 long and 9 short. However, in many dialects, for instance Central Swedish, there is no distinction between [e] and [ɛ], which are both pronounced [ɛ]. This merging seems to become more and more common also in Southern Swedish. Since the speaker (who speaks a South Swedish dialect) did not make any distinction between the two sounds, [e] was excluded from the vowel list.

volves the use of two very thin coated wires, which have been pulled through a hypodermic needle, the ends being bent backwards over the sharp (beveled) end of the needle. One wire is made slightly shorter than the other in order to avoid short circuiting. When the needle is inserted into the muscle and withdrawn again, the "hooked" electrodes are left behind in the muscle. They remain in place during articulation and phonation but are quite easy to remove by pulling the wire. For detailed description and illustrations of the method as used at the Phonetics Laboratory of UCLA, see Hirano et al. (1967 a, b, and c, 1969).

In the present study one pair of hooked wires were inserted on the midline of the upper lip, just above the vermilion border. Another pair was similarly placed just below the vermilion border of the lower lip. The third electrode was inserted between the vermilion border of the lower lip and the edge of the chin, between the midline and the corner of the mouth. Various gestures were performed and recorded, as closing, opening, protruding and everting the lips to test the position of the electrodes. The same gestures were performed and recorded at the end of the run as a control that the electrodes were still in the same position. The activity patterns in these gestures are shown in figs. 1-4.

The electrodes were connected with a preamplifier. The electromyographic activity and the audio signal were recorded on tape simultaneously. The tape recorder had an extra playback head and amplifier to be used for computer processing of data. The EMG and audio data of 20 samples of each utterance were rectified, averaged, and smoothed using the Linc-8 computer as described by Harshman and Ladefoged (1967).

The findings of this preliminary study can be summarized briefly as follows: (1) In terms of onset time, offset time, and location of peaks, the EMG data from the upper and lower parts of the orbicularis oris muscle were in reasonable agreement. One curious but interesting fact, quite consistent throughout the data, is that the EMG from the lower lip always led the EMG from the upper lip by about 40–50 msec (again in terms of onset peak, peak location, and offset time). No explanation for this is offered at this time. See figs. 5–9. As can be seen from figs. 1–4 no such consistent difference in timing occurs in the production of the non-phonatory gestures. (2) The averaged amplitude of the EMG from these two parts of the orbicularis oris was not the same for different vowels. Figs. 5–7 show the averaged EMG and audio signals for the utterances [dɪ'dy:dɪn], [dɪ'dʉ:dɪn] and [dɪ'du:dɪn]. Here one can see that while the signals for the lower lip for each vowel are quite similar, the upper lip EMG data differ considerably, depending upon the type of vowel involved. Thus the different types of rounding were manifested in a difference in the EMG of the upper lip, but of the upper lip only. (3) In figs. 8 and 9 the averaged EMG and audio signals for the utterances [dɪ'pi:pɪn] and [dɪ'pɪp:ɪn] are shown. In the case of the former it is clear that there is only a single peak associated with the second [p]. In the latter case there is a high initial peak followed by a prolongation of the activity at a lower amplitude after a small "dip". Although a second peak could be observed in several individual samples, two clearly defined peaks with a marked dip between were not consistently found which could be associated with a gemination of the consonant following short vowels. The picture can probably equally well be explained as a relaxation and following pick-up of activity due to the extra effort necessary for the prolonged articulatory activity for [p:]; this activity is however clearly very different from that for [p].

The electrode assumed to be located in the depressor labii inferioris gave results that were particularly difficult to interpret. Earlier results with similar samples by the same speaker but with surface electrodes (cf. p. 1), where one electrode was placed ca 5 mm below the vermilion border of the lower lip, were interpreted as showing activity of the orbicularis oris muscle contaminated by activity of the depressor. This time an effort was made to separate the two muscles using two pairs of needle electrodes. The data from the lower electrode might be interpreted as showing the activity of the depressor contaminated by the orbicularis oris. In [dɪ'de:dɪn] only the (assumed) depressor is active (fig. 10). In [dɪdɑ:dɪn] (fig. 11) activity is recorded from both lower lip (L) and depressor (D) while the upper lip (U) is inactive. This may perhaps indicate that (L) is contaminated by (D) instead of the other way round. Another muscle which may have been involved, is the depressor anguli oris (or M. triangularis). According to Öhman et al. (1965) the spread vowels are associated with an activity of M. depressor anguli oris (p. 7).

In samples with strongly rounded vowels as [dɪ'du:dɪn] and [dɪ'dʉ:dɪn] (L) seems rather to show similarities to both (U) and (D) (see figs. 6 and 7). On the other hand (D) might have been expected to be comparatively relaxed when the lips are in a more closed position (acc. to Hirano). See however the large peaks at (D) on the articulation of the p's of, for instance, [dɪ'pi:pɪn], occurring simultaneously with those at (U) (fig. 8). (Activity for the [i:] is only recorded at (D), however.) However, Öhmnan has found (1965 and 1966) that an electrode inserted at a point rather close to the point (D) of the present study, and identified as representing the depressor labii inferioris, showes activity particularly during the articulation of consonants. The production of a bilabial stop is said to involve both the M. depressor anguli oris and the M. depressor labii inferioris (as well as the M. mentalis) (1966, p. 2).

