# One or two velar fricatives in Dutch?

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# ONE OR TWO VELAR FRICATIVES IN DUTCH? *)

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## INTRODUCTION

The various handbooks in the structural tradition on Dutch phonology are in unanimous agreement about the phonemic status of the voiced/lenis and voiceless/fortis velar fricatives in Dutch, the /ɣ/ and /χ/ (Zwaardemaker and Eijkman 1928 p. 195, Cohen et al 1961 p 34, van den Berg 1971 p. 38). There is, however, relatively little agreement on the phonetic realisation of the /ɣ/, apart from its predictable voicelessness in word-final position. Van den Berg calls initial /ɣ/ 'almost voiceless' (1971 p. 38); Zwaardemaker and Eijkman describe initial /ɣ/ as 'voiceless but loose' (=lenis) (1928 p. 196), and Cohen et al.regard a possible initial voiced-voiceless opposition as 'always artificially inspired by the spelling', at least in the region 'North of the big rivers', (1961 p. 34). Only in medial position may the /ɣ/ be expected to show voice according to all authors, although, according to Cohen et al. (1961 p. 34) the opposition /ɣ/ vs. /χ/ 'is not present for many speakers in the West'. Alternatively, 'there are speakers whose /ɣ/ is a variant of /χ/ prevocalically' (1961 p. 87). Zwaardemaker and Eijkman state (1928 p. 195) that 'in the pronunciation of many

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speakers the velar fricative is always voiceless'.

In more recent publications the differences between the voiced and voiceless velar fricative seem more questionable. Hermkens (1971 p. 47) claims total absence of voice in /ɣ/, Nooteboom and Cohen (1976 p. 144) transcribe /χ/ for both fricatives.

Hence, the unanimous position of postulating two phonemes, with logen/loochen /lo:ɣən, lo:χən/ (Cohen et al 1961 p. 34) as perhaps the only minimal pair to be found, is not selfevident on the basis of the phonetic data available. Both in Zwaardemaker and Eijkman (1928 p. 195) and in Cohen et al. (1961 p. 79) a lenis/fortis difference is mentioned next to voice/voiceless as a possible phonetic correlate for the /ɣ/ vs. /χ/ opposition. Physical manifestations of fortis vs. lenis are said to be: greater intensity and longer duration. Transformational phonologists postulate two underlying segments, /ɣ,χ/ differing in voice and tenseness (Spa 1970) for which as an argument differences in past tense alternants viz vlagde /vlɑɣdə/ vs. lachte /lɑχtə/ could be adduced. We know of no proposal in which the underlying contrast is always neutralised at the phonetic level.

Recent phonetic work has demonstrated that a measurable and perceptually relevant physical correlate of the voiced/voiceless opposition can be found in the duration ratio of the vowel immediately preceding and the fricative itself, the summed duration remaining constant, (Slis and Cohen, 1969). This entails that the longer duration of the voiceless, tense fricative is compensated by the shorter duration of the preceding vowel, and that short, voiced, lax fricatives are combined with preceding vowels of longer duration. This phenomenon was only established for the pairs investigated, viz /s,z/ and /f,v/.

The purpose of our investigation is to decide whether the alleged voiced and voiceless velar fricatives are indeed different on phonetic grounds. Though various degrees of abstractness and sophistication of reasoning may be used in experiments aimed at answering this sort of questions, we have, for the time being, restricted ourselves to some of the more obvious and straightforward approaches. Two experiments will be described, one trying to find acoustic correlates of the voice/voiceless contrast with velar fricatives in the time domain, and a second, in which the perceptual difference between the cognates is assessed.

EXPERIMENT I: ACOUSTIC DIFFERENCES BETWEEN VOICED AND VOICELESS VELAR FRICATIVES

If there are indeed two velar fricatives in Dutch, the difference should, as we have seen, be clearest in medial intervocalic position, and it could manifest itself in one or more of the following ways:

1) there is a difference in the presence of vocal cord vibration during the production of the fricative;
2) there is a systematic difference in the duration and/or intensity of the fricative, the /χ/ being more intense and longer duration;
3) there is a systematic difference in the duration of the preceding vowel, (longer for /ɣ/);
4) /VɣV/ vs. /VχV/ would have to yield different perceptual judgments;
5) systematic variation of one or more of the physical parameters should enable listeners to switch from voiced to voiceless judgments and vice versa.

Conditions 1), part of 2) and 3) have been investigated and are reported on below.

.1 Method

Four male speakers of standard Dutch, naive as to the purpose of the experiment, were asked to read 3 times from separate cards 25 sentences in normal spelling of the type 'the following word is - ' in which 12 words containing velar fricatives and 13 fillers were substituted for the dash.

