



# Effects of testosterone levels on temporal and intonational aspects of speech: More exploratory data

Charles A. Lamoureux, Victor J. Boucher

Laboratoire de sciences phonétiques, Département de linguistique et de traduction  
Université de Montréal, Montréal, Canada  
charles.lamoureux@umontreal.ca

## Abstract

There is a growing body of work on the effects of hormonal factors on speech and language behavior. The present research explores the links between speakers' testosterone levels and suprasegmental aspects of speech, namely speaking rate and pitch measures for intonational phrases. Saliva samples were collected from 40 men aged between 20 and 27 years in order to assess testosterone levels. Subjects were recorded reading a standard text. Acoustic analyses of the readings revealed significant correlations where speakers with low testosterone levels tended to use higher and more variable pitch than speakers with high testosterone levels at phrase boundaries. Furthermore, the results also showed significant relationships between salivary testosterone and speaking rate during the readings. These findings reinforce the assumption that some within-sex differences in speech and voice may be based on hormonal factors.

**Index Terms:** speech acoustics, speech physiology, voice, salivary testosterone, prosody

## 1. Introduction

Within linguistics, perhaps since the influential work of Labov [1], there is the view that certain aspects of speech called "free variants" are learned and manipulated by the speakers to convey social identity or affiliation. However, several studies suggest that some of these variants may not be socially motivated, but may rather reflect the influence of hormonal factors.

For instance, mean fundamental frequency (F0), or pitch, has been shown to vary with sex [2]. Considering intrasexual pitch differences, Dabbs and Mallinger [3] found that, for male speakers, there are significant correlations between testosterone levels and mean voice pitch. Furthermore, Meuser and Nieschlag [4] reported higher testosterone plasma levels in bass and baritone singers than in tenor singers. These results suggest that within-sex variation in mean F0 is biologically based. Nonetheless, several attempts have been made to relate this variation with actual or perceived sexual orientation (e.g., [5,6]).

Temporal aspects of speech such as voice onset time (VOT), duration of vowels and fricatives, and speech rate also appear to present sex-related differences, with women producing longer sounds and speaking at a lower rate than men [7,8,9]. Smyth and Rogers [6] hypothesized that differences in VOT and vowel duration that were observed among male speakers may be socially motivated. However, we reported in an earlier presentation [10] that durations of vowels and fricatives correlate with salivary testosterone.

This latter study focused on subjects' productions of syllables at the end of a carrier phrase (i.e. *C'est le mot...* for "It's the word..."). We did not consider temporal and intonational changes within utterance contexts. On the other hand, in exploring speech timing and intonational properties of utterances, one faces several methodological problems. Aspects such as speaking F0 can vary extensively in spontaneous discourse according to situational variables such as topic. Since, at this stage, little is known about aspects of utterances that can fluctuate with hormonal factors, controlled contexts were deemed more useful than spontaneous speech in isolating relevant properties. In particular, the present study focused on speech rate and F0 values at the boundaries of intonational phrases within readings of a standard text. The overall aim of the observations (including those of Lamoureux and Boucher [10]) is to arrive at a more comprehensive record of the types of fluctuations in speech and language that relate to hormonal factors, and to clarify the nature of certain marks that may have been erroneously interpreted.

## 2. Method

### 2.1. Subjects

Forty (40) paid participants, mostly students at the Université de Montréal, served as subjects. These individuals were all native speakers of Québec French and aged between 20 and 27 years (average 24.07 yrs) with no history of speech problems. Use of medication, presence of oral abscess or gingivitis, and diabetes were exclusion criteria [11].

### 2.2. Saliva sampling

Prior to saliva collection, subjects were required to abstain from eating or drinking beverages other than water on the morning of the test [12]. They were also asked to avoid using toothpaste, dental floss or chewing gum [13]. Samples were collected two hours after wake-up. At the time of the experiment, subjects placed a pH paper (Precision Labs, no. 5090) under their tongue for two seconds to ensure pH neutrality. All subjects presented a salivary pH above 6.0. Then, the subjects washed their hands thoroughly with water and soap and rinsed their mouth twice with water to stimulate saliva production. A 10-ml saliva sample was collected in a sterile tube, and the samples were frozen at a temperature of -20°C within two hours following the test. Subjects were only tested once, since single testosterone assays have been reported to be reliable enough for behavioral research [13].

