A cross-language study of laryngeal-oral coordination across varying prosodic and syllable-structure conditions

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Abstract

Transillumination and videofiberendoscopic filming was used to investigate the devoicing gesture in German, Dutch and French for material that compared firstly a strong vs. weak prosodic condition, and secondly singletons vs. clusters (stop + /r/ and /l/). The results showed enhancement of the devoicing gesture in the strong prosodic condition and in the segmental context stop + /r/ for German and French, but not for Dutch. This suggests that the voiceless plosives of French have an active specification for glottal spreading. In terms of timing (e.g. timing of peak glottal opening relative to stop release) French was intermediate between German and Dutch. This indicates that static features are not well suited to capturing cross-language differences in voicing typology and changes in voicing specification over time.

Keywords: laryngeal timing, clusters, prosodic strengthening

1. Introduction

This study investigates laryngeal-oral coordination for voiceless consonsonts in languages that are traditionally considered to differ in terms of their voicing typology, namely German on the one hand vs. French and Dutch on the other.

The basic rationale was that prosodic variation can be used as a probe to make clearer the nature of the articulatory representations underlying the voicing distinction. In English, the VOT of voiceless plosives is often found to be longer in prosodically strong locations, suggesting that the laryngeal abduction gesture is also longer and/or larger. More intriguingly, Cho & McQueen (2005) observed for Dutch that prosodic strengthening can lead to shortening of VOT. This was interpreted as indicating that the phonologically voiceless plosives are implemented phonetically as {+ spread glottis} in English and {- spread glottis} in Dutch (these phonetic features then being reinforced as part of prosodic strengthening). However, neither for English nor for Dutch is anything known about what changes in laryngeal movement actually take place. Further phonological accounts of voicing across languages would also appear to predict differential effects of prosodic strengthening. For example, Iverson & Salmons (2007) analyze voiceless plosives as laryngeally specified for spread glottis in German and English but as laryngeally unspecified for e.g. French and Dutch.

It was hypothesized that further light could be shed on this general issue by systematically varying the syllable onsets of the target items, specifically by comparing singletons (e.g. /p/) with clusters (e.g. /pr/, /pl/). Even though the second element of these clusters would not normally be regarded as underlyingly voiceless, some evidence has been found that the overall duration of voicelessness is longer in the clusters. To the extent that this is an active mechanism involving the glottal devoicing gesture itself, the question arises as to whether the amount of gestural reorganization in the clusters will be sensitive to the underlying voicing typology of the language involved.

2. Material

The target words (part of a larger corpus) all had a voiceless consonant (plosive or fricative) in initial position. Two prosodic conditions were compared: a condition where the target word was in focused position vs. an unaccented condition. The syllable-onset was systematically varied by comparing singleton plosives and fricatives with all combinations with /l/ and /r/ available in the language. A point that will be relevant in the discussion is that the rhotic is dorsal in German and French (ranging from voiced approximant to voiceless fricative, depending on context), and apical in Dutch (for convenience the phonemic symbol /r/ is used throughout).

To date five speakers of German, and four each of French and Dutch have been analyzed. In most cases five randomized repetitions of each target item were available for analysis (for one French speaker only two repetitions were completed).

Details of the material are given below, with the following schematization of prosodic context:

xxx: target; *xxx*: focus; <u>xxx</u>: contrast

<u>German</u>

Plosive onset: p, t, k, pl, kl, pr, tr, kr

Fricative onset: f, ʃ, fl, ʃl, fr, ʃr

Focused: Bis sie ***piep*** sieht, nicht <u>Tisch</u>.
["Until she sees ***piep*** not <u>table</u>"]

Deaccented: Bis sie **piep** *sieht*, nicht <u>hört</u>.
["Until she *sees* **piep** instead of <u>hearing</u> it."]

<u>Dutch</u>

Plosive onset: p, t, k, pl, kl, pr, tr, kr

Fricative onset: f, s, fl, fr

Focused: Als 't-ie ***piep*** ziet, niet <u>last</u>.