Hirano, who fells confident that the electrodes was indeed placed in the depressor muscle, now reports from Japan that contrary to his expectation from reading the literature the depressor may be involved in the lip-closing gestures. Thus, some of his patients with facial palsy show depressor activity when closing the lips, although most subjects do not. Later findings indicate that some speakers normally activate the depressor when articulating labial stops; this activity may be seen quite generally in connection with tight closure of the lips and/or extreme protrusion (personal communication). Some of our findings may however be due to an individual way of articulating or electrode (D) may not have been placed in the optimal position. The experiment will be repeated with the same speaker and also with other speakers for control and comparison.

The difference of timing in the activity at (U) and (L) should also be examined further. The orbicularis muscle consists of a great number of interlacing fibers which do not necessarily act simultaneously, as one unit. This too will be investigated in greater detail, together with a more extensive electrode mapping of the facial muscles involved in the articulatory gestures.

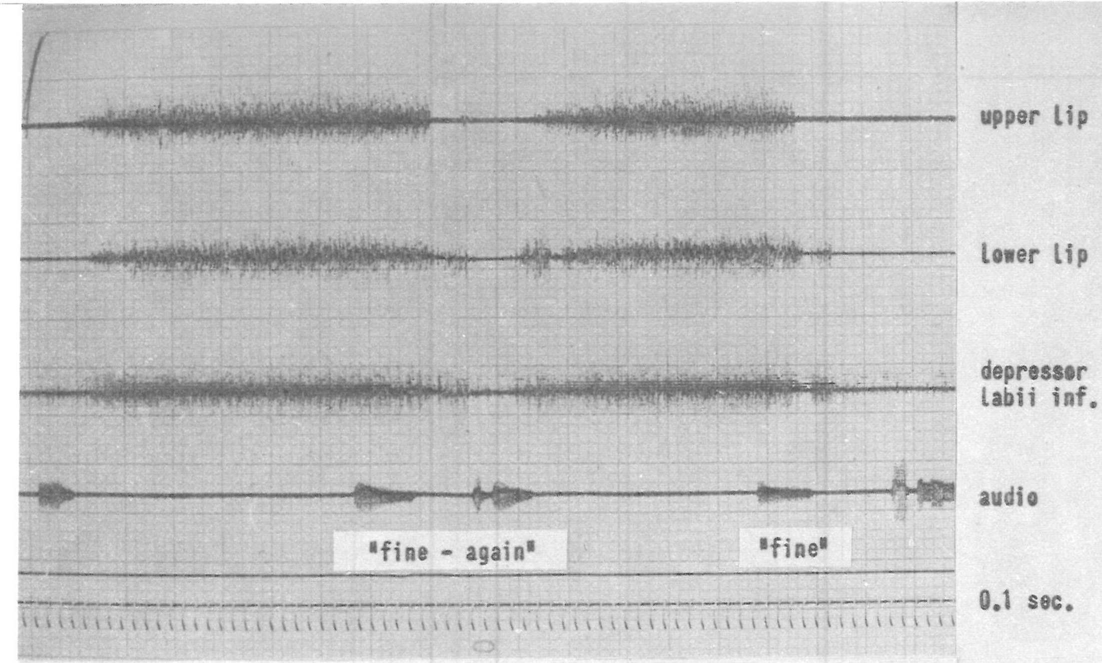


Fig. 1. Gestures on the command: "close your lips tight".

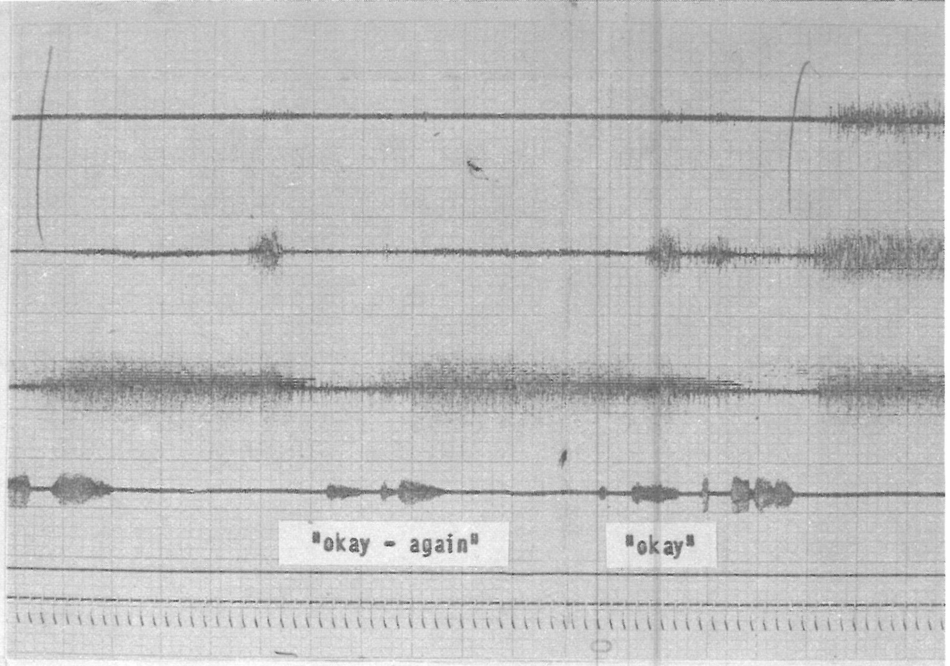


Fig. 2. Gestures on the command: "open your mouth wide".

