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Ataxic /r/ - articulatory description and treatment using electropalatography (EPG): a case study

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Abstract

In this study electropalatography (EPG) is used as a tool for recording details of tongue activity during production of /r/ in a 27 year old ataxic speaker. A description of articulatory patterns for the realization of normal and ataxic dysarthric /r/ is given, where the ataxic /r/ is perceived as [l]. It is shown that an ataxic dysarthric speaker with the help of EPG as a visual feedback device can produce an intelligible /r/ that perceptually differs from /l/. The ataxic speaker's ability to transfer the intelligible /r/ to spontaneous speech and his inability to hold on to it is discussed.

Introduction

Ataxic dysarthria is a motor speech disorder in which a breakdown in the articulatory and prosodic aspects of speech are the predominant features. The imprecise articulation results in abnormal formation and separation of individual syllables leading to a reduction in intelligibility while the disturbance in prosody is associated with abnormal tone, stress and rhythm of individual syllables. The dysprosody results in slow, monotonous and improperly measured speech (Murdoch, 1990:269). Ataxic speakers rarely have suprasegmental disturbances without having segmental disturbances at the same time and therapy will have to deal with both categories (Petersen, 1993). Articulatory placement problems and disturbances in the prosodic aspect of speech are both problems that follows ataxic speech. The major articulatory problems are poor alternating movements of the tongue and reduced ability to make lateral movements and elevation of the tongue (Enderby, 1986). These abilities lead not only to problems such as distorted vowels but also inaccurate consonant production. The articulatory breakdown in ataxic dysarthria is irregular and transient which leads to impairment of overall intelligibility (Murdoch, 1990:274).

Morgan Barry (1989) showed how EPG can be used as a therapeutic tool with children and one adult presenting with dysarthria. According to parents, teachers and peers three of the childrens intelligibility had improved substantially after using EPG in therapy. The adult dysarthric on the other hand could monitor non-speech tongue movements, but he was not able to accurately target previously learned patterns. He also found it difficult to focus on the dynamic feedback display from the EPG screen. Goldstein, Ziegler, Vogel and Hoole (1994) have used EPG in combination with a palatal-lift as a part of speech training of an 18 year old male with a severe dysarthria, caused by a traumatic injury. Training with EPG improved the 18 year old's intelligibility considerably. These reports on dysarthric cases have not involved cases where ataxic speech has been the predominant feature. It is therefore interesting to study this disorder and to implement EPG in the therapy.

According to Hardcastle and Edwards (1992:298) spatial distorted patterns occur frequently in the speech of dysarthrics. Hardcastle, Jones, Knight, Trudgeon and Calder (1989:30) have described spatial distortions as well as speech errors in timing and sequencing. One type of spatial distortion is a target undershoot where there is a decreased contact pattern. Other spatial distortions are target overshoot (increased contact patterns), the absence of contact, double articulations and articulatory contact which is considered abnormal. The timing of specific lingual gestures can be given a direct representation through EPG. Abnormal length in the closure phase for plosives can be seen in detail on the EPG printout. The same is the case for delayed approach and release phases such as abnormally long transitions between the different elements in a cluster. EPG data can also reveal details in connection with serial ordering of lingual gestures, such as ordering the consonants across the morpheme boundary in the word 'catkin' (Hardcastle et al, 1989).

Because of the reduced articulatory potential in dysarthrics one can expect a distorted spatial pattern of the realisation of /r/ in ataxic dysarthria. Abnormal /r/ production will contribute to the impairment of the intelligibility. The articulatory representations of the normal Norwegian phoneme /r/ is in it self interesting to look at because of the allophonic variability.

Norwegian /r/

There are a number of realizations of the Norwegian /r/ phoneme, alveolar tap [ɾ], alveolar trill [r], post-alveolar approximant/fricative [ɹ], post-palatal approximant [j], velar approximant/fricative [ɰ] and [ɣ], uvular approximant/fricative [ʁ] and also uvular trill [ʀ] (Foldvik, 1981:319, Davidsen-Nielsen, Bird and Moen, 1977:79). Front /r/ allophones are common in large parts of the country with [ɾ] as the general allophone. [ɹ], the post-alveolar approximant, as well as [ɾ] are used in the three most northern counties (Nordland, Troms and Finnmark). [r] on the other hand is not very common today, but according to Foldvik (1981:320) it is found in the county Møre and Romsdal. The back /r/ allophones, mainly [ɰ] and [ɣ], have been typical for the cities of the South-West. Over the last 50 years, however, the spread of the back variants have increased and today these sounds are common in a large area covering parts of the counties East- and West-Agder, Rogaland and Hordaland. In small areas within these counties one may find realizations like [ɾ], but the general allophone is [ɣ]. Other allophones that can be mentioned are velarized alveolar flap/tap (Møre and Romsdal and northern parts of Sogn and Fjordane) and palatalized alveolar flap/tap (areas around Oslo) (Foldvik, 1981:319/320). The term 'allophonic variation' may be used for both realisational differences between different dialects and variations within a single regional accent. Unfortunately no work has been published on the disribution of /r/ allophones within any single regional Norwegian accent.

Method

Electropalatography (EPG)

In this study the Reading EPG2-model was used. With this technique spatio-temporal details of tongue contacts with the hard palate are recorded during continuous speech. The subject wears an acrylic plate that is moulded to fit the upper palate, and the acrylic plate contains 62 silver electrodes which are placed according to anatomical landmarks. This enables comparisons to be made between different subjects' lingual contact patterns on an objective basis. The sampling rate for EPG data is 100 frames/s, and the times that are given throughout the work relates to a count of EPG frames. For further details see Hardcastle et al (1989) and Hardcastle, Gibbon and Jones (1991). All perceptual judgements throughout the investigation were done by the author.

Corpus

A list of words was constructed where the aim was to collect data on the realisation of /r/, and /l/. The words used were *rar*, /ra:r/, ('strange'); *irr*, /ir/, ('copper rust'); *ride*, /"ri:de/, (to 'ride'); *ringe*, /"riŋe/, (to 'call'); *sprit*, /spri:t/, ('liquor'); *trekke*, /"treke/, (to 'pull'); *krysse*, /"kryse/, (to 'cross'); *gol*, /go:l/, ('crowed'); *kål*, /ko:l/, ('cabbage'); *alle*, /"ale/, ('everyone'); *drille*, /"drile/, (to 'drill'); *problem*, /pru'ble:m/, ('problem') and *sommerkål*, /"somerko:l/, ('summer cabbage'). Every word was read within the carry phrase "Jeg sa ... " (I said ...). The list, that did not contain minimal pairs, was the basis for the EPG assessment and there was a single representation of it before and after treatment, and again six months subsequent to this.

In most Norwegian dialects accented syllables are associated with one of two pitch patterns (Moen, 1991:539). Both pitch patterns were represented in these words, but not as minimal pairs. A minimal pair where tone group distinction will be found is for example *badet* /'ba:de/ ('the bathroom') and *bade* /"ba:de/ ('to take a bath').

