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Abstract

Following our work on the relationship between eyebrow movements and the fundamental frequency of the voice, this article presents the results of a study on the temporal location of rapid eyebrow movements with respect to speaking turns during dialogue. We used an automatic movement-acquisition system coupled with the simultaneous, synchronized recording of the vocal production. This procedure permits an objective analysis of eyebrow movements in relation to the vocal production. The data obtained show that the speakers' rapid eyebrow movements were associated with turn-taking (occurring on or before speaking turn onset). These findings suggest that rapid eyebrow movements are mainly linked to motivation and the intention to communicate.

1 Introduction

Taking a multimodal approach to communication (Guaïtella et al., 1998, Santi et al., 1998, Cavé et al., 2001), we experimentally study the links between rapid eyebrow movements and vocalization during speech production, in order to test our hypothesis regarding the role of these movements in dialogue situations.

Darwin (1874) described the gestures that contribute to the expression of emotions as resulting from the interaction between physiological constraints and functional needs. For example, an activity like raising the eyebrows to enlarge the visual field and see as far away as possible will be preserved — through the influence of the so-called association principle — as a means of expressing surprise and astonishment, and will thus become a mark of special attention given to what is happening. Scientists like Ekman and Friesen (1975) studied facial cues to gain insight into the emotional aspects of communication, and Ekman (1989) in particular attempted to characterize rapid movements during communication, of which eyebrow movements are a part. Such rapid movements are thought to be mainly linked to discourse production, where they serve as a rhythmic demarcation device (see also Birdwhistell, 1970; Condon, 1976). The function of these rapid movements is thought to be essentially discourse-based, for their use in emotion expression has taken on a linguistic function (an eyebrow movement occurring on an unpredictable word, for example, can be interpreted as "Pay special attention to the word I'm pronouncing"). For Bolinger

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(1998), eyebrow movements even more than other gestural parameters are related in a privileged way to speech, and benefit from a status equivalent to vocality.

Our preliminary analyses with the Elite system allowed us to conduct two studies in a dialogue context. The first was an investigation of the link between rapid rising-falling eyebrow movements and similar changes in the fundamental frequency (Cavé et al., 1996). This study showed that while the eyebrow/F0 coincidence phenomenon is the most frequent configuration — and is probably driven by a synergy effect — it is neither systematic nor mandatory. Certain cases do not follow the rule and therefore must be the result of a "choice" made by the speaker (Cavé, Guaïtella, & Santi, 2002). The second study was aimed at determining whether eyebrow movements are related to discursive forms of interrogation. Analysis of data from the same corpus did not validate the usual hypothesis of a link between eyebrow raising and the expression of questions (Purson et al., 1998).

1.1 Hypothesis

Our hypothesis concerns the potential role played by the eyebrows in managing the conversational interaction, i.e., in turn-taking. It was hypothesized that speakers might use this device to signal their desire to say something and thus, to be given a speaking turn. It appeared valid to test this hypothesis by measuring the interval between eyebrow movements and the beginnings and ends of speaking turns. Eyebrow movements that fell closer to the onset of a speaking turn than to its offset would lend support to this hypothesis. If the presence of a movement before a turn can be interpreted as the desire to speak, then its presence right at the beginning of the turn could have a related meaning: the new speaker may be attempting to establish a place in the verbal exchange by insisting on the fact that he/she has started to talk. On the other hand, an eyebrow movement occurring after the speaking turn has begun would mainly serve to signal the speaker's desire to maintain his/her new position as speaker, i.e., to hold the listener's attention that he/she has managed to capture.

2 Experimental procedure

2.1 Speakers and corpus

Ten unpaid subjects volunteered to participate in the experiment. The speakers were questioned individually about their job or their studies by means of interviews conducted in an informal, conversational mode. For technical reasons, only seven of the ten dialogues were processed. So the final corpus consisted of seven dialogues between an interviewer and an interviewee, each lasting approximately five minutes. For each subject, three types of recordings were obtained: the speech signal, the video image, and head and face movement data. Subjects were videotaped for the full duration of the experimental session. The subject's speech was recorded using a DAT recorder and a Sennheiser microphone (type ME 40).