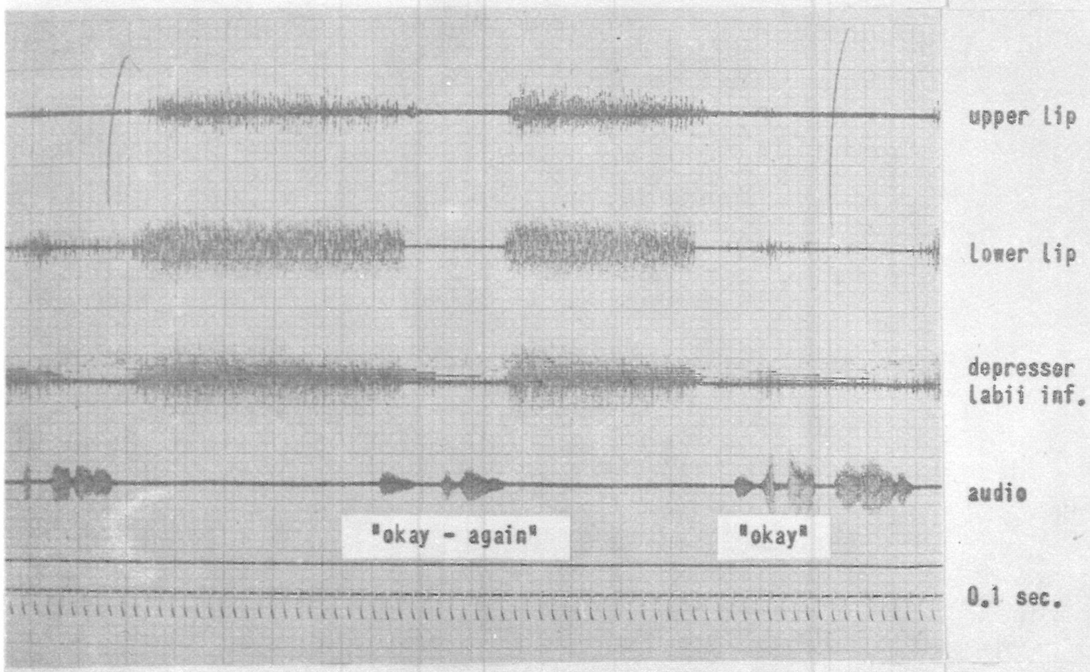


Fig. 3. Gestures on the command: "protrude the lips".

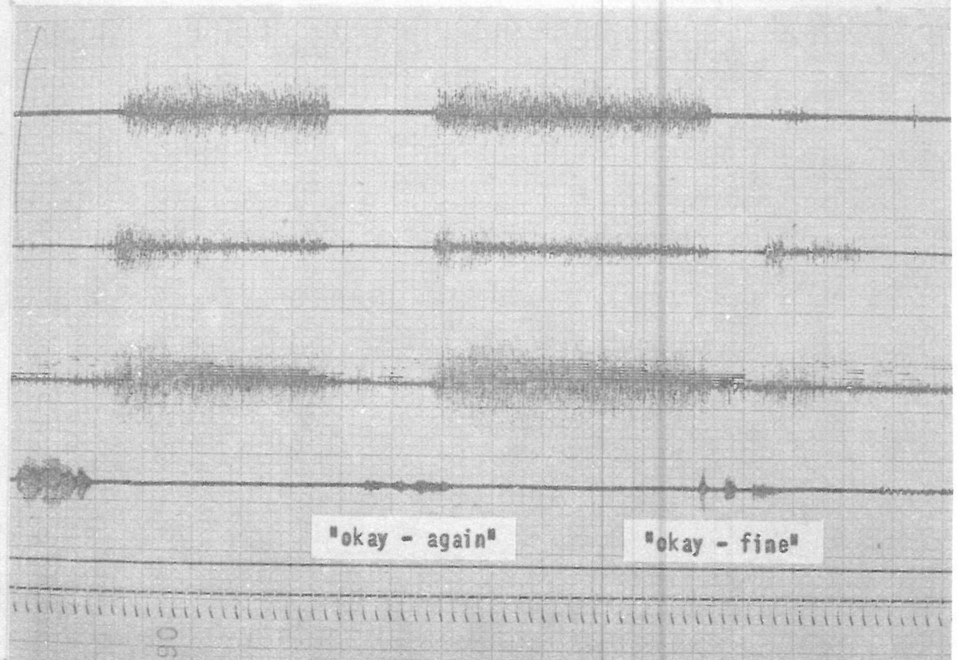


Fig. 4. Gestures on the command: "evert your lower lip".