Deaccented: Als 't-ie **piep** *leest*, niet <u>weet</u>.

<u>French</u>

Plosive onset: p, t, k, pl, kl, pr, tr, kr

Fricative onset: f, ʃ, s, fl, sl, fr

Focused: C'était ***'pipe'*** qu'il citait (pas <u>'quiche</u>')
["It was 'pipe' that he quoted (not 'quiche')]

Unaccented: Voici des **pipes** très étroites
["Here are some very narrow pipes"]

3. Methods

Laryngeal activity was recorded by means of transillumination combined with videolaryngofiberscopy as detailed in Hoole & Bombien (2014). For the present paper we will concentrate on the following measures:

(1) duration of the oral occlusion of C1; (2) voice onset time (from release of C1 to onset of voicing); (3) relative timing of peak glottal opening; (4) magnitude of peak glottal opening.

Relative timing of peak glottal opening was calculated as the time from the onset of oral occlusion to the time of peak

glottal opening, divided by the duration of oral occlusion of C1.
For an aspirated plosive, where peak glottal opening is roughly synchronous with release of the oral occlusion, the relative timing measure gives a value of about 1. For an unaspirated plosive (and also for fricatives), where peak glottal opening occurs at about the midpoint of the oral occlusion, a value of about 0.5 would be expected. Based on previous work, for clusters relatively later timing of peak glottal opening is expected, e.g. values > 1 if peak glottal opening occurs after the end of C1.
Regarding the magnitude of peak glottal opening, since there is no simple way to calibrate the transillumination signal, and since signal level can vary quite substantially over the course of the experiment, a normalization factor was calculated separately for each block of repetitions. Specifically, this was based on the average glottal opening over all items with fricative onsets (in each block of repetitions). The motivation for this was that we are particularly interested in laryngeal differences for the plosives across languages, whereas there is no particular reason to expect major language-specific differences in glottal opening magnitude for the fricatives (the aerodynamic constraints on voiceless fricative production should be very similar across languages). Thus, in the absence of an absolute measure, this allows us to express glottal opening for plosives as a proportion of glottal opening for fricatives.