2.2 Kinematic data acquisition and processing

Head and eyebrow movements were recorded using the Elite motion-analysis system (Ferrigno & Pedotti, 1985), which includes a 100-Hz automatic optical TV-image processor that enables computer reconstruction of the three-dimensional trajectories of small infrared retro-reflective markers. The kinematic properties of five key points were captured by means of hemispherical markers (5 mm in diameter) attached to the interviewee's skin. The marker for recording head movements was placed on the forehead at the upper extremity of the frontal suture. For eyebrow-lowering detection, a marker was placed at each of the inner ends of the left and right supra-orbital arches. Markers for analyzing eyebrow raising and lowering were placed at the outer ends of the left and right supra-orbital arches. For the last two markers, a lateral position was chosen to avoid confusion between the inner and outer markers during head rotation. An external reference marker was placed on a vertical rod behind the subject. Two video cameras equipped with wide-angle lenses were positioned in front of the subject at a distance of 1.5 m, 35° to the right and left, respectively, of the speaker's sagittal plane (Figure 1).

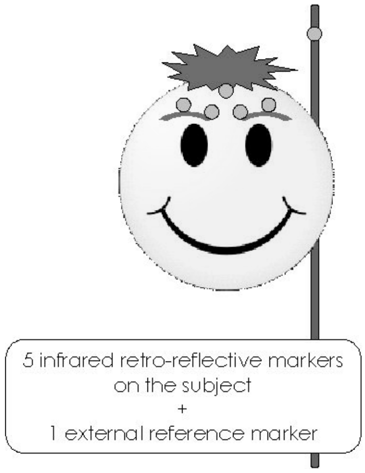


Figure 1. Location of markers.

The Elite system detected the markers in real-time by means of a hard-wired shape-recognition procedure. It then calculated their centroid x-y coordinates and generated a 3-D reconstruction of the marker trajectories. The powerful algorithms used for the centroid calculation and the stereometric procedure allowed us to attain a measurement accuracy of about 1/3000, i.e., 0.5 mm for the linear displacements in our experimental conditions. After digital filtering based on a preliminary automatic selection of the appropriate bandwidth for each signal (D'Amico & Ferrigno, 1990), the first and second derivatives of the markers' linear displacements were computed.

2.3 Data analysis

The kinematic data output by the Elite system (x, y, and z coordinates of the eyebrow movements) and the speech signal were transferred to a Sparc SUN station in a Unix environment. A computer-driven procedure was used to display the spectrogram of the speech signal, the corresponding F0 curve, and the eyebrow-movement curve. In order to separate the real movements of the eyebrows from those resulting from the movements of the head (which also sent data to the eyebrow sensors), the head movement component was factored out by an automatic procedure. The entire output dataset was verified a posteriori by viewing the video documents.

3 Data reduction and results

3.1 Selection of eyebrow movements

We limited the present study to rapid upward-downward eyebrow movements (eliminating slow movements, considered to be "postural"). Only those movements where the two eyebrows moved at the same time were retained for analysis. The cut-off point for inclusion of a movement was set at a displacement of at least 3 mm by at least one eyebrow, even if the other eyebrow moved less than 3 mm (for more details, see Guaïtella, Santi, Lagrue, Cavé, 2009)

3.2 Relationship to phonation

The interval between an eyebrow movement and phonation was defined as the time between the closest point in the movement and the beginning or end of the vocal signal. To relate the occurrence of eyebrow movements to the vocal production, the following intervals were measured:
1) If the eyebrows moved while the speaker was talking, two intervals were measured: the time between the onset of the vocal signal and the eyebrow movement, and the time between the eyebrow movement and the end of the vocal signal (Figure 2). These cases — where the eyebrow movement occurred during phonation — were classified in category 1 (C1).