The twelve words containing medial intervocalic velar fricatives were:

| | | | |
|---|---|---|---|
| lachen | [lɑχən] | vlaggen | [vlɑχən] |
| kuchen | [kœχən] | ruggen | [rœɣən] |
| wichel | [wiχəl] | biggel | [biɣəl] |
| giechel | [χi:χəl] | kriegel | [kri:ɣəl] |
| loochen | [lo:χən] | logen | [lo:ɣən] |
| juichen | [jʌyχən] | duigen | [dʌyɣən] |

Thus each speaker produced 6 intended /ɣ/ and 6 /χ/ realisations preceded 3 times by a short vowel, and 3 times by a long vowel or diphthong in 3 consecutive series yielding a total of 144 words containing velar fricatives. The utterances were recorded in a sound treated Amplifon recording booth by means of a Sennheiser SHL condensor microphone and a Nagra IS 4 tape recorder (19:cm/sec.). Vocal cord activity was recorded through a Frøkjaer Jensen Electroglottograph on one track of a Revox A-77 tape recorder simultaneously with the audio output, which was recorded on the other track. UV-oscillograms were obtained through a Honeywell Visicorder (20 cm/sec.) of the audio output and the electroglottograph signals, together with a trace representing $\frac{I_1}{I_2}$ of the audio-signal via a Frøkjaer Jensen Intensity Meter, $I_1$ being the intensity of the signal in the frequency range 0-500 Hz, (36 dB/octave) and $I_2$ all frequencies above 500 Hz, integration time 5 msec. The intensity ratio was recorded to facilitate segmentation on the oscillograms between vowels and preceding liquids.

The duration of the fricatives and preceding vowels was measured (accuracy 5 msec.) and the output was inspected on vocal cord vibration.

## 1.2 Results

The electroglottograph signal showed that there was no vocal cord vibration in the /ɣ/ realisations for any of the speakers in any of the utterances. A breakdown of means and two 3-way analyses of variance were performed on vowel and fricative durations, with (1) voice x length x speaker and (2) voice x vowel quality x session as factors.

Also, linear regression coefficients and product moment correlation coefficients were calculated for the relation between vowel and fricative duration. Vowel durations preceding voiced and voiceless fricatives are 129(S.D. 47) and 118(S.D. 50) msec. respectively, $F(1,143) = 3.072$, $p = .078$, see Fig. 2.

Inspection of Fig. 1, a-d reveals that this effect is strongly present in speakers 2 and 4, and absent in speakers 1 and 3. Mean fricative durations for voiced and voiceless realisations are 104(S.D. 26) and 118(S.D. 23) msecs. respectively, $F(1,143) = 58.864$, $p < .001$.

Again, individual differences can be found: speakers 1 and 2, but not 3 and 4 shorten their voiced fricatives.

These data indicate the presence of an inverse relationship between vowel and fricative durations. The overall correlation coefficient is rather low, however, ($r=-.114$, p .087). When partialled out for the four speakers there is no negative correlation for speaker 1 ($r=+.157$, insignificant) and ($r=-.001$, insignificant), but there is for speakers 2($r=-.156$, insignificant) and 4 ($r=-.400$, $p < .01$).

There is no noticeable interaction for long and short vowels under /χ/ and /ɣ/ conditions, $F(1,140) = .000$, insignificant. There appear to be marked differences between long and short vowels vis à vis fricative durations. Curiously enough, fricatives after short vowels are shortened more than after long vowels (119-102 msec. against 118-108 msec. respectively). The interaction is significant

F(1,140) = 4.523, p=.003. Again, inspection of figure 1, e-h reveals marked individual differences among the 4 speakers.

### 1.3 Conclusion

Generally speaking, there are physical differences between /χ/ and /ɣ/ in Dutch: mean vowel duration increases and mean fricative duration decreases when going from /χ/ to /ɣ/. The total duration of vowel plus fricative is almost constant (235 msec. on average; 205 msec. for short and 265 msec. for long vowels).

The negative relationship is not very systematic, with marked inter- and intra-individual variations. The voiced-voiceless distinction manifests itself in vowel duration for some speakers, and in fricative duration for others. Generally, speakers behave more uniformly with regard to fricative duration than to vowel duration.

## 2. EXPERIMENT II: PERCEPTUAL IDENTIFICATION OF DUTCH VELAR FRICATIVES

It is commonly appreciated that no acoustic difference between speech sounds is relevant unless it can be shown to play a decisive role in the perception of such sounds.