4. Results

We start the presentation of the results with occlusion duration, since this gives a straightforward indication as to whether the attempt to contrast prosodic strength on the target-word has been successful. Fig. 1 (bottom panel) shows the results obtained by subtracting the weaker prosodic condition from the stronger one (broken down by syllable-onset type and language; note that in this and the following figures 'P' on the x-axis labels stands for 'plosive', not /p/, i.e. syllable onset types are averaged over place of articulation of C1). In all cases the values are positive, indicating that as expected from many previous investigations, occlusion durations are longer under prosodic strengthening. Of the three languages, values are lowest for German (about 10ms), but this still represents a statistically significant difference.
The top panel of Fig. 1 shows the actually measured occlusion durations (again broken down by language and syllable-type), but now averaging over prosodic conditions rather than looking at the prosodically-related differences. We see that values increase from German via French to Dutch. There is a not always very large but nonetheless consistent trend for C1 durations to be shorter in the cluster onsets compared to the singleton onset. The latter effect is certainly not unexpected, but will be relevant for the interpretation of the results for laryngeal-oral coordination.
Turning to VOT (top panel of Fig. 2) the first point to make is that the results are in several respects a mirror-image of the occlusion duration results, i.e. they increase from Dutch via French to German, and also increase going from the singleton to cluster syllable-types. Perhaps the most striking result is that French is actually closer to German than Dutch, which was hardly to be expected from traditional descriptions (values for the French singletons are here in the range that would normally be regarded as aspirated, i.e. about 60ms). Another point to be discussed further below is why the rhotic cluster attracts particularly high values specifically for German and French.
The mirror-image pattern between occlusion duration and VOT is also interesting from a cross-language perspective. There may be a cross-language tendency for voiceless consonants to have a rather similar total duration of voicelessness (and rather similar glottal gesture duration). Varying the occlusion duration effectively varies the point in the glottal abduction-adduction cycle at which release of the oral occlusion occurs, thus in turn directly affecting voice onset time (specific information on this below; see also Hutters, 1985; Bombien & Hoole, 2013).
The bottom panel of Fig. 2 shows the difference in VOT across the prosodic condition. The main point here is that the values for all languages cluster quite close to zero. For German, following previous findings in the literature for English, an increase in VOT with prosodic strengthening might have been expected. Even though the differences do go in the expected direction, they only amount to about 5ms, which was not significant. Similarly, we can also not confirm the opposite finding for Dutch of Cho & McQueen that VOT may reduce under prosodic strengthening. On average the differences are indeed negative, but in magnitude are even closer to zero than the German results are.
Having set the scene with the acoustic measures we now turn to direct measurements of laryngeal activity, looking first at the main measure of laryngeal-oral coordination, namely the timing of peak glottal opening relative to the oral occlusion (Fig. 3).
The first main point is that, on the background of the values for occlusion duration and VOT, it was to be suspected that French would show a timing pattern intermediate between Dutch and German. This is indeed very clearly the case. Illustrating this for the singleton stops (leftmost in the top panel of Fig. 3), Dutch shows a value of about 0.5, i.e. peak glottal opening roughly in the middle of the oral occlusion, as expected for an unaspirated stop. For the aspirated stops of German a wide-open glottis at the release of the oral occlusion is indicated by the values of 1 or greater. The intermediate value of about 0.75 for French indicates that, unlike German, the glottis is already closing by the time of oral release, but is still far enough from actual closure to allow for a substantial period of voicelessness after release. A general trend over all languages is that peak glottal opening is timed later in the clusters than the singletons. This is particularly striking for the rhotic clusters of German and French (values well above 1 in both cases), and it will be recalled that it was precisely these items that had the longest VOTs.
What actually leads to the very clear differences in laryngeal-oral relative timing over languages and syllable conditions?
As discussed in Hoole & Bombien (2014), glottal gestural duration tends to vary less than, for example, oral occlusion duration. Thus changes in relative timing can in effect fall out from the differences in occlusion duration outlined above. German and French indeed had the shortest occlusions for the rhotic clusters. But evidence was also found for longer gestural durations in the rhotic clusters (not shown here, but discussed in detail for German in Hoole & Bombien, 2014). This indicates that German and French speakers may actively enhance the amount of voicelessness in these clusters
Regarding the possibility of glottal timing differences related to the prosodic condition (see bottom panel of Fig. 3): The difference values are slightly negative for all conditions and languages, in other words peak glottal opening is timed slightly earlier in the stronger prosodic condition. This in turn is an indication that the glottal gestural duration does not lengthen as much as the occlusion duration does, and is also a further indication that German speakers are not aiming for an active lengthening of VOT in the prosodically strong

condition. If they were, they would need to ensure that the glottal gesture is lengthened sufficiently to keep at least the same and preferably later relative timing of peak glottal opening as the occlusion lengthens.

Results for the magnitude of peak glottal opening are shown in Fig. 4 (top panel). Clearly, French once again occupies an intermediate position between German and Dutch. Recall that a value of 1 indicates a comparable glottal opening to the fricatives. For German (aspirated), the singletons are only slightly below this value, whereas for Dutch (unaspirated), they are well below 0.5. The other main point of interest is that German and French have in common a particularly large glottal opening in the rhotic clusters. Taken together with the timing measurements this indicates that speakers are actively aiming for substantial glottal opening over a substantial part of the rhotic segment, i.e. they are aiming to ensure its realization as a clear voiceless fricative (amplitude close to 1). As argued in Hoole & Bombien (2014) there may thus be a more active pattern of reorganization in the rhotic compared to the lateral clusters: devoicing of the lateral may be a simple passive coarticulatory effect, falling out from the proximity to the devoicing gesture of the voiceless plosive.

The final result concerns prosodically-related differences in peak glottal opening, clearly a key area given our initial hypotheses. Strikingly, French patterns together with German, rather than lying between German and Dutch: German and French both show a clear increase in movement amplitude in the prosodically stronger condition, whereas the change for Dutch is absolutely negligible (Fig. 4, bottom panel).