C1

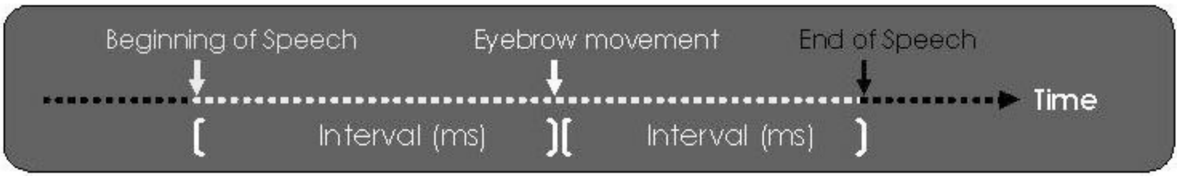
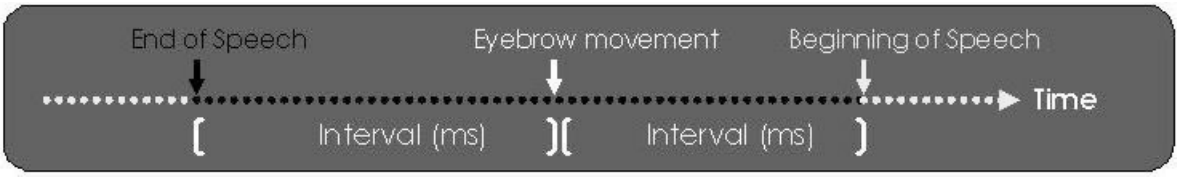


Figure 2. Diagram of temporal relationships between eyebrow movements and phonation: eyebrow movement during phonation.

2) If the eyebrows moved while the speaker was silent (even if the interviewer was talking), the intervals measured were between the eyebrow movement and the end of the speaker's last speaking turn, and between the eyebrow movement and the onset of the speaker's next turn (Figure 3a). Whenever the eyebrow movement and the end of the vocal production occurred within the same time window (difference of 30 ms or less), the interval between the movement and the beginning of the next phonation was measured (Figure 3b). Similarly, whenever the movement occurred within the same time window as the beginning of phonation (difference of 30 ms or less), the time since the end of the preceding phonation was measured (Figure 3c). These cases — where the eyebrow movement took place during speaker silence or at a phonation boundary — were grouped into category 2 (C2).

C2

3a. Eyebrow movement during silence



3b and 3c. Eyebrow movement at the end or beginning of phonation

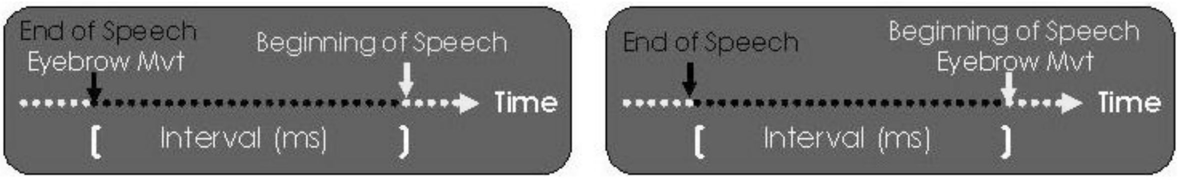


Figure 3. Diagram of temporal relationships between eyebrow movements and phonation: eyebrow movement outside of phonation or at a phonation boundary.

For category C1 (movement during phonation), the eyebrow-movement/end-of-phonation interval averaged 2100 ms and the beginning-of-phonation/eyebrow-movement interval averaged 1500 ms. For category C2, the end-of-phonation/movement interval averaged 1200 ms and the movement/beginning-of-phonation interval averaged 490 ms. These means include the data for one of the speakers whose interactive strategy (the way the speaker construes his/her situation in the interaction with respect to personal communicative intentions and goals) was the opposite of the others (C1: beginning = 543 ms, end = 780 ms. C2: beginning = 1300 ms, end = 1300 ms) (Figure 4).