The ataxic subject

The subject (NN) that comes from the region of East Norwegian was 27 years old at the time of the EPG recording. He was diagnosed as having ataxic dysarthria after a head injury caused by a car accident at the age of 19. There were no signs of aphasia but he had some coordination and visual problems. The case history revealed that he had received different types of training, including speech therapy, on and off over a period of six years. Different reports show that his speech and communication abilities have improved, although very slowly.

He was referred after an initiative by his family because of his slow and unintelligible speech. Family and friends could understand him most of the time but he had great problems communicating with strangers. He was very motivated for speech therapy. For years he had worked systematically to make progress, mostly on his own after initial guidance from a speech therapist. Even though NN was very motivated for therapy he was unwilling to accept his speech as being so unintelligible to strangers that they could not understand him. This had caused considerable communication problems. It was thought that he had come to a point where he and his family felt he could not make any further progress, despite the everyday training.

The Frenchay Dysarthria Assessment (FDA) (Enderby, 1982), (Figure 1), recorded typical ataxic dysarthric signs with some spastic features. Very poor intelligibility, in single words and sentences, as well as in speech, and extreme hypernasality were in NN's case predominant features. There was also a clear breakdown in the articulatory and prosodic aspects of speech. The lip movements and all the tongue movements were very slow and imprecise, when observed as oral movements as well as in speech. The laryngeal conditions were poor as well. He had involuntary contractions in the larynx during phonation, which seemed to be the reason for his problems controlling breath during speech. He was able to produce a prolonged /ɑ/ for 6-7 seconds. In the FDA 15 seconds was considered normal, and in a Norwegian study normal phonation time (Tveterås, 1994, unpublished), 22 seconds was considered to be the norm.

Figure 1 The initial FDA recording.

Other perceptual judgements showed that the length of segments deviated to a large extent, as a result of speech rate reduction. The speech rhythm was disturbed, it was perceptually a problem to separate words because he did not stress accented syllables or he stressed the wrong ones. He was unable to produce any tone group distinction and his voice was monotonous, and he usually used voiceless plosives for both voiced and voiceless ones. In particular the distinction between /g/ and /k/ seemed hard to realize. In the production of bilabials the lips hardly had any contact at all, and labiodentals were produced with the underlip and the upper teeth far apart. Because of the hypernasality and the undershoot of lip activity in speech it was hard to separate vowels, especially /i/ and /y/, and /e/ and /ø/. The articulatory movements were slow and exaggerated, the consonants were imprecise or distorted. Every sound combination that require fast tongue movements presented difficulties. Consonant combinations, like /br/, /rp/, /tr/, /kr/ and /kt/, were produced very slowly, with prolonged segment duration.

The normal speakers

Two normal speaking subjects of different regional accents participated in this work. The East Norwegian region was represented by a 50 year old female and the subject of the North

Norwegian region was a female of 28 years. Their representation of /r/ in the word "rar" and the word "alle" (Figure 2a and b) was recorded twice within the same carry phrase, "Jeg sa ... " (I said ...), as the ataxic speaker. The /r/ production of NN was compared with the normal East Norwegian and the North Norwegian /r/, and the latter was chosen as a goal for training.

(a) (b)

Figure 2 Computer printouts showing the electropalatopraphic representations of /r/ production in two normal speakers. (a) East Norwegian, "Jeg sa rar", [ɾ ɑːɾ], ('strange') and (b) North Norwegian, "Jeg sa redd", [ɹ ɛ ɻ], ('afraid').

Two EPG representations of front /r/ allophones are presented in Figure 2. East Norwegian [ɾ] in "Jeg sa rar", [ɾ ɑːɾ], ('strange') is shown in 2 (a), and North Norwegian [ɹ] in "Jeg sa redd", [ɹɛɻ], ('afraid') in 2 (b). The two [ɾ] in 2 (a) are very brief and are produced with complete closures (here defined as: when all electrodes of at least one row are contacted). The first frame showing complete closure for the initial /r/ is number 94 (see number above the frame), and the first frame showing a complete closure for the final /r/ is number 132. In this case there is a complete closure in the post alveolar area, in row three. Depending on the speaking rate, the closure typically lasts between 30-50 msec. The [ɹ] in 2 (b) is produced with a stricture and not a complete closure, the first frame showing a narrow constriction is number 4016. The constriction is located in the alveolar area, row two and three. Similarly to 2 (a), this sound is also very brief, it might last 30-50 msec as well.

This information was used when designing a therapeutic program, where information about the allophonic variation may be important for the therapeutic strategy.

Lingual/palatal contacts prior to EPG therapy

Producing an East Norwegian /r/ or any other intelligible /r/ was a great articulatory challenge for NN. On the basis of an audio tape recording and direct conversation his realization of /r/ was judged as /l/ most of the time, in some cases as /t/, /d/ or /n/ but almost never as /r/. This persisted despite the fact that there had been made attempts in previous therapy to establish [ɾ], and [r], using a variety of productions, for example minimal pair contrasts therapy, auditory discriminating practice and direct articulatory exercises. The complexity of his problem, the overall unintelligibility and hypernasality, made the progress towards intelligible /r/ production very slow.

[r] was an unrealistic goal, but [ɾ] on the other hand, which is the main allophone for /r/ in his original dialect, seemed more realistic even though NN had not been able to establish this one in spontaneous speech. His production of /l/ was always perceived as /l/ although the EPG patterns showed some differences. At this point EPG was implemented in therapy to see if any progress towards an intelligible /r/ could be achieved.

(a) (b)

Figure 3 EPG representation of ataxic /r/ production prior to treatment, where (a) " rar", ('strange'), in "Jeg sa <u>rar</u>" was perceived as [lɑ:l], and (b) "ringe", (to 'call'), in "Jeg sa <u>ringe</u>", was perceived as [liŋ:ə]. Frame 54 marks the beginning of /r/ in 3 (a) and the beginning of the closure phase of /r/ in 3 (b). Frame 152 in 3 (a) indicates the initial phase of the second /r/ in "rar". In 3 (b) the beginning of the segments /i/, /ŋ/ and /e/ in "ringe" are marked with the phonemic signs above the corresponding frames.

EPG assessment

NN was asked to read the different words on the list within the carry phrase while wearing the artificial palate. The data was stored and a tape recording was performed simultaneously. Compared to the normal representations (Figure 2 a and b) NN's attempts to produce /r/ (Figure 3a and b) resulted in spatially distorted patterns and segments with abnormal duration.