Fig. 5 dɪdy:dɪn

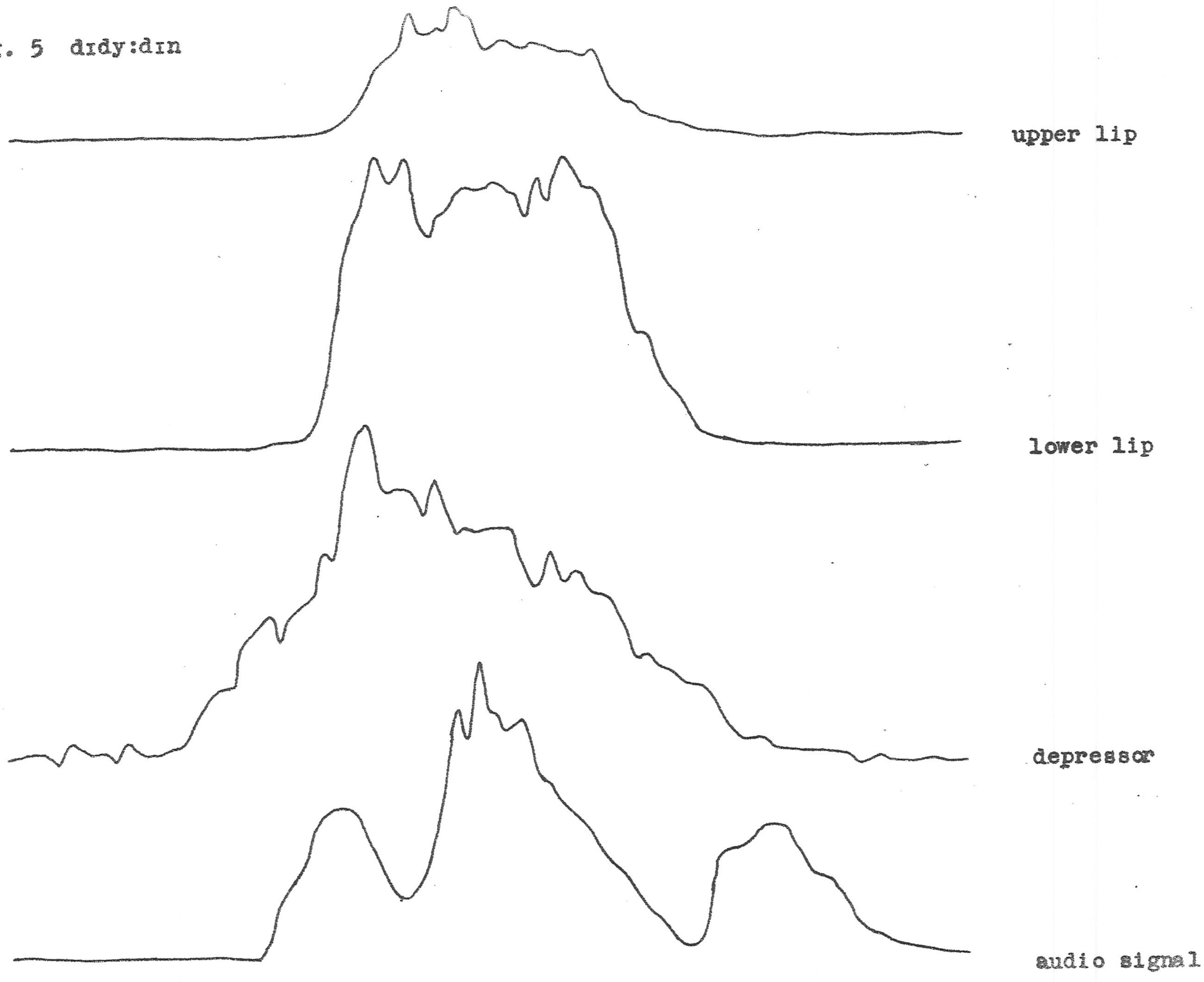


Fig. 6 dɪdɯ:dɪn