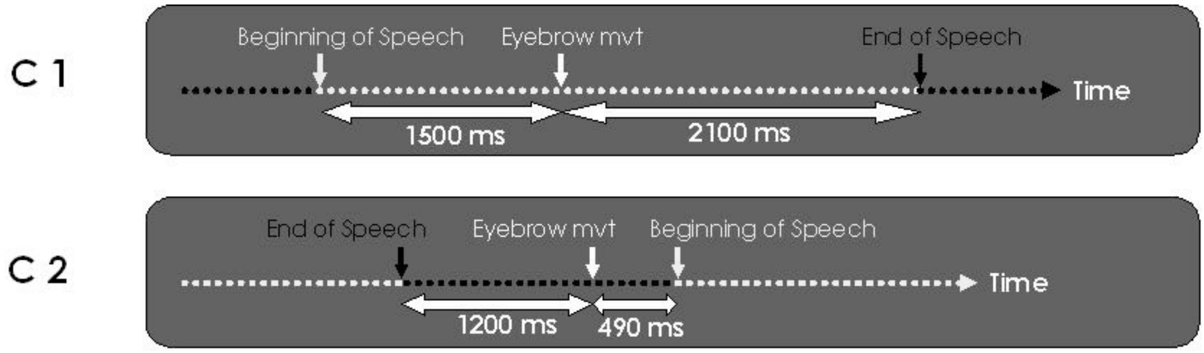


Figure 4. Diagram of average time intervals between eyebrow movements and phonation in categories C1 and C2, for all speakers pooled.

An Anova was conducted on the interval data for the two categories pooled. The results showed that eyebrow movements occurred closer to the beginning of a vocal production than to the end. Despite the subject whose deviant data weakened the overall tendency (see Discussion), this effect was statistically significant ($p < .05$). This allows us to suggest that rapid eyebrow movements are more often linked to initiation of a speaking turn and the beginning of phonation.

4 Discussion

The observed proximity of phonation onset and eyebrow movements seems to support the idea that eyebrow movements act as markers of a new speaking turn. Indeed, whether the eyebrow movements were located in the silent period before speech or at speech onset, they always seem to be linked to speaking-turn initiation and appear less useful once the position of speaker is recognized and established.

Paradoxically, the data of the speaker whose behavior differed from the others did not invalidate this hypothesis. Unlike the other participants, this very young speaker was intimidated by the situation, and although he readily agreed to participate, he did not try to get involved in the interaction despite the interviewer's attempts to make him feel at ease. His results still support our hypothesis in a certain sense: this speaker did not display any motivation to interact, and accordingly, his rapid eyebrow movements were not related to his speech-turn taking.

We can consider that rapid raising/lowering of the eyebrows acts as an attention-getting device, whether during the speaker's silent periods ("Look, I would like to speak") or during speech production ("Listen, what I'm saying is important"). We can contend that this gesture derives from an eyebrow-raising behavior whose original function was to manifest enhanced visual attention. The brevity and the function of these movements does not prevent them from having a meaningful and symbolic value.

In conclusion, the data obtained show that the speakers' rapid eyebrow movements were associated with turn-taking. These findings suggest that rapid eyebrow movements are mainly linked to motivation and the intention to communicate.

Bibliography

Birdwhistell, R.L. (1970). *Kinesics and context, Essays on Body Motion Communication*. Philadelphia: University of Pennsylvania Press.

Bolinger, D.L. (1998). Intonation in American English (preliminary version of article not published in its entirety). In: D.J. Hirst & A. Di Cristo (eds), *Intonation systems: a survey of twenty languages*. Cambridge: Cambridge University Press.