It seems reasonable to expect that if listeners are at all able to identify voiced and voiceless velar fricatives in Dutch, the better cue will be provided by the parameter the speakers in our previous experiment behaved more uniformly to. Fricative duration rather than the duration of the preceding vowel was found to vary in accordance with the voice-voiceless opposition. At the time that the acoustic measurements were carried out there were no adequate facilities in our department to determine the spectral composition of the produced quasi-minimal pairs. Partly by way of exploring the necessity of such additional measurements in the future we thought it of vital importance to examine the cue value of the duration parameters in a perception experiment. Correlation of identification scores with the duration parameters should enable us to establish their relative cue value. Should it appear that a major part of the identification variance still goes unaccounted for after such a correlation, we must assume that spectral composition is an important factor. *)

Two perceptual tasks will be employed, in both of which subjects will be asked to identify the fricative in the stimulus as either voiced or breathed. Of course, the words as spoken by our informants could not properly serve as stimuli for the reason that they never constitute a minimal pair, so that correct identification could always proceed on the basis of word recognition. For this reason the members of such quasi-minimal pairs as vlaggen/lachen [vlɑɣən]/[lɑχən] were mutilated into nonsense words so as to preclude word recognition. This was done by electronically removing the initial consonant(s) of each word recorded in the production experiment. This procedure yielded nonsense minimal pairs like aggen/achen [ɑɣən]/[ɑχən] with which standard identification tasks could be used. Two perceptual tasks were imposed on our subjects. With clear-cut voice-voiceless distinction (e.g. as reported by Slis and Cohen, 1969) absolute identification, i.e. on the basis of one word in isolation, would be a sufficient experimental task. It was foreseen, however, that listeners confronted with Dutch velar fricatives would need a more subtle approach, in which the voiced- and voiceless members of one minimal pair were presented in rapid succession so as to enable comparative judgement.

*) A recent experiment by Debrock (1977), however, shows that yet another parameter in the time domain may be relevant to the voiced-voiceless (or lenis/fortis) opposition: the decay time of the vowel off-set preceding the (velar) fricative.

## 2.1 Method

### 2.1.1 Stimulus material

With the aid of a Grason Stadler 1287B Electronic Switch controlled by a Devices Digitimer D-4030 programmable counter, the 144 words recorded by our speakers in the previous experiment, were gated out from the master tape using the set up described in Van den Broecke and Versteeg (1976), and recorded on a Revox A-77 half track tape-recorder at 19 cm/sec. Initial consonants were suppressed up to the point where the amplitude definitely started to rise towards a vowel peak. The precise closing moment of the switch was determined by repeated comparison of the gated out portion of the signal with the complete original on a dual beam storage oscilloscope. Independent performance of both authors on the same items did not deviate more than 10 msec. The switch was set at a rise time of 25 msec, i.e. the gated out signal reached its full amplitude 25 msec. after the closing of the switch, so as to obviate distortion and the resulting auditory illusion of a plosive ('t Hart and Cohen, 1964). The gated out items were recorded at 7 sec. intervals in the same (random) order in which they had been recorded on the master tape. From this tape, which we shall refer to as tape I, a second tape (tape II) was composed in such a way that the members of each minimal pair spoken within one round by one speaker were copied on a Revox A-77 half track recorder at 19 cm/sec. with 2 sec. intervals between the members of one pair, while complete pairs succeeded with 9 sec. intervals. The order in which the voiced and voiceless counterparts appeared within a pair was random. Each of 72 pairs occurred once on the tape.

### 2.1.2 Subjects

63 subjects took part in the first experimental task, 33 of whom remained to take the second as well. They were male and female first year students of English at Utrecht University, native speakers of Dutch, who received at least one year of phonetic and

linguistic training. All cooperated on a voluntary basis, and no money was paid for their services.

### 2.1.3 Procedure

Before the experiment started it was explained to the subjects that the status of the velar fricatives in Dutch was an unsettled issue, and that they could help solving the problem by listening as accurately as they could. They were warned that the differences between the sounds to be discriminated would at times be very difficult to hear, if at all, but that they should not allow themselves to be demotivated. They were then issued reponse booklets and instruction sheets: (translated from Dutch).

You are about to listen to 150 non-existing words which could conceivably belong to the Dutch language, whose structure is vowel-velar fricative-en. They were in fact obtained by electronically cutting off the initial consonant(s) in such words as vlaggen, lachen, juichen, duigen. Your task will be to determine for each given word whether the fricative is g or ch, and to fill this in on your response booklet. You should record your first impression, and never revoke an earlier decision. You are not allowed to skip back to an earlier page.

We realize that this task will be extremely difficult and at times impossible, but it is essential that you make a choice in all cases, and to gamble when the choice cannot be made. If there are any questions concerning this procedure please ask them now.