They were informed of the purpose of the saliva sampling only at the end of the recording session to avoid a biasing of speech style.

### 2.3. Speech recording

The subjects sat in a sound-treated booth with a microphone on a headset (AKG, model C477) placed at 5 cm and at a 45° angle from their lips. They were asked to read *The North Wind* passage [14] as naturally as possible without hesitation. They were given time to familiarize themselves with the text. The readings were recorded at a sampling rate of 44.1 kHz using a 16-bit soundcard (CSL4400, Kay Elemetrics).

### 2.4. Analysis

#### 2.4.1. Salivary testosterone assays

Saliva samples were assayed at an accredited laboratory (Rocky Mountain Analytical, Alberta, Canada), following a standardized procedure. First, an extraction of each sample was done to concentrate the hormones. The reliability of assays was ensured by repeating assays on duplicated samples. If the agreement between the two duplicates was poor, a second independent extraction was performed.

#### 2.4.2. Acoustic analysis

The readings were analyzed using signal analysis software (*MultiSpeech*, version 3.1.6, Kay Elemetrics). Prior to the analyses, hesitations, pauses between utterances, and non-speech sounds were removed. Then, speech rate was measured as the duration of the entire reading divided by the number of syllables (162) in the text. As for F0 values, these were measured via peak-detection routines of *CSL4400* (Kay Elemetrics). From listening to the recordings, end portions of intonational phrases possessed particular fluctuations that were feminine-sounding in some subjects. Several subsequent measures confirmed that F0 variations were particularly marked at these phrasal end points, which are typically lengthened in French [15]. On this basis, F0 values were measured with reference to the last syllable of the four first intonational phrases of the reading. All F0 analyses were performed by setting functions to a frame length of 25 ms and a 20-ms frame advance. For some speakers, F0 fluctuated to quite low values, sometimes extending to a “creaky voice”. In those cases, the software could not detect pitch, so peaks were visually detected on waveform displays and voice period marks were manually added. The analyzed variables included F0 mean, minimum, maximum, range and variance (standard deviation/mean).

## 3. Results

It should be noted that a preliminary analysis of pitch applied on the whole reading sample correlated only marginally with testosterone levels ( $p = .06$ ). Subsequent analyses focused on the final syllable of the first four intonational phrases, as described in the above section.