In fact, it is not quite clear ***why*** German and French speakers increase the magnitude of glottal opening. Even if the finding is not unexpected, at least for German, given the many articulatory correlates of prosody that have been found (more background in Hoole & Bombien, 2014), the greater glottal opening cannot be part of a set of adjustments to increase the duration of voicelessness since we observed above that VOT was only weakly influenced by prosody. Future work will need to look in detail at the acoustic properties of the burst and aspiration phase of the plosives for prosodically related differences that could be useful to the listener in recovering the prosodic structure of the utterances.

5. Discussion

The results for German conformed to expectations in that the magnitude of the laryngeal abduction gesture increased under prosodic strengthening. Interestingly, this was the case for French as well. In fact, many of the French voiceless plosives in our material would be regarded as aspirated, with peak glottal opening usually located well into the second half of the oral occlusion. This suggests that French voiceless plosives have an active specification for glottal spreading, with a timing pattern that is still different from German but nonetheless results in substantially positive VOT values. This active glottal spreading can then be targeted by the phonetic reinforcement processes forming part of prosodic strengthening. The results for Dutch were different, since there was no tendency towards an increase in the magnitude of the glottal abductory movement in strong prosodic contexts. Accordingly, while French and Dutch are traditionally regarded as typologically similar with regard to the voicing distinction, the articulatory representation of the voiceless consonants may well have started to diverge.

This interpretation is confirmed by the syllable-structure condition in the corpus. For German, clusters with /r/ (e.g. /pr, tr, kr/) typically showed a longer and/or larger glottal gesture compared to the corresponding singleton aspirated plosives (confirming Jessen, 1999). At first sight this is an unexpected result since /r/ would not normally be regarded as having an active specification for glottal abduction (and so a combination of e.g. /p/ + /r/ should not result in two smaller glottal gestures blending into one larger one). However, this may be quite a natural process in cases where /r/ is realized with a dorsal constriction, which gives conditions that are very unfavourable for voicing at the release of the plosive (see Hoole & Bombien, 2014). Thus speakers reinforce the tendency towards voicelessness by enhancing the glottal abduction already present for the plosive itself. Once again, the more striking result was that a very similar pattern occurred for French. The presence of a strong glottal abduction gesture in these clusters in French is mysterious if the voiceless plosives are assumed to be laryngeally unspecified or even specified as {-spread glottis} at the oral release, since such a representation would hardly predict an enhancement of the glottal abductory movement in specific contextual conditions. But the problem dissolves if French is assumed to represent voiceless plosives in terms of an active glottal abductory movement that is simply timed somewhat differently from German and English. (The results here for French also have an interesting parallel to recent work of Beckman et al. (2011) on Swedish, which indicated that representation of voicing in terms of a single privative feature may not be appropriate for all languages.)

Assuming a representation in terms of coordination patterns, rather than in terms of discrete atemporal features (cf. Löfqvist & Yoshioka, 1981), also gives a much more natural account of how languages may diverge as a result of subtle shifts in intergestural timing.

6. Acknowledgements

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7. References

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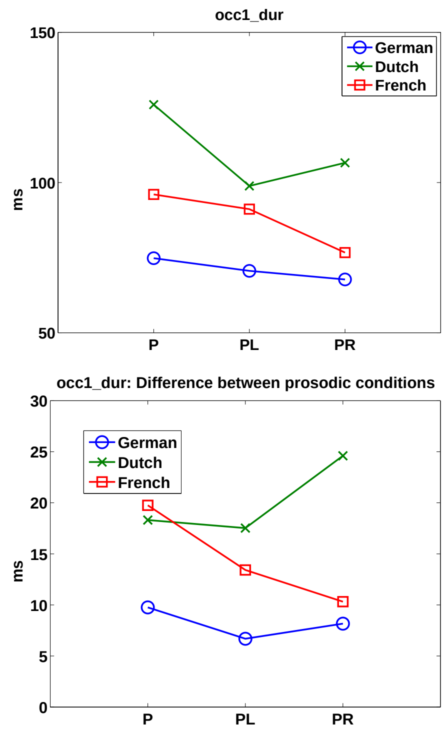

