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Motor control in speech production and the perceptual efficiency of anticipatory gestures

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Research partners

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Implications and objectives of the project

The present project, which focuses on a major aspect of the study of coordination of articulatory gestures – anticipation – represents one of the most essential steps towards the understanding of control and coordination mechanisms in speech production and perception. Such mechanisms underlie, to a large extent, language acquisition, some speech pathologies, or a proper functioning of anthropomorphic speech synthesis systems.

The main thrust of research works carried out within this project is to understand the organisation of anticipatory gestures that govern speech production and perception activities, for diverse languages using such fine-grained spatio-temporal mechanisms for phonological purposes.

Results should therefore account for both motor and cognitive strategies, specific to complex and varied linguistic tasks, and other strategies largely shared by animal sensory-motor behaviour in general.

Research milestones

Year 1: Saving movies, data acquisition and processing

- X-ray data: contour acquisition, contour and movie digitising at IPS – Strasbourg;
- kinematic and acoustic data acquisition for coarticulation at ICP – Grenoble;
- processing X-ray, kinematic and acoustic data at IPS and at ICP respectively;
- data analyses (measurements) and statistical processing (in the two laboratories)

Year 2: Developing models

- development of statistical models (in the two laboratories)
- conceptual modelling by the two laboratories
- publications and participation in scientific meetings
- organisation of an interdisciplinary meeting on “Anticipation”

Work in progress (September 2002)

The very concrete objective of Year 1 was:

1. acquisition of profiles, profile and movie digitisation, presentation of results by the IPS team: G. Brock P.-Y. Connan V. Hecker F. Hirsch J.-P. Roy R. Sock B. Vaxelaire;
2. acquisition of video and acoustic data for coarticulation at the ICP – Grenoble.

Only point 1 was carried out during Year 1, before September 2002. Point 2 will begin in September 2002. However, two research investigations on visual anticipation were conducted during Year 2 by the ICP team: M.-A. Cathiard, H. Lovenbruck, C. Savariaux.

Research stages relative to point 1 were:

- selection of movies (3 movies on French) on the basis of their quality;
- identifying relevant sequences for the study of anticipation in each movie;
- inventory of available tracings for these sequences;
- digitisation of tracings;
- transfer of movies from a 35 mm cinematographic standard to a BetacamSP video standard, a professional standard of high quality that ensures optimal preservation of image precision;
- image and sound synchronisation;
- digitisation of video movies
- measurement and extraction of data relative to labial and lingual anticipatory vocalic gestures.

Preliminary results obtained from X-ray data

The relationship between labial and lingual anticipatory gestures and the precocious auditory perception of a rounded French vowel, in Vowel-Consonant-Vowel sequences (V1CV2), was examined. V1 always corresponds to vowel /a/ and V2 to vowel /u/; C is either /t/ or /k/. Contribution of anticipatory coarticulation to the perception of the rounded vowel is observed both on the motor (articulatory) and acoustic domains. Resistance of the temporal extension of the perceptual effects of anticipation is also tested by increasing speech rate. The paradigm consists in generating sentences by two speakers, then some segments are truncated and listeners should recognise the missing elements.

In summary, results (percentage of correct responses and confidence thresholds) show that:

1. The rounding gesture, together with the lingual constriction of the protruded vowel, traverses the intervocalic consonant, and could even attain final configurations of vowel /a/. However, although such anticipatory gestures are visible (to be tested in Year 2), they are not audible, since the portion of the gestures that have auditory effects are located after consonantal closure release, going towards the protruded vowel.
2. Anticipatory perception of vowel /u/ happens earlier in the velar context. This could be explained with regards to closure release (apical or velar), knowing that this release happens earlier in the velar context compared with the apical one. Consequently, perception of the subsequent vowel becomes more precocious. Formation of the velar consonant (contact – closure – release) takes less time than that of the apical consonant, presumably to allow emergence of vowel /u/, with which the /k/ shares the same velar gesture. Notice that at closure release, labial protrusion is at a peak value, a factor that reinforces the anticipatory auditory efficiency of the vowel.