Branderud, P. (1985). Movetrack — A movement tracking system. *Symposium franco-suédois sur la parole* (pp. 113-122). Grenoble: GALF, AFSR.

Cavé, C., Guaïtella, I., Bertrand, R., Santi, S., Harlay, F., & Espesser, R. (1996). About the relationship between eyebrow movements and F0 variations. *Proceedings of the 4th International Conference on Spoken Language Processing* (pp. 2175-2178). Philadelphia.

Cavé, C., Guaïtella, I., & Santi, S. (2001). *Oralité et gestualité: Interaction et comportements multimodaux dans la communication*. Paris: L'Harmattan.

Cavé, C., Guaïtella, I., & Santi, S. (2002). Eyebrow movements and voice variations in dialogue situations. *Proceedings of the 7th International Conference on Spoken Language Processing* (pp. 2353-2356). Denver.

Condon, W.S. (1976). An analysis of behavioral organization. *Sign Language Studies*, 13, 285-318.

D'Amico, M., & Ferrigno, G. (1990). Technique for the evaluation of derivatives from noisy biomechanical displacement data using a model-based bandwidth-selection procedure. *Medical and Biological Engineering and Computing*, 28, 407-415.

Darwin, C. (1874). *L'expression des émotions chez l'homme et les animaux*. French translation by S. Pozzi & R. Benoit, Reinwald & Cie Libraires-Editeurs.

Ekman, P. (1989). La mesure de l'expression faciale. *Science et Vie*, 168, 24-31.

Ekman, P., & Friesen, W. (1975). *Unmasking the face. A guide to recognizing emotions from facial clues*. Englewood Cliffs, NJ: Prentice Hall.

Ferrigno, G., & Pedotti, A. (1985). ELITE: A digital dedicated hardware system for movement analysis via real-time TV signal processing. *IEEE Transactions on Biomedical Engineering* (pp. 943-949). BME-32, II.

Guaïtella, I. (1995). Mélodie du geste, mimique vocale? *Semiotica*, 103, 3/4, 253-276.

Guaïtella, I., Cavé C., & Santi, S. (1993). Relations entre geste et voix: Le cas des sourcils et de la fréquence fondamentale. In: *Images et Langages: Multimodalité et modélisation cognitive*. Actes du colloque interdisciplinaire du Comité National de la Recherche Scientifique (pp. 261-268). Paris.

Guaïtella, I., Santi, S., Cavé, C., Bertrand, R., Boyer, J., Faraco, M., Lagrue, B., Mignard, P., Paboudjian, C., & Purson, A. (1998). Les relations voco-gestuelles dans la communication interpersonnelle: Emergence d'une problématique et carrefour interdisciplinaire. In: S. Santi, I. Guaïtella, C. Cavé, & G. Konopczynski (eds), *Oralité et Gestualité, communication multimodale, interaction* (pp. 13-24). Paris: L'Harmattan.

Guaïtella, I., Santi, S., Lagrue, B., & Cavé, C. Are Eyebrow Movements Linked to Voice Variations and Turn-Taking in Dialogue? An Experimental Investigation. Language and Speech, (2009), 52, 2/3, 207-222.

Nguyen N. (2000). A MATLAB toolbox for the analysis of articulatory data in the production of speech. *Behavior Research Methods, Instruments, and Computers*, 32, 464-467.

Purson, A., Bertrand, R., Guaïtella, I., Boyer J., Cavé, C., Santi, S., & Harlay F. (1998). Mouvements de sourcils dans le questionnement : Relation entre geste et voix. In: S. Santi, I. Guaïtella, C. Cavé, & G. Konopczynski (eds), *Oralité et Gestualité: communication multimodale, interaction*. (pp. 561-566). Paris: L'Harmattan.

Santi, S., Guaïtella, I., Cavé, C., & Konopczynski, G. (1998). *Oralité et Gestualité, communication multimodale, interaction*. Paris: L'Harmattan.