Acoustic and kinematic correlates of phonological length contrast in Italian consonants

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Résumé
Les consonnes géminées de l'italien ont été étudiées aussi bien pour leurs caractéristiques phonétiques que phonologiques, en se focalisant sur des données acoustiques et cinématiques. Un corpus de mots contenant des occlusives, dentales et vélaires, et des liquides dentales, a été lu par deux sujets à deux vitesses d'élocution. Les mouvements de la langue sont comparés pour les consonnes simples, les géminées et les groupes consonantiques. Les résultats sont discutés par rapport à une précédente étude sur les occlusives bilabiales.

1. Introduction

The phonological system of Italian presents a pervasive use of length contrast for homorganic consonants in within-word intervocalic position. At the same time, regional pronunciations can affect the phonetic realization of this contrast, especially in informal speech. In particular, speakers from North-Eastern Italy often do not realize geminates, while speakers from the Center and the South generally enhance them. Several studies have focused on consonant gemination in Italian, both from a phonological and from a phonetic point of view (Loporcaro, 1992).

With respect to the latter, data often stem from acoustic analysis, and common findings are longer duration for geminates than for singletons, and shorter duration for the vowel preceding geminates (Esposito & Di Benedetto, 1999). However, very few studies have focused on kinematic data (Smith, 1995; Gili Fivela & Zmarich, 2005).

With respect to the phonological status of geminate consonants, two positions are found in the literature, according to whether geminates are given a monosyllabic, monosegmental, representation, or a heterosyllabic, bisegmental, representation. Similarly, by adopting a gestural phonological frame, geminates may be modeled with reference to a single gesture or to a two-gesture model (as suggested by Smith, 1995).

This study discusses both acoustic and kinematic material collected in two different experiments, and aims at ascertaining the degree of variability due to regional difference, at presenting new evidence on the phonological status of geminates, and at attempting to formulate hypotheses on how the contrast may be modeled in terms of speech motor control theories (Löfqvist, 2005; Löfqvist & Gracco, 2002).

A first experiment was performed by recording a read speech corpus and by analyzing it both acoustically and kinematically, after a perceptual check on the persistence of the contrast [4]. Two adult speakers, a man from NE Italy and a woman from NW Italy, read a set of utterances aloud three times. The corpus was devised as a function of ELITE, an optotracking 3D analyzer, and consisted of target words with a CaC(C)a structure, where C could be either a bilabial stop (i.e., /m p b/), or a labiodental fricative (i.e., /f v/). Thus the consonants could be realized as a singleton (e.g., /m/), as a geminate (e.g. /mm/) or as a cluster (e.g., /mb/). In order to highlight the singleton vs. geminate phonetic characteristics, speakers were asked to read the utterances at a natural speech rate, at a fast speech rate, and with contrastive focus. At normal rate, with respect to the acoustic characteristics, geminates and clusters had longer duration, and were preceded by shorter vowels, as expected. With respect to the kinematics, quite unexpectedly (given the results of Smith, 1995 and Löfqvist, 2005), the closing gesture of lower lip was less important in distinguishing geminates from singletons than the opening gesture. The lower lip opening gesture in bilabial nasals was similarly characterized in geminates and clusters, and it showed longer duration, greater amplitude, greater time-to-peak, and lower stiffness (as estimated by the "max. velocity/amplitude" measure) than in singletons. At an increased speech rate, only one speaker differentiated geminate and singleton acoustic duration,

together with their preceding vowel duration; on the contrary, duration, amplitude, time-to-peak and stiffness of the lower lip opening gesture were significantly different for both speakers. The fact that geminates appeared to pattern kinematically together with clusters and to differ from singletons was interpreted as supporting a heterosyllabic status to geminates.

Focusing on the same experiment reported by Gili Fivela & Zmarich (2005), more complete data will be presented here on the relevance of the opening gesture for gemination, and a new topic will be introduced, i.e., the analysis of the gestural timing in "CaC(C)a" sequences, predicted by Smith (1995) to be of the *Vowel-to-Vowel* type. Evidence based on the temporal intervals between the peaks of labial closure for the two consonants in the "C_1aC($C)_2$a" sequences will show that only one subject clearly conformed to this pattern.

However, some doubts remain about the generalization of these conclusions to consonants other than the bilabials, and to other individuals. A second corpus was thus collected, focusing on bilabial, dental and velar consonants, from a wider set of subjects, speakers of different varieties of Italian. Two subjects were kinematically and acoustically recorded by means of the EMA system. They were from the same regions as the subjects of the first experiment – NE and NW Italy. They were asked to read the corpus aloud ten times, both at natural and fast speech rates. They pronounced short phrases with "CaC(C)a" targets, containing the voiced stops /d/ and /g/ (besides /m/, for comparison with the previous results), and the approximant /l/ (to compare clusters such as /ld/ and /dl/ with /d/ and /dd/). Moreover, in order to more adequately test the *Vowel-to-Vowel* model, the stressed vowel was also changed (e.g., ['mam(m)a] vs. ['mim(m)a]).

After a perceptual check on the persistence of the gemination contrast, we tested kinematic and acoustic evidence in favour of the heterosyllabic status of Italian geminates, their modelling as two gestures, their compatibility with the *Vowel-to-Vowel* model, and their susceptibility to regional variability. In the acoustic analyses, we performed measurements of the durations of consonant(s) and contextual vowels, and we looked for other possible acoustic cues, like formant transitions, stop bursts, VOT etc. In the kinematic analyses, vertical and horizontal position, speed, acceleration and curvature for each of the four tongue's coils were determined (see Löfqvist, 2005; Löfqvist & Gracco, 2002).

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