The EPG pattern for the first segment in "rar" (Figure 3a) shows an incomplete closure where there is no contact in the middle of the alveolar area, only on the sides. The production may be described as a spatial undershoot compared to the normal /r/ realised as the allophones [ɾ] and [ɹ]. When saying the word "ringe" (Figure 3b) NN produced a complete closure for /r/, in the middle of the alveolar area, the area for the normal subject's closure for [ɾ] was more retracted. NN's production of /r/ in this word was a clear spatial overshoot compared to the normal subject's [ɾ] and [ɹ]. The duration of the NN's two realisations shows his problem with segment timing. Where the normal subjects produced [ɾ] and [ɹ] within 30-50 msec the ataxic /r/ versions lasted between 170 msec (closure) (Figure 3b) and 340 msec (constriction) (Figure 3a). Although /r/, in both "rar" and "ringe" were produced with spatial differences they were both perceived as a prolonged [l]. The second /r/ in "rar" (Figure 3a) was also was perceived as [l], although it was produced with a constriction that was slightly more narrow in the alveolar area than the first /r/. Frame 54 (Figure 3a) indicates the beginning of NN's /r/ pattern prior treatment in the word "rar".

It was interesting to look at normal and ataxic realisation of target /l/, where EPG data showed there was not a big difference between the two. Presented in the word "alle" both normal (Figure 4a) and ataxic (Figure 4b) were perceived as [l]. The timing of the closure phase was more or less similar but NN shows a spatial undershoot (Figure 4b) in his version, which has nothing to do with the intelligibility of the sound.

(a) (b)

Figure 4 EPG representations of normal, (a), and ataxic, (b), realization of /l/ in the word "alle" ('everyone').

EPG Therapy

When planning the strategy for therapy it was taken into account what is known, through EPG, about the production of front allophones of /r/ in Norwegian. It was equally important for therapy planning to note that NN had a very short attention span and became tired very quickly, therefore the tasks and goals had to be limited. Subsequently, therapy focused on what was judged to be NN's predominant articulatory problem, the production of an intelligible /r/, and the inability perceptually to separate /r/ from /l/. Therapy aimed to find an articulatory representation of /r/, a front allophone, that would be perceived as /r/ and to establish a perceptral distinction between /r/ and /l/. Normal adult speakers' production of [ɾ], [ɹ] and [l] was used as control. The EPG frame showing maximum number of contacts at any phase during the production of the target sound was selected to illustrate the qualitative differences. Transcriptions that are presented in this work are based on auditory judgement.

After the initial sessions of assessment, where the EPG was introduced and the concept explained, NN was given a two-day intensive course using EPG in therapy. He had been given the practice palate in advance of the treatment which he had worn regularly for shorter and longer periods each day, and was therefore familiar with the artificial palate at the start of treatment. Three sessions of 40 minutes for each of the two days were planned. But because NN was unable to concentrate for more than a few minutes at a time, it was therefore decided on shorter and fewer sessions during the intensive course. Following this course came 21 weekly sessions over a period of nine months. NN still became easily exhausted, and had to take a lot of breaks throughout the sessions, which did not leave much time for treatment. The sessions varied from five to 40 minutes, with a mean time of 15 minutes.

Despite his short attention span NN was highly motivated to go through with the EPG treatment. At the beginning of therapy the visual problems NN had made it hard to focus on the target lingual/palatal contact patterns on the screen, so he needed time before he could give response, but this did not seem to disturb him. After a while he was able to focus on the feedback display without any major difficulties.

Therapy was planned on the basis of the guidelines given in Hardcastle et al (1991) where the principles of therapy using EPG as a visual feedback device are presented. The training was concentrated around syllables and words containing /r/ and /l/. The first target that was aimed for was to establish [ɾ]. We wanted to see if he was able to make one relatively fast movement of the tongue. [ɾ] was originally NN's main allophone for /r/, which was considered to be a good reason for trying to establish this sound. Attempts were made to reduce the duration of the tongue contact and to retract the articulatory placement, compared to NN's /r/ production in "ringe". Although he was able to reduce segment duration a little, moving the tip of the tongue towards the alveolar area still took a very long time compared to the normal subjects, and the sound was perceived as [l]. This confirmed earlier treatments which did not use EPG, suggesting it was impossible for NN to make fast movements with the tip of the tongue and that it was very unlikely he would be able to produce [ɾ].

Since the speaking rate was a problem as well as the relative inability of the tip of the tongue, [ɹ] seemed to be a more realistic target to aim for. Even though this is not a common allophone in Eastern Norwegian it is accepted as a Norwegian variant, (see above). Attempts to increase the contact in the central alveolar area were made, compared to NN's /r/ in "rar" before EPG therapy (Figure 3a), and at the same time reduce the duration of the segment. By making very strong friction, perceptually controlled, when moving the front part of the tongue towards the post-alveolar area NN was more capable of controlling the /r/ production and found it easier to aim for [ɹ]. Because there is no lateral fricative in his dialect (he did not produce one either), his production of [ɹ] has less similarities with his realization of /l/ than was the case with his attempts of making [ɾ].

Results

Lingual/palatal contacts post EPG therapy

Despite the adjustments that were made concerning the length of each session NN made no progress during the intensive therapy course. But after a few weekly sessions he managed to produce an intelligible /r/ that perceptually was judged as [ɹ], although it took 21 sessions before he was confident enough producing it without visual feedback.

NN's /r/ was after therapy produced with a narrow constriction in the alveolar area with a more forward pattern than the normal representation. The degree of the constriction in the ataxic representation was acceptable since the target sound, the frames 40-67 (Figure 5a), and the second /r/, the frames 114-145 (Figure 5a), both were perceived as [ɹ], and on occasions [ɹ̟]. The word "rar" was perceived as [ɹ ɑ: ɹ].

(a) (b)

Figure 5 (a) NN's realisation of /r/ in "Jeg sa rar", ('strange'), after EPG therapy. Both the first /r/, the target sound, and the second /r/ were perceived as [ɹ]. (b) NN's realisation of /r/ in "rar" before therapy, when /r/ was perceived as [l], (see Figure 3a).

In order to assess any lingual/palatal contacts improvement after therapy further EPG recordings were made of the chosen words used in the initial assessment. This was done immediately after the last therapy session (Figure 5a) and again six months later (Figure 7). The /r/ representations prior and after therapy were compared, and the difference between NN's pattern before therapy (Figure 3a, 3b and 5b) and his pattern immediately after therapy (Figure 5a) was noticeable. He had established an intelligible /r/ (Figure 5a), that perceptually was different from /l/, by making audible friction through a narrow constriction in the alveolar area, producing [ɹ], and [ɹ̝]. The length of the representations before and after therapy was more or less the same, in both cases the representations are longer than the normal one. Compared to how he managed to produce an intelligible /r/ only on occasions after conventional therapy, he managed better after treatment with EPG.

Figure 6 FDA scores recorded after EPG therapy.

According to the FDA scores, recorded direct after therapy (Figure 6), lateral movements and elevation of the tongue had slightly improved. The intelligibility rate of his conversational speech was much higher, the intelligibility of sentences had increased just a little but the production of single words was on the same intelligibility level as before the EPG treatment.

Figure 7 Ataxic /r/ produced six months after treatment. The target /r/ and the second /r/ in "rar" were again perceived as [l], like before therapy (see Figure 3 (a) and 3 (b)), although there are spatial differences according to the EPG data.

