Word Final Aspiration as a Phrase Boundary Cue: Data from Spontaneous Swedish Discourse

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Abstract
The Swedish sound string /at/ (graphically: att) is associated with two grammatical functions: a) (part of) a subordinate conjunction and b) as an infinitive marker. Previous studies connect final lengthening and pauses with prosodic and syntactic boundaries in spoken discourse. Following these findings, this pilot study, with 5 short spontaneous discourses from 3 male speakers shows a correlation between pauses after att, and aspiration of /t/ in att. We also show a tendency for att with aspiration to be associated with the grammatical function of subordinate conjunction. Further, looking at the distribution of aspiration in the subordinate conjunction att, and in the infinitive marker att, we are able to show a tendency for the infinitive marker to be unaspirated in the normal case, while the subordinate conjunctions are characterized by final aspiration in 40 % of the cases.

Introduction
Previous studies on phrasing have shown how prosodic cues such as phrase accents and final lengthening serve to signal boundaries in spoken discourse [1], [2], [3], and [4]. It has also been observed that even segment-related secondary articulations are often associated with phrase-boundaries (see e.g. [5] for a discussion of phrase-initial vowel glottalization in English).

Aim
The goal of this paper is to present pilot data from Swedish that illustrate how segmental strengthening (realized as aspiration and affrication) is often associated with the right edge of 'subordinate' prosodic phrases in Swedish.

Consonant strengthening
Phonological processes are often termed 'strengthening processes' and 'weakening processes', explained by relating them to a scale of sonority (for a discussion, see [6]). For example, vowels are assumed to be the most sonorant segments, whereas aspirated stops and africates are the least sonorant segments:

![Figure 1: The sonority scale.](image)

Within each category in the sonority scale, one can make finer divisions. For example, voiced fricatives are more sonorant than voiceless fricatives, since they are associated with the feature [+voice] like vowels. Within the vowel category, low/open (a-type) vowels are more sonorant than non-low vowels since for low vowels, F1 and F2 resonate close to each other and thus enhance each other [7], and full vowels are more sonorant than 'reduced' vowels which lack a steady-state formant structure.

Phonological processes involving consonants which lead to a category change to the right in the sonority continuum are termed 'weakening processes', where the segment becomes associated with more vowel-like features, whereas a change which involves a movement to the left is termed a 'strengthening process'.

Consonant strengthening, where a consonant becomes less vowel-like is observed to be associated with other environments, e.g., the beginning of stressed syllables, e.g., devoicing in Amsterdam Dutch: Vries [fri:s], zijn [sEin] 'his'. Consonant strengthening also occurs in final position, e.g. final devoicing in German and Dutch (e.g. pad [pAt] 'toad').

In the present study, it will be shown how the strengthening of stops to strongly aspirated variants occurs in phrase final position to mark the end of a phrase fragment, which forms part of an uncompleted message. The degree of aspiration is assumed to be associated with the complexity of the uncompleted part of the message.

Aspiration
Aspirated and unaspirated variants of voiceless stops are common in several Germanic languages as contextually conditioned variants. Their distribution is highly predictable in terms of phonetic context. In English, aspirated variants are observed to occur at the beginning of stressed syllables. In Swedish, aspirated stops are also found in this position, but are even found in "final" [8], or "prepausal" [9] position. Aspirated voiceless stops are characterized by a period of noisy airflow after the burst that lasts for a considerable period of time. For Swedish, the lower boundary for perception of aspiration is about 40 ms [8]. Below that level, aspiration is not heard.

![Figure 2: Waveform of [at:'] with final aspiration.](image)
The Swedish word *att*

In Swedish, the sound string /at/ (graphically *att*) is ambiguous. It can be associated with two grammatical functions: 1) infinitive marker corresponding to English 'to' as in *att se* to see' and 2) subordinate conjunction corresponding to 'that' as in *Anna sa att Maria var sjuk* 'Anna said that Maria was sick'. In its second function, *att* is also part of several, more complex subordinate conjunctions, e.g., *så att* 'so that'.

In spontaneous speech, *att* as an infinitive marker is often pronounced as [ɔː] whereas *att* as a conjunction is never reduced to [oː]. There are no clear rules that predict when the infinitive *att* is reduced, such as, e.g., infinitive *att* is not reduced when it is emphasized.

As a conjunction, *att* can be reduced to [at] with an unreleased [t] (see fig. 3). However, it is very often realized [atː] (see fig. 2), or even [atːː] - a strongly aspirated or affricated long consonant in this function. Since this aspiration is an easily identifiable acoustic cue, it could be used in algorithms for automatic speech understanding. The degree of aspiration is observed to vary, however, and we speculate that this variation can be related to the degree of speech planning.

Although *att* is analyzed syntactically as a conjunction introducing a subordinate clause, it is often realized phonetically at the end of the preceding clause. Thus, for speech parsing purposes, *att* signals that the message is incomplete and that a new clause is being planned. We further speculate that the degree of aspiration/affrication can possibly reflect the degree of complexity of the new item being processed.

With reference to the Commit-and-Restore model of disfluencies as Clark and Wasow [10] describe it, the disruption of speech after *att* 'that' can be interpreted as a "commitment" by the speaker to utter a larger constituent that begins with 'that' and that "the more complex a constituent the more likely the initial function word will be repeated".