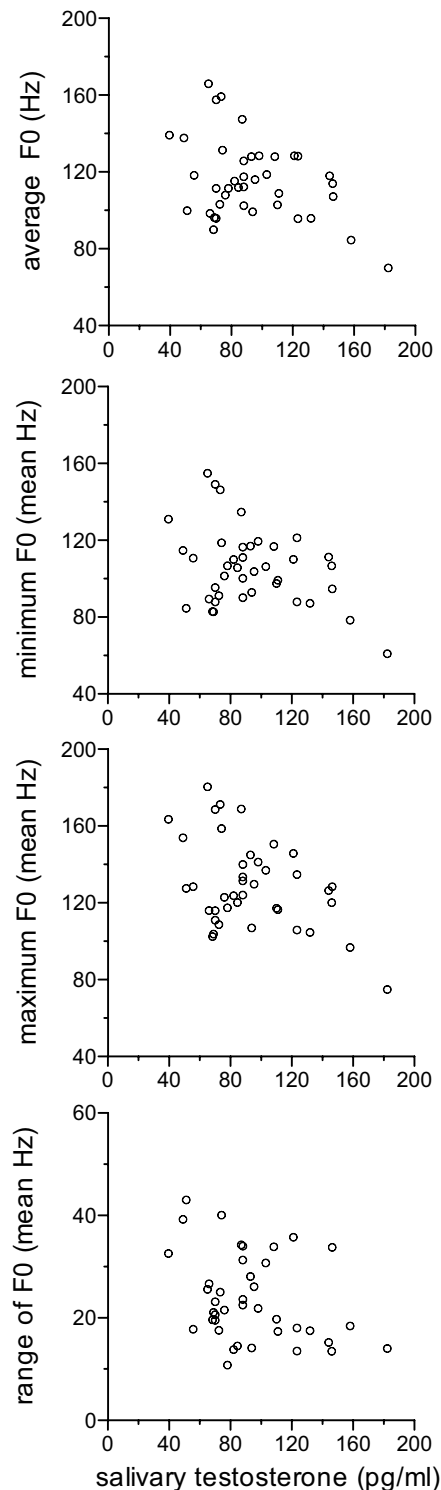


Figure 1. Relationships between salivary testosterone levels and various F0 measures ( $n = 40$ ).

As for the main results, correlations analyses revealed that salivary testosterone levels of the 40 speakers are significantly associated with average F0 ( $r = -.393, p = .012$ ). The correlations were also significant for minimum F0 ( $r = -.360, p = .023$ ), maximum F0 ( $r = -.432, p = .005$ ), and range of F0 ( $r = -.331, p = .037$ ). It should be noted that the magnitude of these correlations is similar to that of other studies relating salivary testosterone and pitch (e.g., Dabbs [3] reported  $r = -.26$  for  $n = 59$ ). On the other hand, the

relationship between testosterone levels and F0 variance did not reach significance ( $r = -.168, p = .302$ ). The data plots for the significant variables are presented in Fig. 1. By reference to the distribution of data points,  $z$  scores indicated that none constituted outliers ( $z$  score  $< 3.29$ ) [16].

Significant correlation was also obtained in terms of speech rate ( $r = .377, p = .017$ ). Fig. 2 illustrates the distribution of measures for this variable.

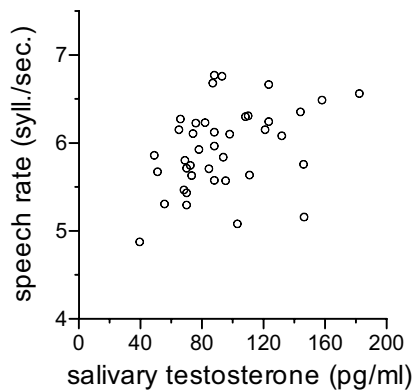


Figure 2. *Speech rate as a function of salivary testosterone levels* ( $n = 40$ ).

#### 4. Discussion

The above results corroborate previous studies that found a significant correlation between testosterone levels and mean F0 [3,4]. It may be argued that differences in pitch result from variations in the length and mass of vocal folds, which may be affected by hormone exposure during development. However, these well-known effects of hormonal factors on peripheral morphology do not, as such, serve to explain the particular pitch patterns that were produced at phrase-final points and that appear to be related to testosterone levels. In fact, the biological underpinnings of such patterns are difficult to ascertain. On the other hand, the differences in speech timing that were observed in the present study conform to general effects of testosterone on rapidity of motor and psychomotor processes [17].

An interesting aspect of the results is that the wide pitch range and slow speaking rate found in men with low testosterone levels conform to values reported for female speech (e.g., [9]). These observations offer further support for the assumption that between- and within-sex speech differences may be best described in terms of a single masculine/feminine continuum [6].

#### 5. Prospective conclusion

The above study is part of an ongoing research program aimed at uncovering the effects of hormonal factors not only on speech, but also on language and cognitive processes. In fact, these behaviors are likely to be linked. For instance, shorter duration of sounds, quicker movements and shorter reaction times may all be fundamentally related to higher testosterone levels [10,17]. Moreover, observations of a link between hormonal factors and a number of speech variables offer support for theories of primitive sound symbolism [18]. Thus, research on hormonal factors not only bear implications on distinguishing learned and innate aspects of speech, but may also lead to explanations of the rise of meaningful signs in human communication.

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