Despite the progress that took place during the EPG sessions, NN did not succeed maintaining the new articulatory pattern and transfer it to spontaneous speech. This is illustrated through the EPG recording that was made six months subsequent to the completion of treatment (Figure 7). His /r/ was again perceived as [l] only this time the EPG pattern was similar to his /l/ production (Figure 4b) and deviated from the patterns of his earlier /r/ production (Figure 3a and b). There are spatial differences in production of /r/ before and six months after therapy according to the EPG data. When producing /r/ before therapy in "ringe" there is more contact on the sides of the palate than is the case with the first /r/ in "rar" six months after therapy.

Persons who are strangers to NN have given reactions that leaves the impression that his spontaneous speech more or less is as unintelligible as it was before the EPG treatment. Those who are used to his speech, family and friends, are able to recognize an improvement. In situations when NN is concentrating on making his speech distinct and intelligible, family and friends are able to separate /r/ and /l/ more often than prior to the treatment.

Discussion

This case study suggests that an ataxic dysarthric speaker can use the visual representation provided by EPG to establish a link between the tactile/kinaesthetic information and the auditory sensation. Even though NN was unable to hold on to what he had learned through EPG treatment and transfer it to spontaneous continuous speech, he became more capable of noticing when his /r/ is unintelligible and when he has to correct it. He even seemed to have accepted that strangers are unable to understand his speech equally well as his family and friends.

The fact that NN's tongue-palate pattern for /l/ (Figure 4b) are different from those of /r/ before (Figure 3a and b) and after therapy (Figure 5a), suggests that NN on a articulatory and phonemically level is able to differ /r/ and /l/. That his /r/ six months after therapy is perceived and produced as [l]. It may be an illustration of his inability to coordinate the articulatory movements well enough, the fact that his /r/ six months after therapy is perceived and produced as [l]. According to Enderby (1982:190) there is, with regard to the FDA, a disparity between what an ataxic patient can do in a speech task and his ability to control his articulators in a speaking situation. For example in NN's case, lateral and alternating tongue tasks showed higher mean scores than alternating tongue movements in conversational speech. Enderby states further that the difficulty shown by ataxic dysarthrics when attempting to make alternating movements of the articulators is concealed behind the cumulated scores. The variability of tongue item scores is not apparent compared to the cumulated scores, which are higher for "reflexes, lips, jaws" and "rate" for ataxic dysarthrics than it is for any other neurological group. This corresponds with NN's problems of coordinating the tongue movements in speech and his inability to transfer the new representation of /r/ to spontaneous speech.

Why NN's realisations of /r/ were perceptually indistinguishable from /l/ before therapy might be caused by the prolongation of the /r/ sound. /r/ is expected to be short in time. But when it lasts longer than expected it might, as in this case, be perceived as /l/. This despite the fact that NN's realisations of /r/ lasted even longer than his realisations of /l/.

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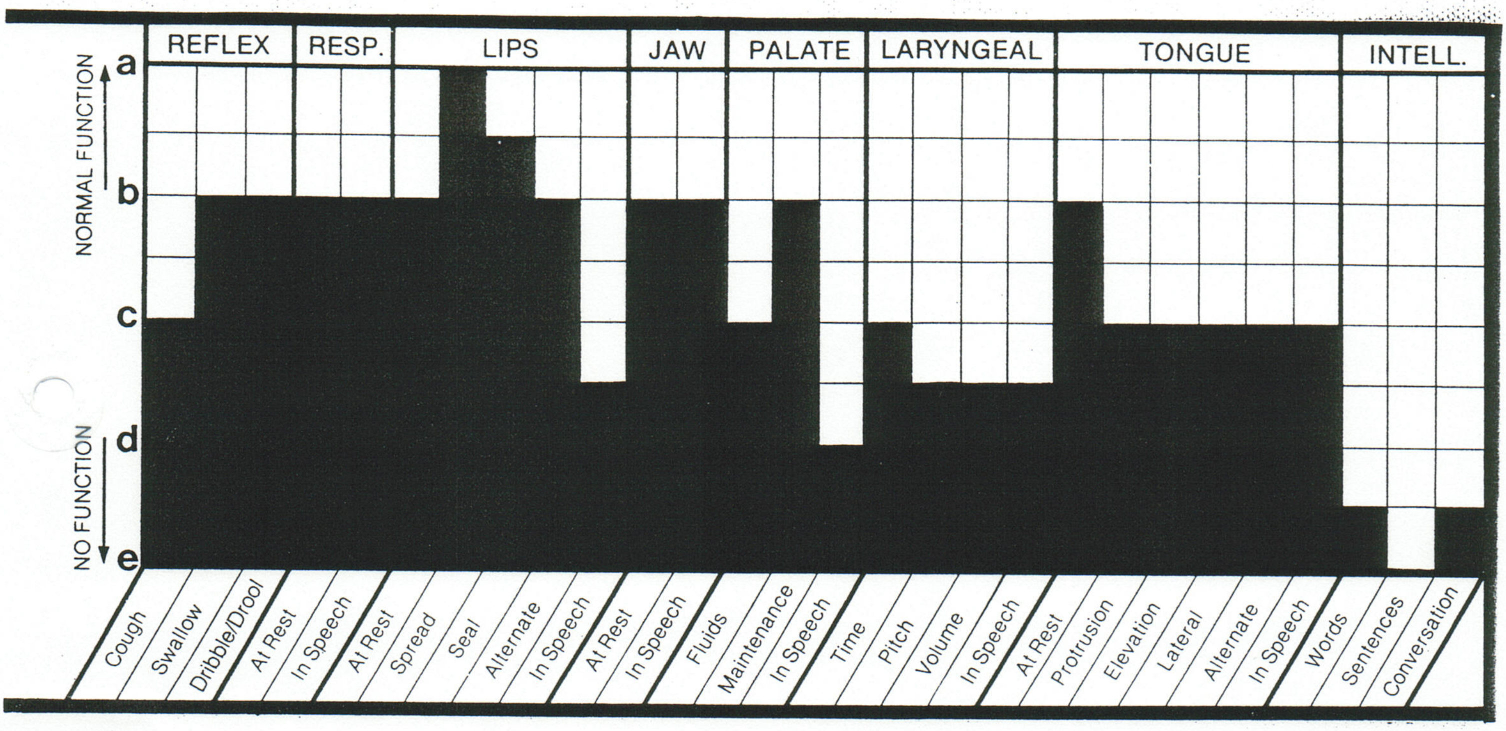
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Fig 1