The response booklets contained 12 identical pages, one for each round of 12 stimuli, which occurred in a fixed order. On each page the responses were printed without the initial consonants, and with the fricative left blank.

Tape I, preceded by 5 randomly selected stimuli included to familiarize the subjects with their task, was then played to them by means of a Revox A-77 half track recorder and a Quad 30-303 amplifier with Quad Electrostatic loudspeakers. The subjects were seated in a normal lecture room, and the experiment constituted part of a routine lecture on phonetics. After a 10 min break just over half of the subjects returned to take the second part. They received a new response booklet along with the following written instructions:

(translated from Dutch)

You will now listen to the same non-existing words as before, but this time we have facilitated your task by arranging the members of each minimal pair in immediate succession for the sake of comparison. Your task is to determine the order in which the g and ch words occur within each pair. On the tape this order varies unsystematically. You indicate your choice by filling the symbols g and ch in the blanks on your response booklets in the order of their occurrence on the tape. Remember that you must make a choice at all times, even if you cannot decide on the order. If there are any questions concerning this procedure, please ask them now.

Then tape II was played to the subjects, in the same fashion as in the first part. The first 5 items were pairs selected at random, which were included to familiarize the subjects with their task.

## 2.2 Results and conclusions

### 2.2.1 Absolute identification

Three subjects had not kept to the instructions, and their responses were excluded from further data processing.

Absolute identification scores were calculated for each of the 144 stimuli by dividing the number of correct identifications by the number of valid responses. Identification scores are given in figure (3) for each of the 4 speakers, separated out for /ɣ/ and /χ/, as well as for long and short preceding vowels. When the subjects had no indication as to the identity of the stimulus, scores should be 50 (%). Figure (4) gives the same information but pooled for long and short preceding vowel.

It appears that speaker I and III are responded to in a more or less random manner, that speaker IV generally lies just above chance (52%), and that moderately successful identification is obtained with speaker II only (60%). A classical analysis of variance performed on these data with speaker, vowel quantity, vowel type and voice coefficient as factors revealed that these speaker differences are significant, $F(3,140) = 5.483$, $p=.002$.

There seems to be no systematic between long and short preceding vowels as far as identification accuracy is concerned. When pooling the results for the four speakers identification of voiceless /χ/ is 3% above chance, of voiced /ɣ/ 2%.

We have attempted to correlate these identification scores with the duration parameters measured in experiment I. These results, together with a multiple regression analysis, are given in table I:

| | fric dur x vowel dur r= | ident x fric dur r= | ident x vowel dur r= | multiple prediction R= |
|---|---|---|---|---|
| speaker I | .157 | -.054 | -.013 | .054 |
| speaker II | -.156 | -.070 | -.098 | .130 |
| speaker III | -.000 | .062 | -.064 | .089 |
| speaker IV | -.400 | .026 | .087 | .109 |
| pooled speakers | -.114 | -.012 | -.004 | .013 |

Table I

Correlation, intercorrelation and multiple correlation coefficients for duration parameters and identifications scores.

These correlations indicate that no general relations hold, and that the best prediction, if any, obtains with speaker II, although even here only 2% of the variance is accounted for.

In conclusion of the absolute judgement task we may state that our subjects were able with very modest success to detect a voice-voiceless distinction in the velar fricatives as produced by only one of our speakers, but that no (complex of) duration parameter(s) seems to govern their decision behaviour.

### 2.2.2 Discrimination

Discrimination scores were obtained for each stimulus by dividing the number of subjects that had chosen the correct sequence of voice and voiceless cognates, by the number of valid responses. Results are presented graphically in figure (5) for the speakers separately, and in figure (6) for the pooled speakers.

Average performance on the discrimination task was about random: 49.3% of the valid responses was correct. Again speaker II was responded to with greater accuracy (63% correct) than any of the other speakers, who were all below chance. A classical analysis of variance on the discrimination scores with speaker and the order of intended voiced and voiceless member within a pair as factors indicated that the speaker effect is significant, $F(3,58) = 12.452$, $p < .001$. A curious secondary effect is that the succession of the voiced and voiceless members within a pair influenced discrimination accuracy to the extent that 8% better discrimination scores were obtained when the second member within a pair was meant to be voiced, $F(1,70) = 3-995$, $p=.048$. Together, speaker and sequence effects account for 41% of the variance. There is no effect of the phonological length of the preceding vowel, although short vowels with speaker II lead to 4% better discrimination than long vowels; this speaker quantity interaction, however, is not significant, $F(3,64) < 1$, by a three way extension of the analysis of variance.

