Coarticulation in sign and speech

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Abstract

Different manifestations of coarticulation have been within focus of speech sciences for quite some time now. In sign research the focus has recently covered also coarticulation research through latest techniques. Studying coarticulation is easier in sign because all the articulators are visible all the time, which makes it different from speech where articulators are mostly hidden. In speech research the study of coarticulation is thus concentrated on the manifestations of coarticulatory phenomena in acoustic signal.

1 Introduction

In speech the sounds are not discrete phenomena but speech is a continuous string of articulatory movements, where previous and following sounds affect each other. This on-going movement pattern from one sound to another is called coarticulation. Coarticulation is a way to make transitions from one sound to another easier. In this way we are acting according to the *ease of articulation* –principle (e.g. Shariatmadari, 2000). Simultaneously, we also tend to use all the capacity available if needed (Lindblom, 1981). That interplay of coordinating movements makes speech easier and faster.

When recording speech usually coarticulatory phenomena are controlled by using carrier words and sentences such that different sounds occur in similar positions coarticulatorily. This is a way to control what is said in order to make subjects' production comparable to each other. Coarticulation provides us knowledge on how different sounds are represented in different contexts. Coarticulation studies are made through acoustics in speech because the articulators are not visible. This is different from studies of sign language since in sign the articulatory patterns are visible and thus it is more straightforward to study coarticulation in sign.

Coarticulation has the same function in sign as in speech, it functions to make the message smoother and more compact. In sign the compactness aspect is even more important since hands are slower as articulators than speech organs. Speech rate usually ranges 90-160 words per minute while within this study signing rate is between 20-30 signs per minute. In signing both hands participate in coarticulation, so there are two levels of coarticulatory patterns – each hand separately and then the interarticulation – both hands together. Coarticulation is also present in facial expressions and gestures but those are left out of scope in this study. There is a distinction between manual and non-manual coarticulation and this study concentrates on manual coarticulation.

The controlling of coarticulation in sign language studies is through task design. This is the only way to have control on what is signed because there is no written form of any signed languages. In this study task design was based on an imaginary floor plan and a map task along with spontaneous signing.

Studies on coarticulation in sign first concentrated on fingerspelling research. Fingerspelling is converting text into a visible form by means of manual alphabet. It has a very limited amount of coarticulation: in most inventories of manual alphabets only one hand participates and the hand has a very limited movement patterns. There is though an exception to this: British Manual Alphabet, which uses both hands. But still the effects of coarticulation are great also within the scope of fingerspelling (Wilcox, 1992). Recently the scientists have made first investigations on coarticulation of signing: the effects are similar to those on speech – coarticulation makes articulation more fluent and its effects can be seen both on handshapes and places of articulation (Mauk, 2003; Ann, 1996). Thus also signing obeys the ease of articulation –principle.

Especially anatomy and physiology of the hand and fingers affect articulation of handshapes. The economy of articulation is for its major parts depended on dimensions and movement ranges of individual fingers. According to physiological research results state that thumb has the widest range of movement patterns and that the ring finger is the most restricted in movement patterns (Ann, 1996).

2 Material and methods

The aim of this study was to investigate whether there are similarities in coarticulation between sign and speech, since they both are means of human communication and in the previous studies various researchers have stated analogous findings between speech and sign, e.g. in perception studies (on handshape perception see e.g. Ojala & Aaltonen, 2007).

The data have been gathered as a part of larger study, which concentrates on gathering data from the production and perception of Finnish Sign Language. Data consists of signed answers to a set of questions and tasks. The questions ranged from given tasks to spontaneous signing. The study design was equivalent and analogous to speech research sound samples, where tasks include different carrier sentences (read speech) and spontaneous speech (informants are asked to tell how they spent their last holidays or they had the option of telling a 2-3 minute story of whatever subject). The productions were gathered into a digital video which were then further processed and analysed with video software.

The data of this study consists of one informant's production HERE APARTMENT *Here is an apartment, which has a rectangle shape.*[1] The signed sentence consists of 3 individual signs and 6 rhythm units. The rhythm units were defined visually from the alternation of accelerations and decelerations. Furthermore the coarticulation analysis was made frame by frame, that is every 42 milliseconds. In each frame the coarticulation points were measured and that analysis served as the basis of the study of movements in time for both hands. There were 10 measurement points in each hand in order to gather precise material on how different handshapes manifestate in a continuous sign flow.

In this preliminary study we have measured 6 of those 10 measurement points from each hand. Other 4 measurement points were used to specify the orientation of the hand when it was possible.

Figure 1. The coarticulation measurement points in the whole study (dark and light diamonds) and in this data (light diamonds). These points are measured in each hand.

The orientation of the hand within this study translates as the orientation of the palm of the hand in relation to the body of the signer. The pixel coordinates of the coarticulation measurement points were inserted in a matrix. The matrix was the input for the 3D image of movements of coarticulation points in time. This served also as an input of 2D images of the speed and acceleration as changes of each coarticulation point frame by frame. The matrix was also the basis according to which the median of the speed was calculated. All figures and calculations were accomplished by MatLab scripts.

