

# DURATION AS A VOICING CUE IN DUTCH

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## ABSTRACT

Voicing in Dutch fricatives is marked acoustically by periodicity, duration, and intensity, but devoicing of fricatives is common. Participants from North-Holland and Limburg identified syllables starting with fricatives without periodicity but varying in duration (5 steps) and intensity (5 steps) to determine whether duration and intensity are effective voicing cues, and whether this depends on the level of (de)voicing in the different areas.

Noise duration significantly affected identification, with up to 20% more voiceless responses for longer fricatives, while intensity did not, indicating that speakers of Dutch use fricative duration as a perceptual cue for voicing in the absence of periodicity. Interestingly, there were no significant differences between the responses from participants from Limburg and North-Holland nor any interactions with region, suggesting that the use of duration as a voicing cue is pervasive throughout the Netherlands rather than dependent on the extent of devoicing in varieties of Dutch.

**Keywords:** speech perception, fricatives, voicing, cue weighing

## 1. INTRODUCTION

The Dutch phoneme inventory is generally described as having both voiced and voiceless fricatives, but there is considerable regional variation. The full fricative inventory is shown in Table 1, including post-alveolar fricatives that only occur in loanwords or as a result of palatalisation [1]. For all supraglottal places of articulation, a distinction is made between voiced and voiceless fricatives, and this distinction can be marked acoustically by periodicity in the frication noise, frication noise intensity, and duration of the frication noise.

An acoustic study of Standard Dutch pronunciation across the Dutch language area [2] showed that voiced fricatives were realised with periodicity during more than half of the of the duration of the frication noise, much more than in voiceless fricatives, where the presence of periodicity during up to 19% of the fricative duration was thought to be the result of coarticulation with adjacent vowels. In addition, it was reported that while the intensity of

the frication noise differed mainly depending on place of articulation, the intensity of most voiceless fricatives was also slightly higher than voiced fricatives with the same place of articulation, and they found the durations of voiced fricatives to be on average 12% to 21% shorter than voiceless fricatives. In line with these findings, a different study on Dutch labial fricatives [3] found a duration difference of 18% between [f] and [v], and similar patterns of noise duration and amplitude have been reported for English fricatives [4]. Noise duration and intensity are thus well-established acoustic correlates of voicing differences in fricatives in addition to periodicity.

**Table 1:** Fricatives in Dutch.

	labial	alveolar	post-alveolar	velar	glottal
voiceless	f	s	ʃ	x	-
voiced	v	z	ʒ	ɣ	ɦ

Despite being traditionally described according to the distinctions in Table 1, devoicing of the voiced fricatives in Dutch, particularly in word-initial position, has been noticed since the early 20th century and is at various stages of completion in different regions of the Dutch language area. Analysis of voiced fricatives in Dutch and Flemish radio broadcasts from 1935 to 1993 [5] showed that the dominant realisation of /v/ in the Netherlands had become [f] by the end of the documented period, /z/ was devoiced up to half the time, and /ɣ/ was hardly ever voiced, in contrast with Flanders where /ɣ/ was voiced more often and /v/ and /z/ were nearly always voiced. In a more recent study [6], devoicing of the labial plosive and fricative was investigated in multiple regions in the Netherlands and Flanders. Fricative voicing turned out to be retained to a much larger extent in the regions in Flanders and the southern Dutch region Limburg than in the north and west of the Netherlands, but some level of devoicing is now present in all regions.

Given the increasing overall loss of periodicity in fricative productions and the regional differences in this respect across the Dutch language area, the aim of the current study was to investigate i) the role of cues other than periodicity, i.e. duration and intensity, in the perception of fricative voicing, and ii) whether

the use or weighing of these cues differs between listeners from regions where devoicing happens more (North-Holland) or less (Limburg) structurally. As velar fricatives do not occur in North-Holland, rather being realised as [χ], only the more anterior places of articulation were included in the current study.