Figure 1. *Duration of stop occlusion phase. Top panel: averaged over prosodic conditions and subjects. Bottom panel: Difference between prosodic conditions (strong-weak) averaged over subjects.*

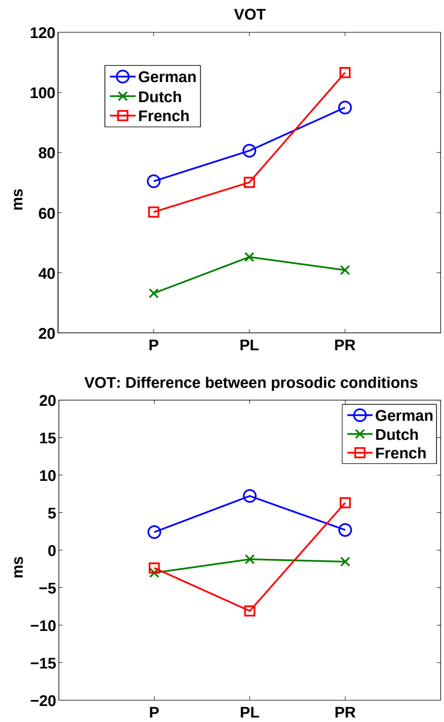

Figure 2. *Duration of voice onset time. Other details as for Fig.1*

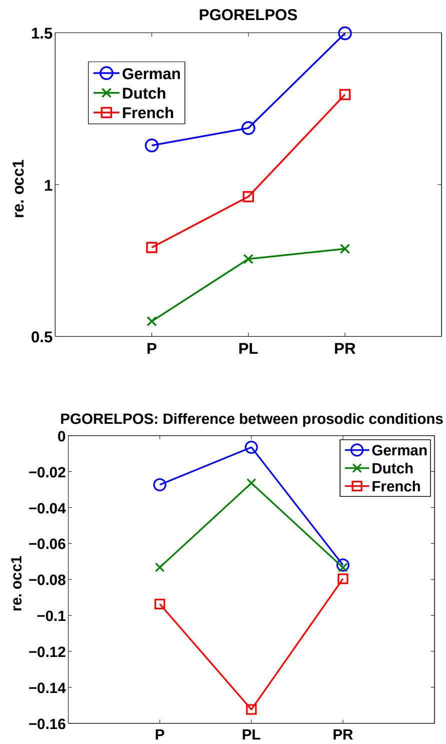

Figure 3. *Relative position of peak glottal opening in stop occlusion phase. Other details as for Fig. 1*

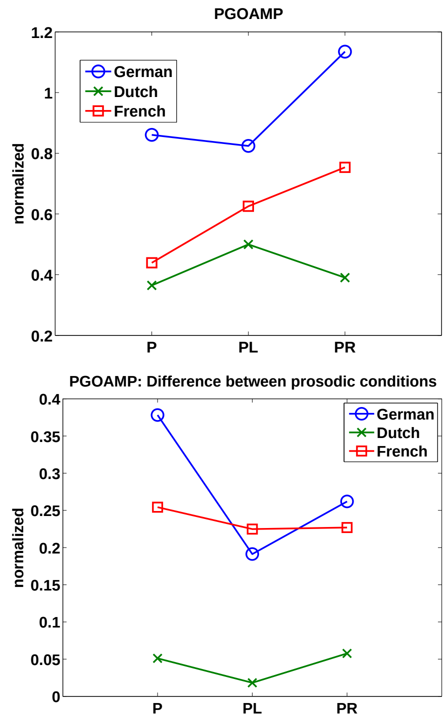

Figure 4. *Magnitude of peak glottal opening, normalized by glottal opening in fricatives. Other details as for Fig. 1*