3 Results

Coarticulation in sign can be studied within two different scopes: a broader one with focus on the interarticulation of both hands and a more precise one considering coarticulation within the

[1] There are no standardized ways of transcriptions, so within this article glossing of signs is used. Glosses consist of capitalized transcriptions of signs and translations of signs in English with italics.

movement patterns of one hand only. Interarticulation seems to effect in such way that the hands move faster when they are more apart than when they are closer to each other.

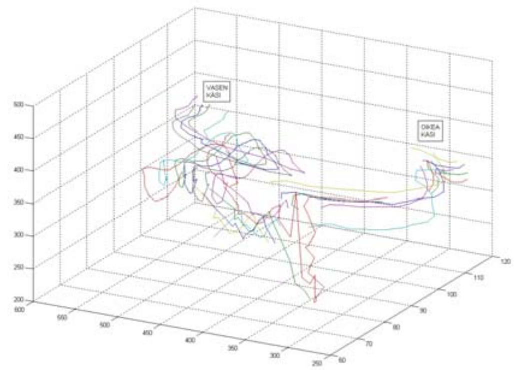

Figure 2. 3D graph of movement envelopes of individual fingers in space. The discontinuities in graphs are due to coarticulation measurement points not being visible to camera.

Most of the time all fingers move simultaneously and with the same speed, but both index fingers have broader and faster movement envelopes when compared to other fingers. When comparing between the index fingers the right index finger has slightly broader and faster movements. A similar handedness effect can be noted in thumb movement patterns but not on other fingers. The movement envelopes become smaller when going from the index finger to little finger, however, little finger has a broader movement envelope than ring finger. In other words, the ring fingers in both hands have the most compact movement patterns. The thumb has a broader movement envelope than index finger, but the movements are slower. The overall movement patterns in both hands are quite similar, both in timing and in broadness.

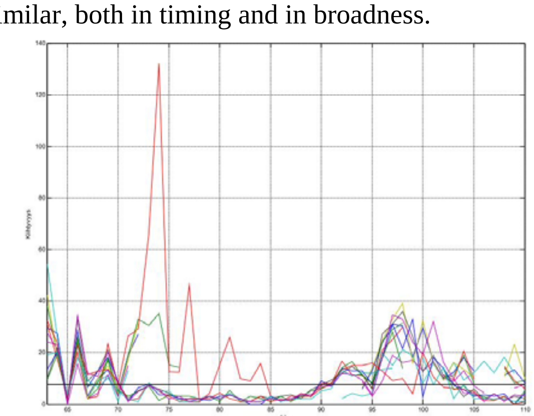

Figure 3. Changes in speed of individual fingers in time.

Changes in movement were investigated frame by frame. The graph shows both the speed of individual fingers and the relations between different finger movement patterns. Most of the time within this material the momentary/instantaneous differences between individual fingers' speeds are so minute that the graph would be sufficient with just one finger's movement description, but there are exceptions too. According to preliminary results it seems so, that individual vertical movements are faster than movements along the horizontal plane, but this observation needs further investigations. The graph also shows the tendency to keep movements as slow as possible but the scarce data might distort the results.

4 Conclusion

The alternations of deceleration and acceleration in signing movements are a similar pattern to speech – also speech has intertwining rhythms in different levels. The bases for these rhythms at least for some parts vary according to the individual language (e.g. O'Dell & Nieminen 2001). In speech the rhythm is achieved with the coordination of articulatory movements and it might be that the alternations between consonant and vowel sounds are one of the very corner stones of human evolution (MacNeilage, 1998). In this preliminary study we have concentrated on the observations of movement patterns on the lower level of coarticulation. Previously the alternations of decelerations and accelerations have been studied by Loomis et al (1983). The movement patterns in sign seem to have an oscillation pattern and cyclical form as do the articulatory movements in speech (See also Lindblom et al., 2006). The basic rhythm on the higher level of hierarchy in signing materialises in the movements and holds within and between individual signs in on-going signing (Liddell & Johnson 1989; Kita et al. 1998).

According to this material the index finger seems to be the determining fact in the amplitude and the rate of signing. Other fingers follow the movement patterns of the index finger, but are more restricted in their patterns. The index finger also has a special task: pointing. Pointing is an important part of both signing and speaking – it is a convenient way to refer to something which is present and visible, let it be an object or a person. (More on pointing, please see Corballis 2002.) The thumb seems to have more independent movement patterns than other fingers. This demonstrates the tendency of signing to exploit the capabilities in individual fingers' movement patterns as widely as possible whereas the ring finger's more restricted movement patterns demonstrate that signing tends to avoid such patterns that are more difficult to produce. In this way, signing as a form of communication acknowledges the physiological restrictions in the hands and operates accordingly.

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