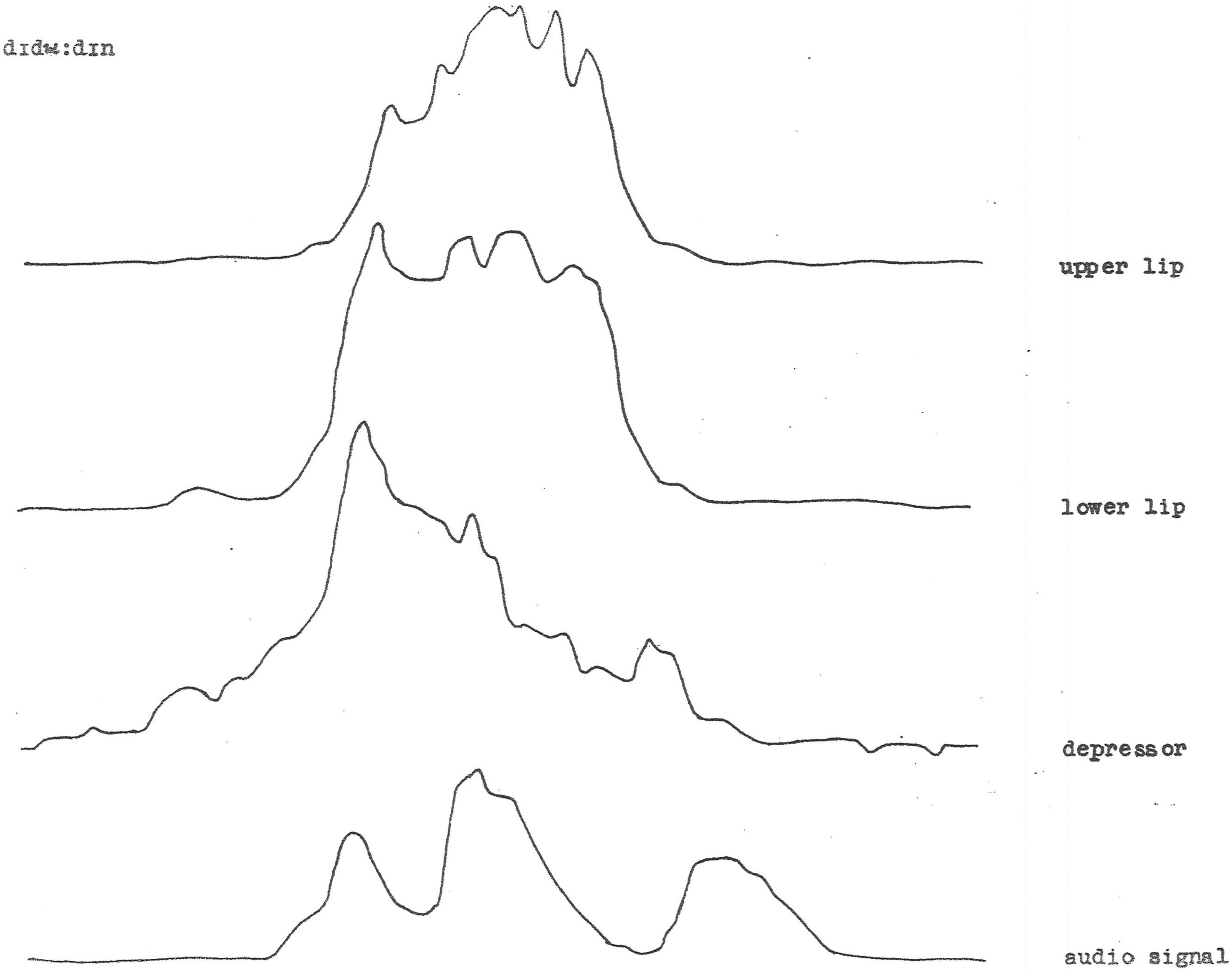


Fig. 7 dɪdu:dɪn

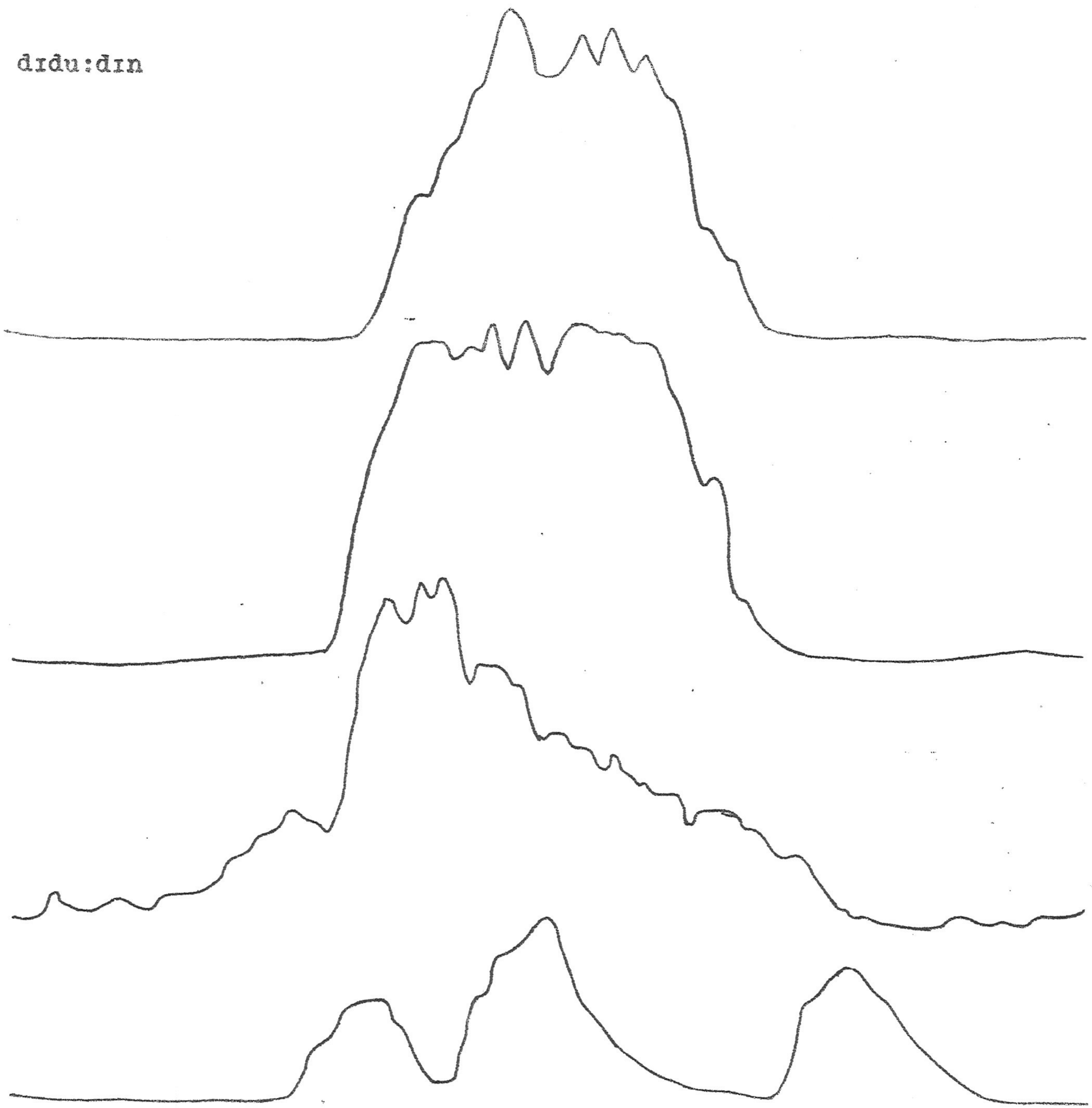


Fig. 8 dɪpi:pɪn