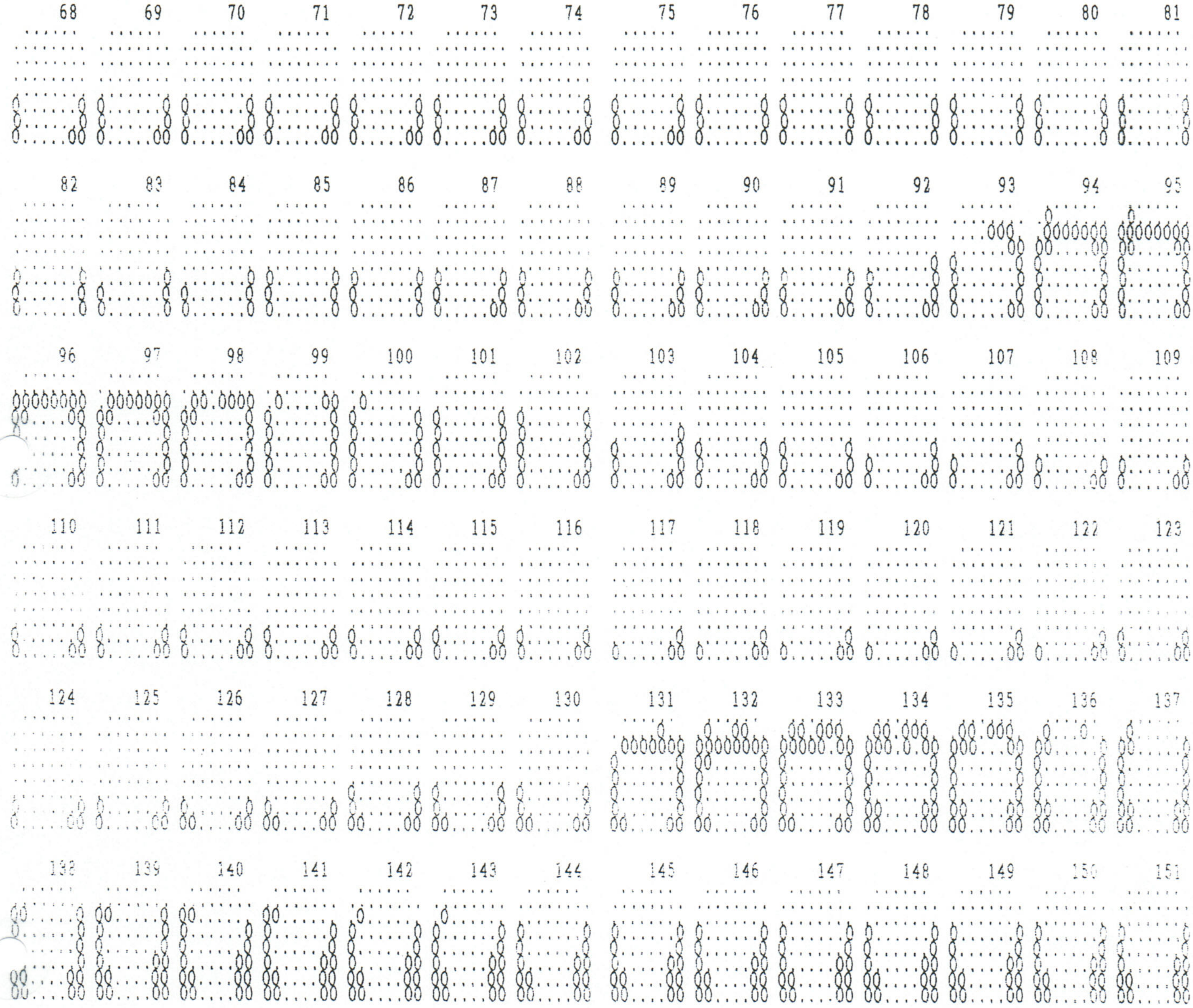
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Fig. 2a