Since this concerns a relative judgement task, we felt that correlation of discrimination scores with duration parameters should proceed on a relative basis. Therefore the differences in vowel and fricative durations between the two members of each pair presented were calculated and correlated with the corresponding discrimination scores. Table II summarizes the results.

| | fric dur x vowel dur r= | ident x fric dur r= | ident x vowel dur r= | multiple prediction R= |
|---|---|---|---|---|
| speaker I | .248 | -.324 | .066 | .357 |
| speaker II | -.103 | .552 | .114 | .578 |
| speaker III | .176 | .058 | -.138 | .161 |
| speaker IV | .234 | -.132 | -.040 | .132 |
| pooled speakers | .288 | .511 | .166 | .511 |

Table II

Correlation, intercorrelation and multiple correlation coefficients of duration parameters and discrimination scores in relative judgement task.

It appears that discrimination scores improve as the difference in fricative durations increases. Although the predictive power of the duration parameters is far from spectacular, it seems justified to draw the conclusion that fricative duration rather than vowel duration is primarily responsible for the discrimination of voiced/breathed velar fricatives, vowel duration adding little or nothing in a multiple regression analysis in which both parameters were entered simultaneously. Thus in the pooled data about 25% of the variance is accounted for by the duration parameters, mainly due to the influence of speaker II, in whose case 33% of the variance is accounted for.

Examination of scattergrams of discrimination scores and physical parameters (not included) seemed to indicate that the correlations are most disrupted in the random response area (between 40 and 60%). On the basis of this observation it seemed attractive to perform a multiple regression analysis for the non-random scores, which were rather arbitrarily defined as more extreme than 40 or 60%. The results of this procedure (table III) indicate that 45% of the variance in the recognition scores can now be accounted for.

| difference in fric dur x difference in vowel dur r= | diff in fric dur x discrimination score r= | diff in vowel dur x discrimination r= | multiple prediction R= |
|---|---|---|---|
| .345 | .661 | .337 | .671 |

Table III

Correlation, intercorrelation, and multiple correlation coefficients of relative vowel and fricative duration on discrimination accuracy.

This superiority of the cue value of fricative duration over the duration of the preceding vowel ties in with our earlier finding that our speakers generally behaved more uniformly with respect to the former parameter. However, we have seen that more than half of the variance still goes unaccounted for, so that inclusion of spectral parameters in the regression analysis seem warranted for the future*).

Apparently it is rather difficult to adequately recognize Dutch velar fricatives under the circumstances introduced in our experiment,

*) A recent experiment by Debrock (1977), however, shows that yet another parameter in the time domain may be relevant to the voice/voiceless (or lenis/fortis) opposition: the decay time of the vowel off-set preceding the (velar) fricative.

especially so when recognition is to proceed on an absolute basis. In the comparative task, however, moderately successful discrimination of voice versus voiceless velar fricative proved feasible with one speaker, and moreover, seemed to have been governed by the same durational cues as have been reported in the literature on phonemic oppositions of less questionable status.

## 3. GENERAL DISCUSSION

Now we have arrived at a situation in which only some speakers make a distinction in the production of the cognate pairs, and find at the same time that a significant majority of listeners are able to perceive this difference if it has been properly made.

Are we now in a better position to argue for one or two phonemes? We take the view that differences at the production stage, however, systematic and reproduceable, can never provide conclusive evidence for phoneme status; rather we believe that the results of perceptual experiments should prevail. Unfortunately, there has been very little research on the perceptual consequences of the voice-voiceless distinction in stimuli taken from natural speech. We do not know, for instance, how Dutch listeners would perform in discrimination tasks with labial and alveolar voice-voiceless contrasts, involving either fricatives or stops. Would similar differences in performance on absolute and comparative identification obtain? An equally important question is whether comparative identification can ever be accepted in evidence for phonemic contrasts. After all, in normal communicative situations one never meets immediate successions of minimal pairs. Such a view would dictate that only those contrasts that can be upheld in absolute identification experiments may be given phonemic status. On the other hand, ABX phoneme identification tasks, or (language master) card sorting experiments are common procedures in perceptual research, relying on comparative judgements.

Slis and Cohen, (1969) may be regarded as a first attempt at establishing relative cue values of the various spectral and durational parameters, but its scope was too wide and its method too qualitative to allow conclusions as to a hierarchy of perceptual cues.

Rather than having found an answer to the title question, we have discovered that conclusive evidence on this type of questions can only be gathered from an exhaustive and meticulous investigation of the perceptual cue value of acoustic parameters in a complete paradigm of (alleged) phonemic contrasts.

Title received 1976

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