3. Listeners' reaction to the productions of the two speakers seems to depend on differences in anticipatory strategies. If for speaker A.E., vowel perception may occur as from release, with protrusion at a maximum value, however, the combination of the two latter gestures does not suffice for an anticipatory perception, when it comes to speaker M.M. For this speaker, another gesture – minimum lip opening – should also occur, a gesture that only arrives a few milliseconds later, relative to release and peak protrusion. Thus, anticipatory perception of the vowel always happens later for M.M., compared with A.E.
4. Since relative timing of articulatory gestures is comparable in both speech rates (normal conversational and fast), no coherent behaviour, with regards to anticipatory auditory perception and a speaking rate condition, has been found. Note, once again, that the extent of anticipatory auditory perception depends on the occurrence of the critical articulatory event: consonantal release.

Research programme for 2003

1. As a contribution to extension and generalisation of knowledge acquired for French, from X-ray data, in the domain of control of anticipatory movements, further research work is being carried out in order to:
 - a) analyse available X-ray data for Turkish rounded vowels (Asci, 2002);
 - b) analyse acoustic data for Wolof (Sock & Vaxelaire, 2002) and Twi (Adu Manyah & Sock, 2002) rounded vowels.
2. Moreover, supplementary acquisition of anticipation video data for the lips and face of the speaker, together with the synchronised audio signal, will be carried out at the ICP, with the help of a video-speech system and softwares for processing images of a speaking-face.
3. Confronting results obtained from X-ray, kinematic and video data, together with evaluation of the auditory (Hirsch, 2002; Sock *et al.*, 2002) and visual (Cathiard, Lovenbruck, Perrier & Savariaux, in preparation) efficiencies of anticipatory gestures, will allow:
 - a) developing statistical models (in the 2 laboratories);
 - b) proposing a biomechanical modelling of anticipatory phenomena in speech, following methods elaborated by Perrier *et al.* (2002);
 - c) proceeding to a conceptual modelling of anticipation in speech by the two laboratories.
4. An interdisciplinary meeting on “Anticipation” will be held in Strasbourg in 2003. This meeting will convene speech scientists, linguists, psychologists, philosophers...
5. Significant research results will be submitted to international journals for publication.
6. Elaboration of a tool for information and scientific popularisation. By contributing to the elaboration of a set of spatio-temporal constraints related to nasality and lip rounding, two anticipatory phenomena highly exploited phonologically in French, a multimedia tool for information and scientific popularisation will be constructed. Such a tool should allow visualising articulatory gestures during speech production. The final product will contain 3 types of digitised and animated data: X-ray data, acoustic signals, and tracings of midsagittal contours of the vocal tract. All files will be phonetically labelled and the entire platform will be accompanied by an audio commentary.

Publications within the project (2002)

Adu Manyah K. Sock R. (2002) La quantité vocalique en twi. Considérations phonologiques et analyses acoustiques préliminaires. XXIV Journées d'Études sur la Parole de l'Association Francophone de la Communication Parlée (JEP de l'AFCP), Nancy juin 2002, 41-44.

Payan Y. Chabanas M. Pelorson X. Vilain C. Levy P. Luboz V. Perrier P. (2002) Biomechanical models to simulate consequences of maxillofacial surgery. *C. R. Biologies, Vol. 325*. (In Press)

Perrier P. Payan Y. Perkell J.-S. Zandipour M. Fuchs S. Mosshammer C. Pelorson X. (2002) Tongue kinematics, biomechanics and control in speech production. Proceedings of the *Eleventh Biennial Conference on Motor Speech: Motor Speech Disorders and Speech Motor Control*. March 14-17, 2002, Williamsburg, VA, USA.

Sock R. Vaxelaire B. (2001/2002) Réflexions sur le timing de la quantité. *Travaux de l'Institut de Phonétique de Strasbourg* 31, 89 - 126.

Vaxelaire B. Hecker V. Sock R. (2002) La perception auditive de gestes vocaliques anticipatoires. XXIV Journées d'Études sur la Parole de l'Association Francophone de la Communication Parlée (JEP de l'AFCP), Nancy juin 2002, 109-112.

Reports

ASCI A. (2002) Étude phonétique des consonnes constrictives du turc parlé à Istanbul. Analyse cinématographique. Thèse de Doctorat de Sciences du Langage. Institut de Phonétique de Strasbourg – E.A. 3403. Dir A. Bothorel. 2 vols. 500 p.

Hirsch F. (2002) Contribution à l'étude de la perception des effets auditifs de l'anticipation de la labialité en français : le cas de trois voyelles. Communication à l'Institut de la Communication Parlée de Grenoble, 3-4 mai 2002. Mémoire de Maîtrise de Phonétique Générale et Expérimentale. Institut de Phonétique de Strasbourg – E.A. 3403. 178 p. Dir. R. Sock.