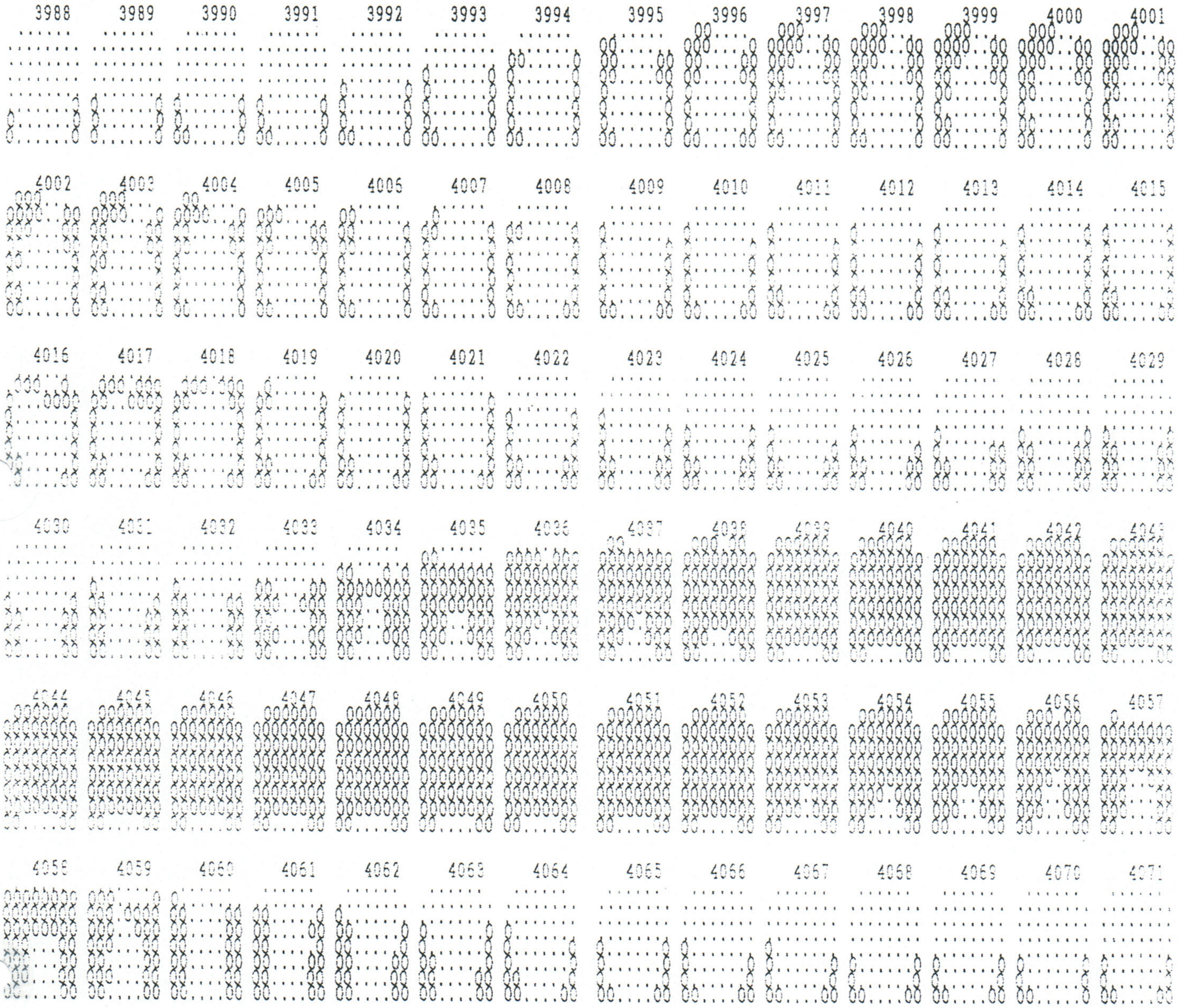

Fig. 2b

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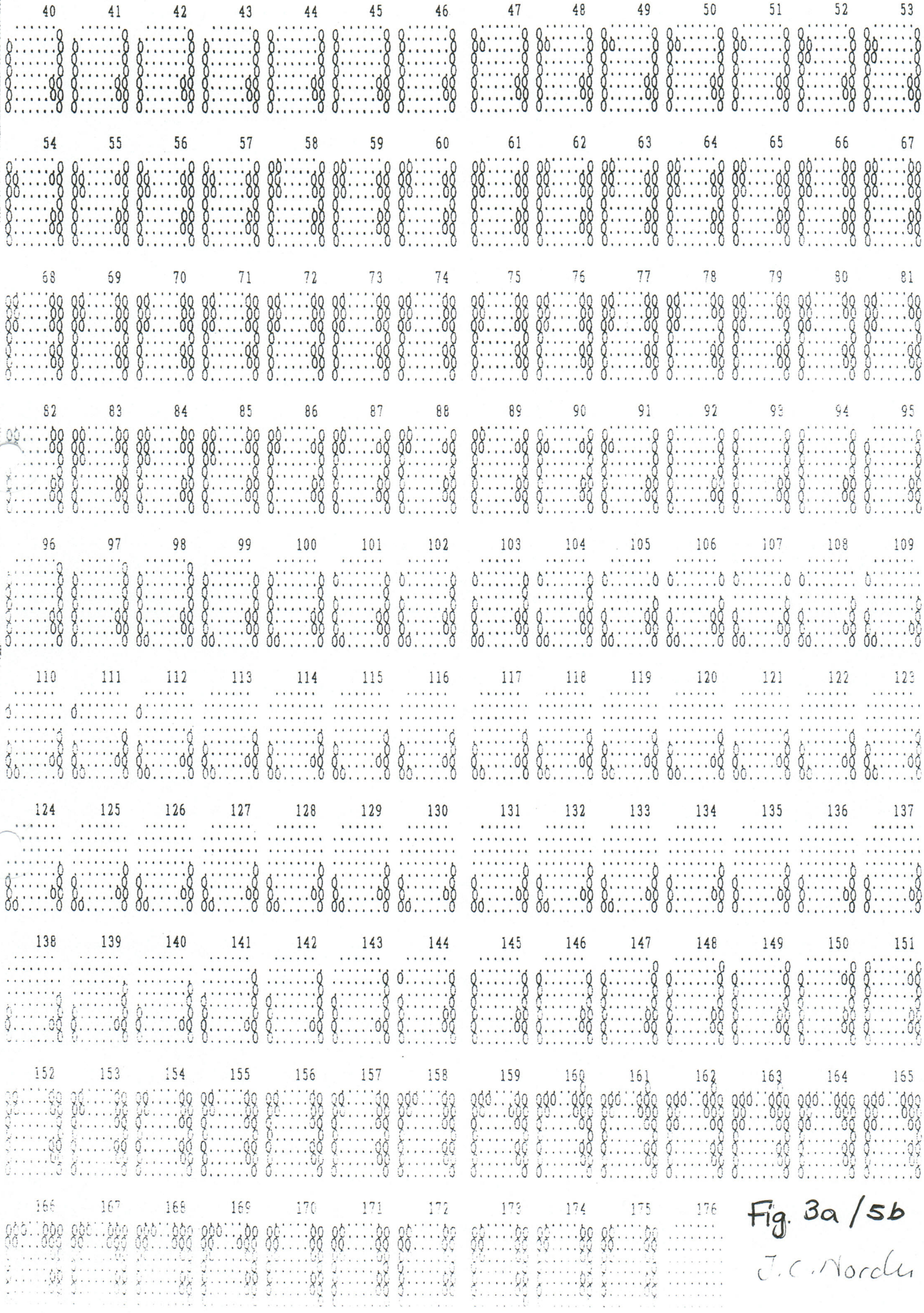

Fig. 3a/5b

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Fig. 3b

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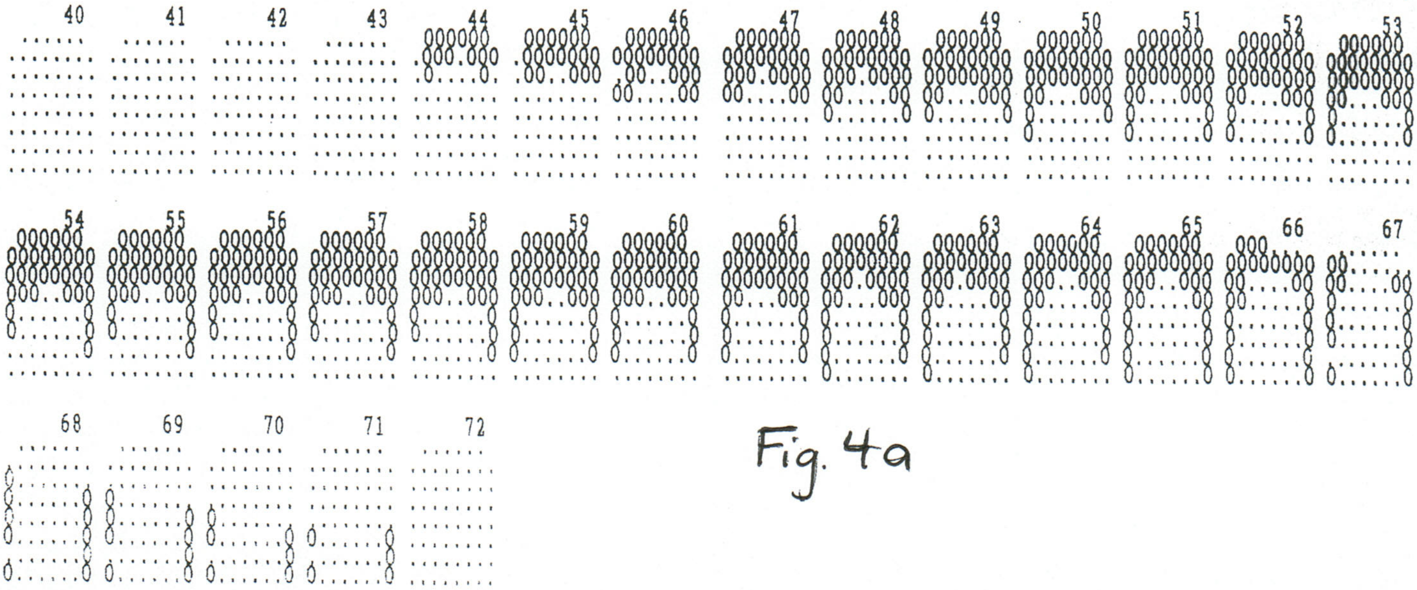