We expected that duration and intensity would both influence fricative perception, with duration possibly having a stronger influence than intensity because duration is a more robust stimulus property across places of articulation that is less affected by listening conditions than intensity. With respect to regional differences we expected either of the following options: people from North-Holland might use duration and/or intensity to a greater extent than people from Limburg because they have more exposure to devoiced fricatives, which might have led them to tune in more to alternative cues in order to maintain lexical contrast; alternatively, people from North-Holland might be less sensitive to any of the cues because they have fully neutralised the contrast.

## 2. METHOD

### 2.1. Participants

A total of 26 native speakers of Dutch who lived and grew up in the regions North-Holland or Limburg, and whose parents met the same criteria, took part in the experiment. The final analysis includes data from 14 speakers from North-Holland (mean age 36) and 9 from Limburg (mean age 40), as 3 participants either turned out not to meet the inclusion criteria or failed to comply with the experimental procedure.

### 2.2. Stimuli

Fricative-initial nonsense syllables including both voiced and voiceless fricatives were recorded from a phonetically trained female native speaker of Dutch from the region of Haarlem. The duration and intensity of the naturally voiced and voiceless fricatives in these recordings were taken as the starting point for the experimental manipulations to preserve some of the natural variation. For the experimental items, 12 different syllables starting with a naturally voiceless labial, alveolar, or post-alveolar fricative followed by [i], [u], [a], or [ɑ] were altered using Praat [7] to create 25 versions per syllable, with 5 different durations and 5 different intensity levels. To determine the range of fricative durations in the experimental items, the duration differences between naturally voiced and voiceless fricatives were increased by 8 ms on the lower and the higher end, and 5 steps were interpolated along this enhanced range. To determine the range of fricative intensities, the intensity differences between naturally

voiced and voiceless fricatives were increased by a factor of 1.3 and 5 steps were interpolated along this enhanced range. Crucially, all experimental items were based on naturally voiceless fricatives where no periodicity was present in the frication, they were only shortened and attenuated in order to elicit the percept of a voiced fricative.

### 2.3. Procedure

The 25 versions of the 12 different base syllables resulted in 300 unique experimental items, which were identified by the participants in a 2-alternative forced-choice task. Participants were seated in a quiet room behind a laptop and heard the stimuli over headphones. The question in the middle of the laptop screen was always “Which consonant did you hear?” and the two answer options were orthographic representations of the relevant fricative pair: “f” and “v”, “s” and “z”, and “sj” and “zj”. Participants were familiarised with the sounds that the labels referred to. After hearing each stimulus once, participants responded by pressing a key associated with the left or the right answer option. The stimuli were presented in pseudo-random order with the same base syllable never appearing twice in a row, and participants took a self-timed break every 100 stimuli. Prior to the real experiment, participants completed 6 practice trials where they needed to identify natural plosive-initial syllables to get used to the procedure. Participants who made multiple mistakes on the practice trials and participants with unrealistically short reaction times were excluded from analysis.

## 3. RESULTS

Participants’ responses were coded as either ‘voiced’ or ‘voiceless’. Table 2 shows the percentage of ‘voiceless’ judgements of the listeners from North-Holland (panel A) and from Limburg (panel B) for each step on the duration and intensity continua, averaged over the different stimulus syllables. The highest percentages of ‘voiceless’ judgements are found in the upper right parts of the tables where both intensity and duration are highest, which is expected if intensity and duration are not only acoustic correlates but also perceptual cues to fricative voicing.

The responses were analysed using the `lmer` package [8] in R [9]. A binomial model of the participants’ responses was fitted with Duration and Intensity as within-subject factors and Region as a between-subjects factor, with random slopes and intercepts for the within-subject factors and their interaction. As we had no a priori expectations regarding the effects of place of articulation and

vowel quality on participants' judgements, these factors were not included in the model.

**Table 2:** Percentage of 'voiceless' judgements by participants from North-Holland (A) and Limburg (B) along the 5x5 intensity and duration continua with means per row and column. Darker shading indicates more 'voiceless' judgements.