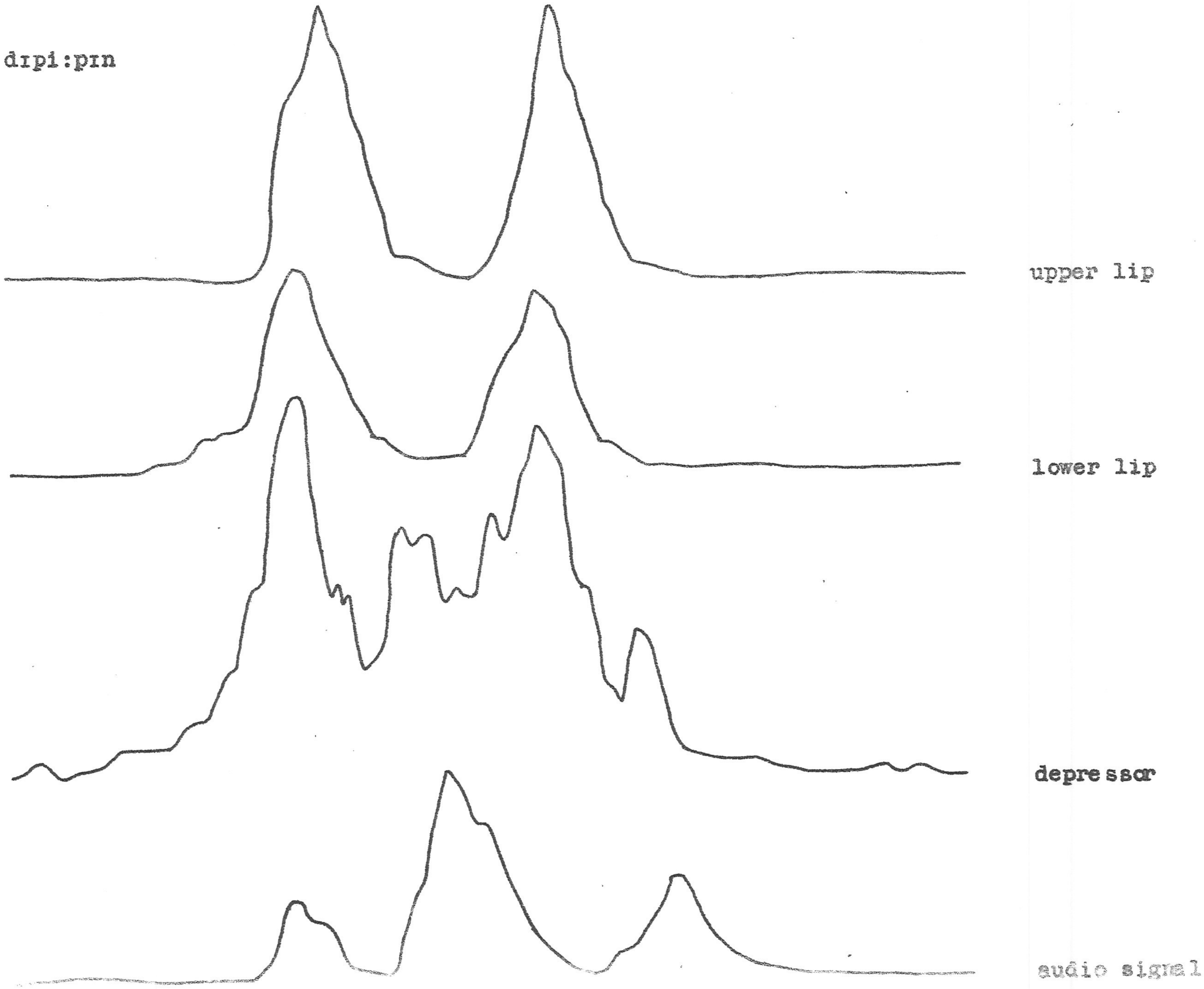


Fig. 9 dɪpɪp:ɪn

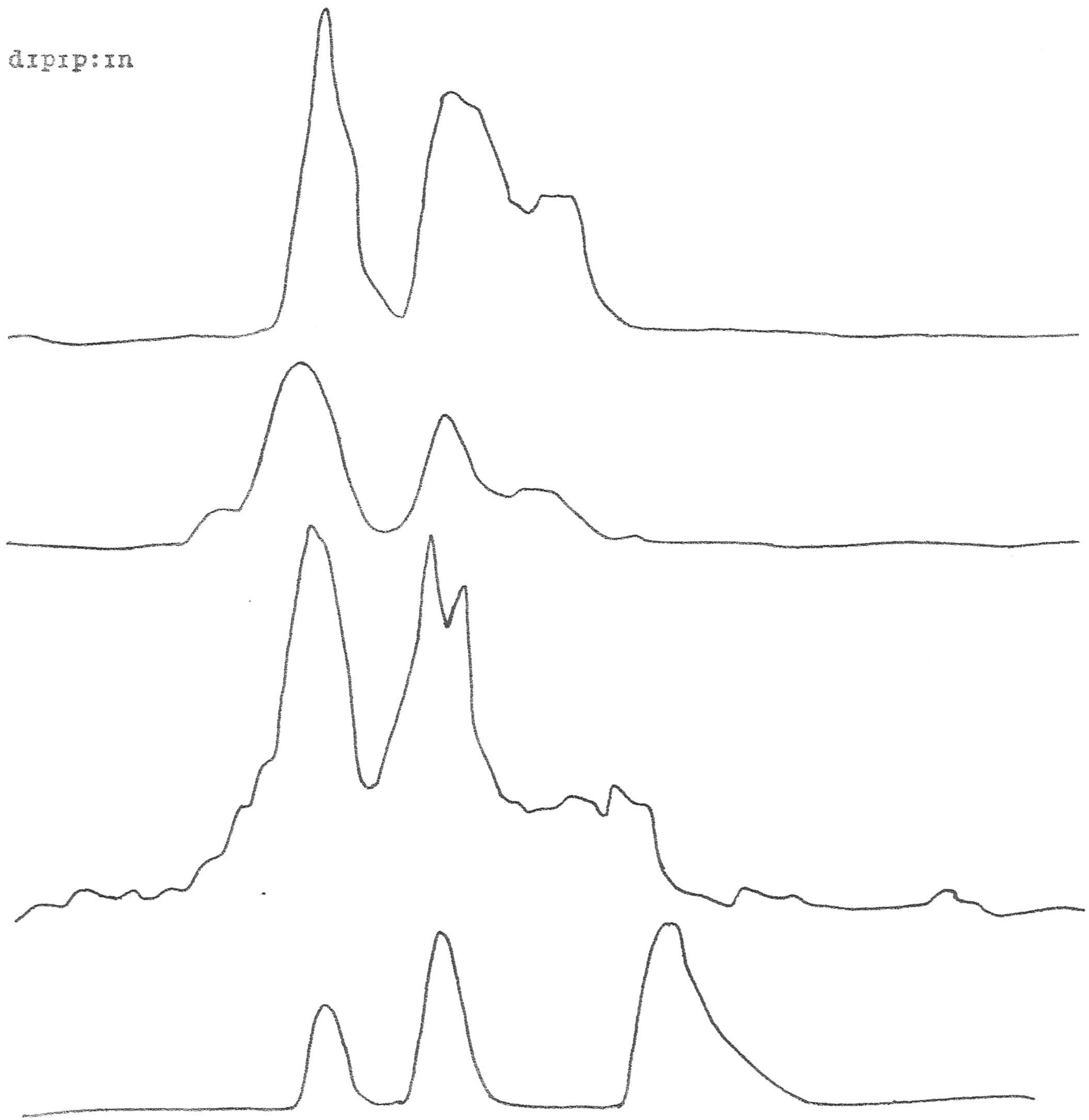