Fig. 4a

epal103.102

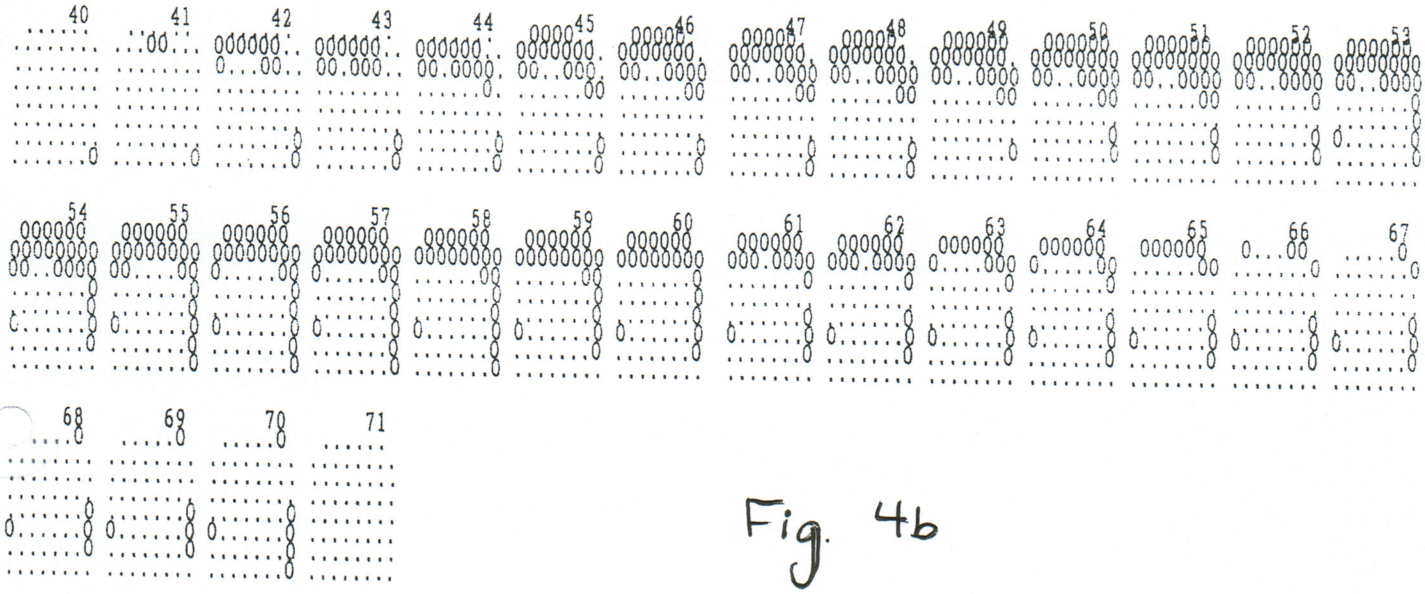

Fig. 4b

J. C. Nordi

eprar03.600

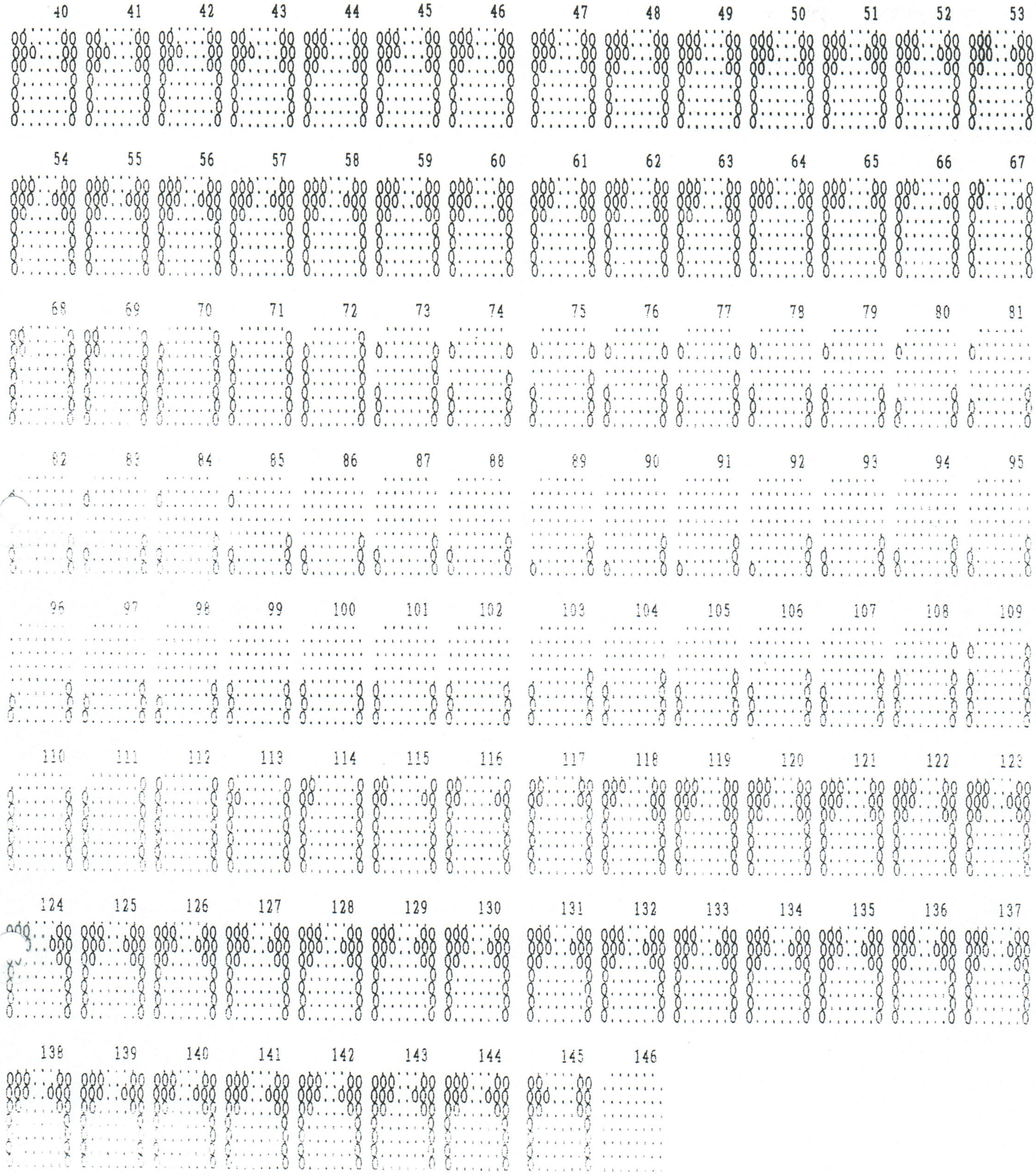

Fig. 5a