A: North-Holland			intensity (lowest to highest)				
% voiceless responses							
		-1-	-2-	-3-	-4-	-5-	
		47,2	44,6	46,8	46,4	50,6	
duration (shortest to longest)	-5-	55	56	54	55	51	59
	-4-	50,4	51	45	49	52	55
	-3-	46	47	39	48	45	51
	-2-	43	43	45	40	41	46
	-1-	41,2	39	40	42	43	42
B: Limburg			intensity (lowest to highest)				
% voiceless responses							
		-1-	-2-	-3-	-4-	-5-	
		53,8	51,6	52,8	56,8	55,8	
duration (shortest to longest)	-5-	66,8	64	68	64	70	68
	-4-	58,4	55	55	58	64	60
	-3-	53,2	54	50	52	52	58
	-2-	46,2	48	41	46	51	45
	-1-	46,2	48	44	44	47	48

We found a significant overall effect of duration on voicing perception, with higher odds of 'voiceless' answers for longer durations (odds ratio 1.18, 95% c.i. from 1.06 to 1.31,  $p = 0.002$ ), but no significant overall effect of intensity (odds ratio 0.94, 95% c.i. from 0.86 to 1.03,  $p = 0.17$ ) and no significant overall effect of Region (odds ratio 0.68, 95% c.i. from 0.34 to 1.36,  $p = 0.27$ ). The results do not provide evidence regarding the weighing of Duration and Intensity relative to each other, as there were no significant interactions between the experimental manipulations. There were also no significant interactions with

Region, and the effect of duration was significant in each individual group, with an odds ratio of 1.15 favouring 'voiceless' answers for longer durations for listeners from North-Holland (95% c.i. from 1.03 to 1.28,  $p = 0.009$ ) and an odds ratio of 1.21 for listeners from Limburg (95% c.i. from 1.01 to 1.44,  $p = 0.03$ ). These results show that, in the absence of periodicity, Dutch speakers interpret differences in the duration of fricatives as voicing cues regardless of their region of origin.

#### 4. DISCUSSION

We set out to investigate how speakers in different regions of the Dutch language area weigh duration and intensity in the perception of fricative voicing, as these cues are well-established acoustic correlates of voicing. Our results show an overall effect of fricative duration on voicing judgements, which is present in both the North-Holland group and the Limburg group, but not of intensity. The lack of an effect of intensity is as likely to be the result of stimulus or testing quality as of the lack of use of the cue in general. Since the intensity of fricative noise varies not just with voicing but also between places of articulation [2,4], it could be that the variation in place of articulation among the experimental items in the current study discouraged listeners from using this cue.

Unexpectedly, we found that people from both North-Holland and Limburg used duration to judge fricative voicing, in contrast with the findings in [10]. In their study, listeners from various regions in the Dutch language area categorised syllables with an initial labial fricative that varied in the level of periodicity during the noise (9 steps) and the noise duration (9 steps). Listeners from all regions were sensitive to the level of periodicity, but not all in a categorical manner, with those from strongly devoicing areas showing more gradient responses. Duration, on the other hand, did not influence listeners' categorisations at all in the regions most comparable to those in our study, Limburg and South-Holland.

Taken together, these findings suggest that even though fricative voicing has multiple acoustic correlates, listeners do not always weigh all these cues in perception, but rely fully on the cue that is most salient in the current context – periodicity in [10], and duration in the current study. The availability of duration as a perceptual cue to fricative voicing in both the North-Holland and the Limburg groups indicates that even in strongly devoicing regions, the phonological contrast is maintained by speakers of Dutch. This is in line with phonological

accounts of Dutch fricative voicing that posit length as the fundamental opposition [11].

## 5. CONCLUSION

The reliability of duration as an acoustic correlate of phonological voicing in Dutch fricatives has been firmly established, but its relevance in perception was not as clear. We show in the current study that speakers from different regions in the Netherlands that are known to differ in the extent of fricative devoicing all use duration as a voicing cue in the perception of initial fricatives when there is no voicing in the signal. This suggests that listeners can flexibly select the acoustic cues that map onto phonological categories in a given situation, and that even in strongly devoicing regions speakers maintain a phonological contrast.

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