The string *att* is one of the absolute most frequent words in Swedish [11], [12], and both of the grammatical functions occur very often. Since the subordinate conjunction *att* would normally trigger a more complex construction (i.e., a subordinate clause) than the infinitive marker *att* (normally initiating a simple infinitive construction), one could expect more features of planning to be associated with the former form of *att*. Such planning features would be pauses following *att*, and consonant strengthening in the form of aspirated /t/.

**Method**

The material for this pilot study was collected within the Spencer Project on Developing Literacy in Different Contexts and Different Languages [13]. The data consist of five spontaneously spoken discourses from three Swedish men, 25-30 years of age. When eliciting the discourses, the subject was asked a) to tell about a time when he was saved from a predicament, and b) to discuss some general problems in schools (such as cheating and harassing) that were shown in a short video previous to the elicitation question. The recordings were made in a sound studio.

Prosodic analyses were carried out using the ESPS/waves environment. Every occurrence of *att* was measured for word duration. Length of aspiration and duration of [t] were measured. The duration of pauses and filled pauses following *att* were also measured. In doing this, we were able to compare length of aspiration a) as part of the whole word [atːː], and b) as part of the segment [tːː], between *att* as a subordinate clause and *att* as an infinitive marker. This would enable us to look for a correlation between long aspiration and (filled) pauses.

Since Lindblad [8] argues that aspiration shorter than about 40 ms is not heard, aspirations shorter than 35 ms were counted as having no aspiration.

**Results**

In the five discourses studied, *att* occurs 99 times. Of these, *att* functions as a subordinate conjunction in 67 cases, as an infinitive marker in 8 cases, and as part of other, more complex subordinate conjunctions in 24 cases. Thus, *att* as a subordinate conjunction is more frequent than *att* as an infinitive marker. (It is worth noting that the infinitive marker occurred an additional 17 times in the reduced form [oː].) In the following, we will only look at the 75 cases where *att* occurs as a single subordinate conjunction or before an infinitive.
Fig. 4 shows that 18 of the 75 investigated cases of *att* were followed by a pause. 17 of these cases also had an aspirated /t/, which makes a strong implication, in that pauses are connected with aspiration. However, from fig. 5 we find that the opposite is not true; of the 57 cases where /t/ was not followed by a pause, 21 of the cases were aspirated. Thus, the implication that aspiration automatically leads to a pause following /t/ is not true.

Discussion

Many studies have claimed that pauses are used for planning, and that pauses therefore are often found at clause boundaries (see e.g., [14], [15]). Other studies suggest that final lengthening signals boundaries in spoken languages [1], [2], [3]. Aspiration could be considered to be one kind of final lengthening. This would lead us to look for a correlation between pauses and final aspiration. Thus, this should mean that an *att* followed by a pause should also have an aspirated /t/. Indeed, this is found in this pilot study.

Finding this, we can conclude that pauses and aspiration are connected. When looking at the distribution of the two types of *atts* followed by a pause, we find that most of these cases involve *att* as a subordinate conjunction. Although it is not possible to prove it statistically, since the number of infinitive *atts* is so low, we would still like to suggest that *att* as a subordinate conjunction is more likely to be connected with a pause. The question is what happens if we take away the cases where *att* is followed by a pause and see if we then can find any differences in aspiration between *att* as a subordinate conjunction and *att* as an infinitive marker.

However, as fig. 6 shows, we find that 0 % (0 of 6) of the realizations of infinitive *att* have aspiration, while 40 % (21 of 51) of the realizations of *att* as a subordinate conjunction had final aspiration. Although the low number of cases with *att* as an infinitive marker makes it impossible to run statistics on this result, it is worth stressing the fact that when the cases followed by pause were excluded, none of the infinitive *atts* had final aspiration, while 40 % of the *atts* as subordinate conjunction had final aspiration.

Fig. 5: Distribution of *att* followed by a pause collapsed over *att* as infinitive marker and *att* as a subordinate conjunction. To the left: cases where *att* is followed by a pause; to the right: cases where *att* is not followed by a pause. The upper, lighter layer shows the cases of *att* as an infinitive marker, whereas the lower, darker layer shows the cases of *att* as a subordinate conjunction.

Fig. 6: Distribution of *atts* not followed by a pause. To the left: infinitive *atts*; to the right: *atts* as a subordinate conjunction. The upper, lighter layer shows the cases where there is no final aspiration, whereas the lower, darker layer shows the cases where *att* has final aspiration.

Conclusions

In this study, we have tried to show a connection between aspirated /t/ in the frequently occurring homonym *att* in Swedish, and its function as a subordinate conjunction. Although this is only a pilot study, it nevertheless suggests that aspiration of *att* could be a useful cue in developing algorithms for automatic speech recognition. If *att* has final aspiration and is followed by a pause it is more likely that we are dealing with the realization of *att* as a subordinate conjunction, rather than the realization of *att* as an infinitive marker.

The tendencies we have found so far show that it would be fruitful to carry out a larger investigation, preferably with more cases of *att* as an infinitive marker.

References