J. C. Nordli

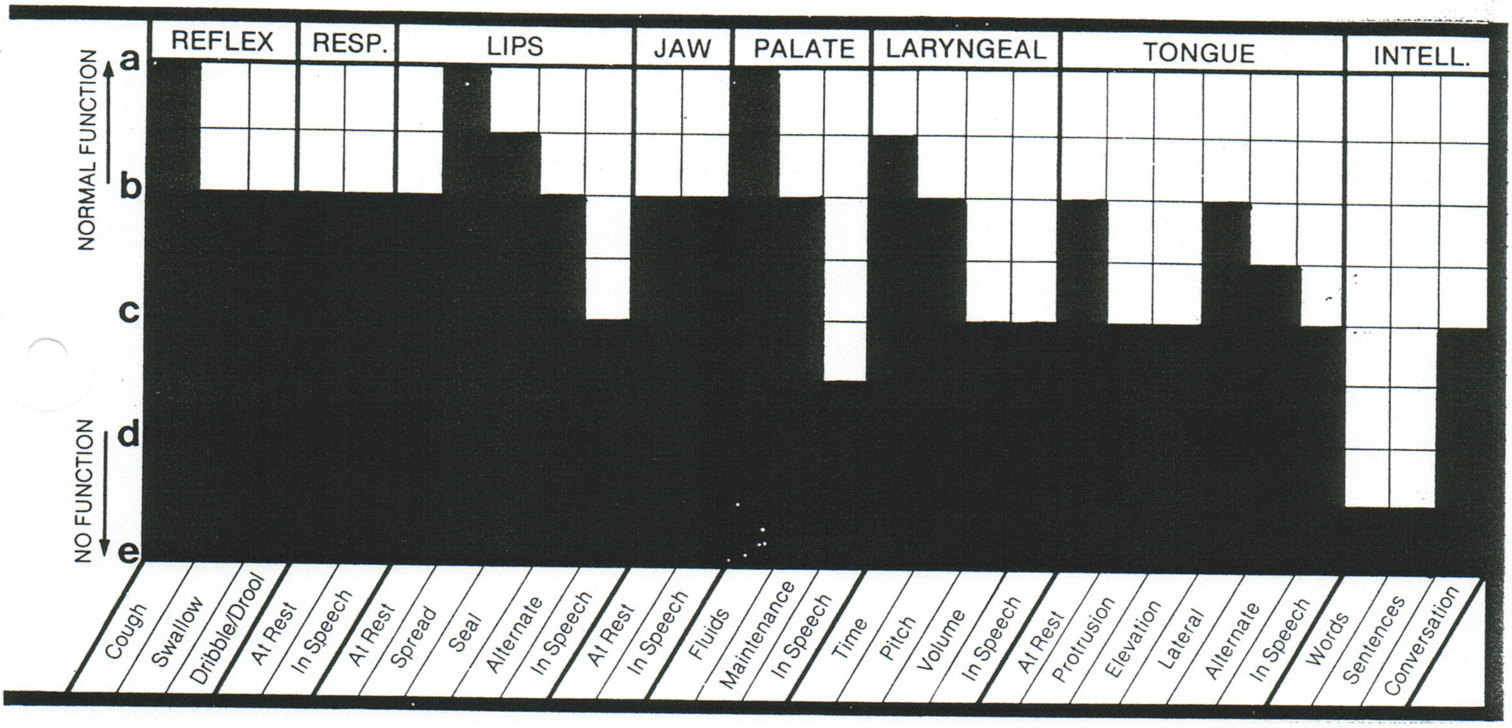

Fig. 6

J. C. Nordli

eprar03.700

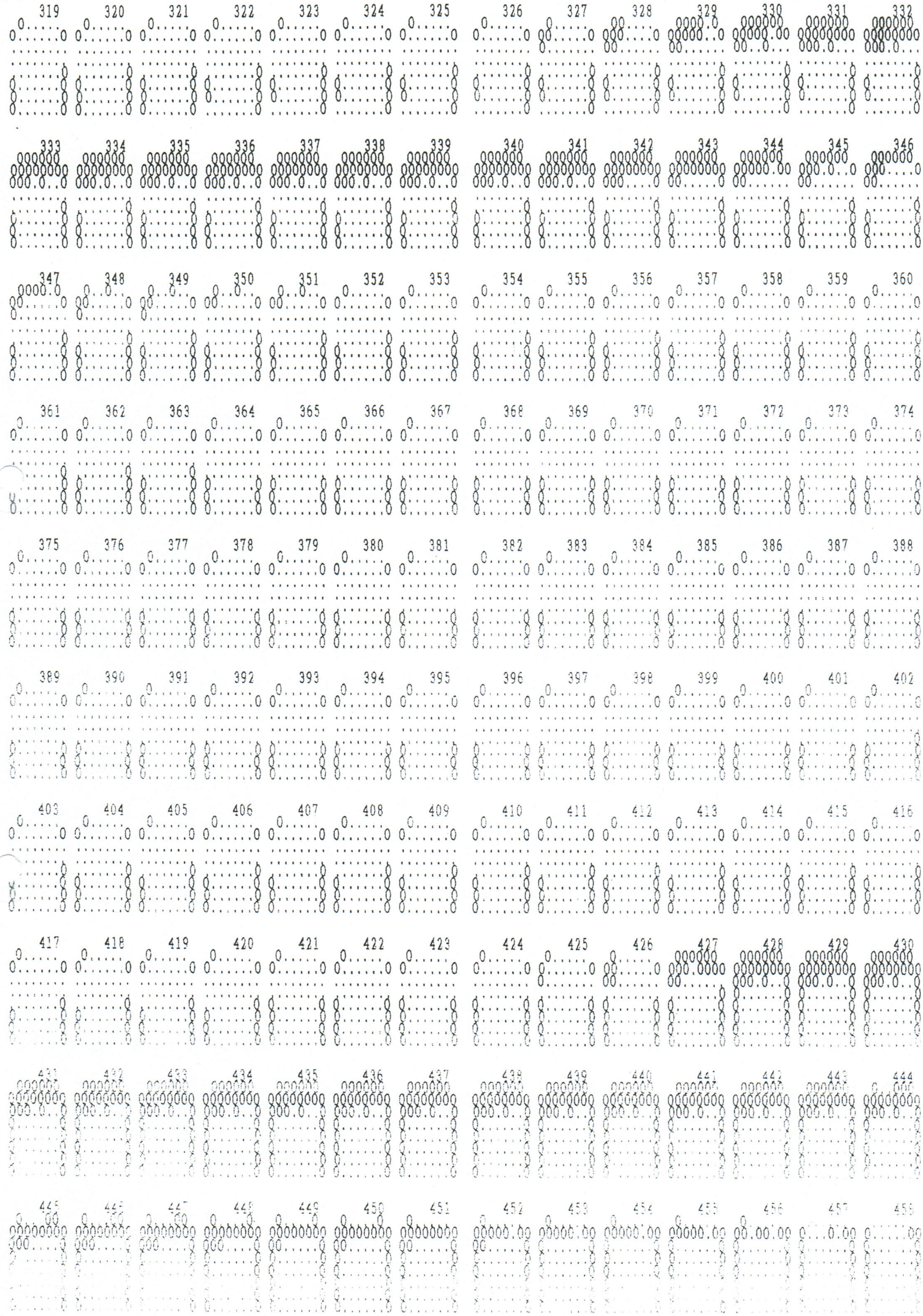

Fig. 7 J. C. Norelli