Fig. 10   dɪde:dɪn

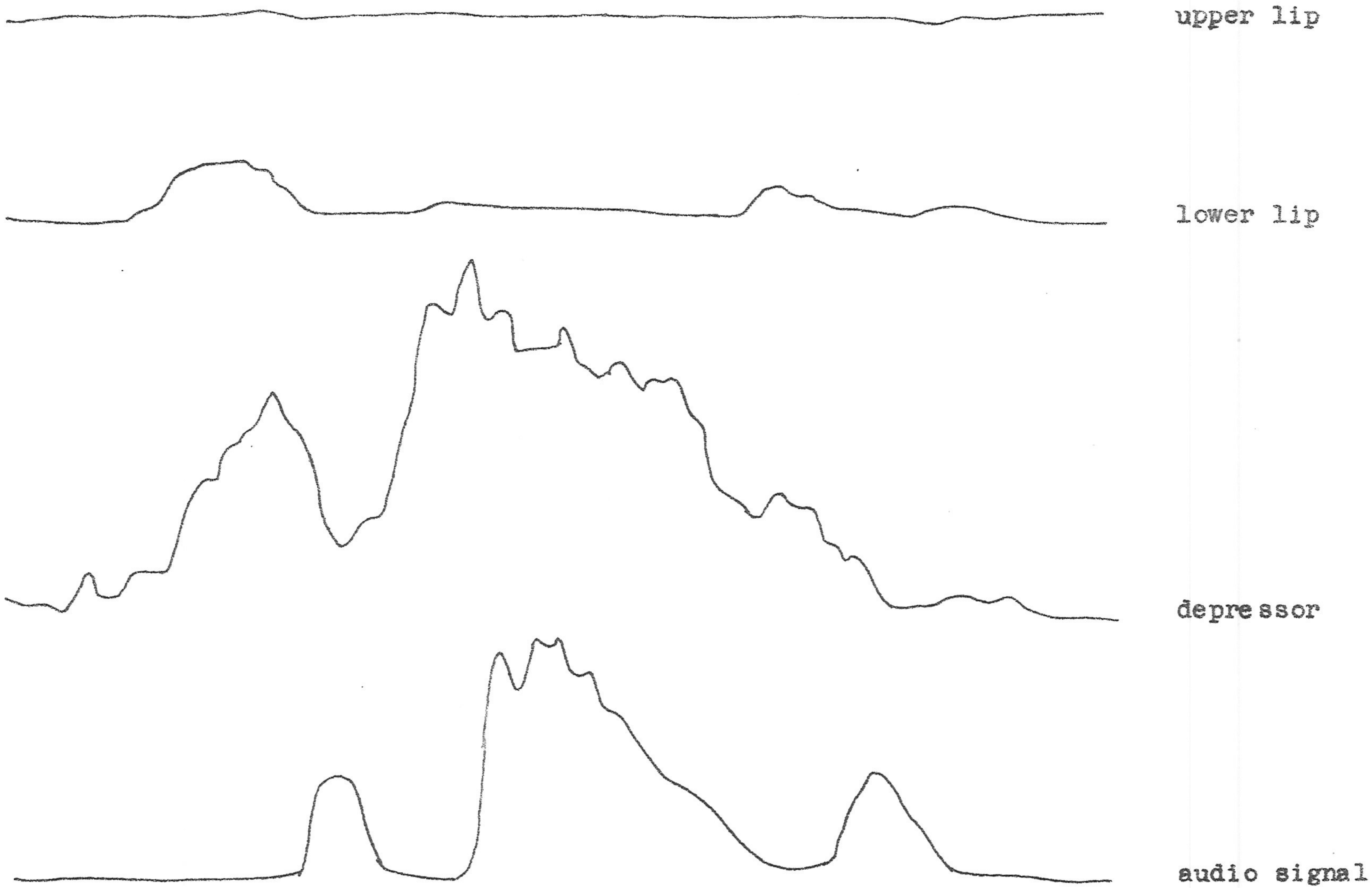
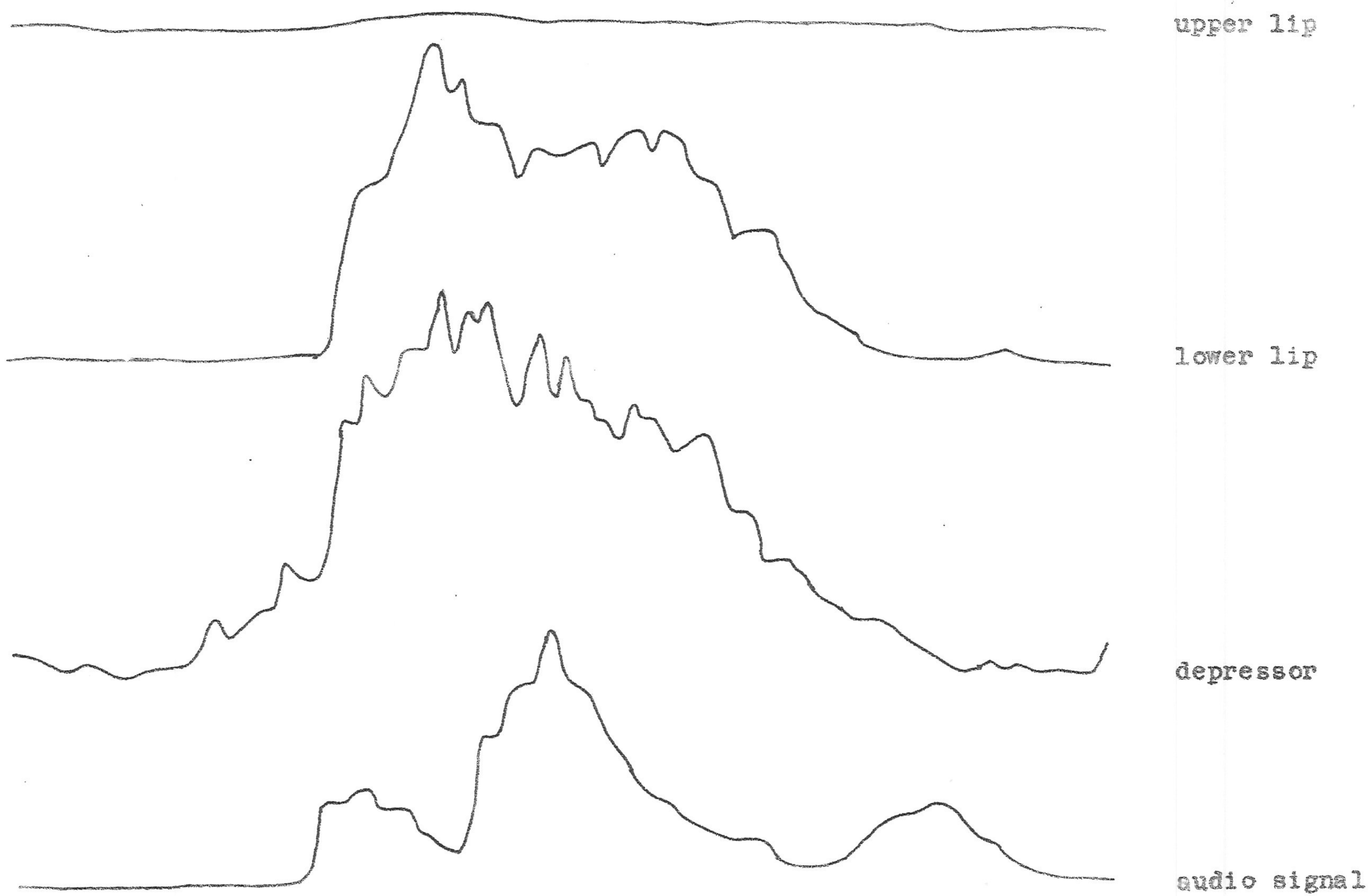


Fig. 11   dɪdɑ:dɪn



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