Expression and communication of doubt/uncertainty through facial expression

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Abstract
There is a wide debate on the mental state of doubt/uncertainty; one wonders whether it is a predominantly cognitive or emotional state of mind and whether typical facial expressions communicate doubt/uncertainty. To this purpose, through a role playing procedure, a large sample of expressions were collected and afterwards evaluated through a combination of encoding and decoding procedures, including also FACS (Facial Action Coding System) analysis. The results have partially confirmed our hypothesis, identifying two typical facial expressions of doubt/uncertainty, which share the same facial actions in the inferior part of the face and show differential facial actions in the upper face.

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Introduction

Face and facial expression

The face plays an important role in social interaction, both in its static dimensions (structural feature, physiognomy) and in its dynamic dimension (facial expression), being a rich source of information and interactive signals. The face is in fact able to send a lot of information concerning age, gender, social status, etc., and affects impression of personality through the process of interpersonal perception. Facial expression on the other hand is an effective signaling system in interpersonal communication. In combination with other nonverbal signals it has a strong and immediate impact in expressing emotions such as fear, anger, happiness, sadness… and in communicating interpersonal attitudes such as cordiality, hostility, dominance, submission and so on; it communicates also other mental activity such as attention, memory, thinking, etc. Moreover the face takes part actively in conversation: the "speaker" accompanies his/her words with facial expression to emphasize or modulate the meaning of verbal communication; the "listener" during conversation provides a constant feedback through facial expression. Facial movements take also part in regulating the interpersonal exchanges and synchronizing the turn taking. The face may finally produce mimic movements that can play the role of adaptive behavior (correlated with the level of arousal experienced by the individual) or symbolic signals.

Facial expression of cognitive processes

In relation to facial expression of cognitive processes, De Sanctis (1902) an Italian pioneer in facial expression study, dedicated an entire book to *La Mimica del Pensiero* (The Facial Expression of Thought) posing many questions, such as: do thought processes manifest themselves in facial expressions? Is there a relationship between mental states such as attention and concentration and the concomitant facial expression? What relationship exists between the expression of emotions (or affective states) and the expression of other mental processes, such as attention, concentration or cognitive engagement? Can the extent and intensity of the facial movements act as a measure of the degree of concentration? Of course, De Sanc-

Pio E. Ricci Bitti, Luisa Bonfiglioli, Paolo Melani, Roberto Caterina, Pierluigi Garotti – *Expression and communication of doubt/uncertainty through facial expression*

160

tis' considerations were mainly the result of observation and speculation; they did however open a very interesting chapter, which did not subsequently receive the due attention from researchers.

De Sanctis identified frowning and the movements of the eyebrow region as the most significant indicators of cognitive processes; in particular he maintains, in agreement with Duchenne (1876), that the frontalis muscle can be considered as the muscle that chiefly expresses attention towards external objects (also called sensory attention or external attention). To this he added the movement used for internal attention (or reflection), during which a marked reduction of the eyelid opening is observed. A particular form of integration between the two previous expressions is represented by the so-called interrogative attention (Cuyer, 1902), in which both frowning and the relative tightening of the eyelids are observed. Another interesting form of facial expression of a specific cognitive process is observed during mnemonic effort: here too, the eyes are narrowed due to the eyelids tightening and the direction of the gaze can be diverted, upwards for example. Also Darwin (1872) had a certain interest in the so-called "blank" expression of the eyes, which expresses a kind of "assortment" of the thoughts, an "enchantment" in which the gaze is blank and the eyelids slightly narrowed.

In short, we can say that the expressive structures of the face that manifest the various cognitive processes (external attention, reflection, concentration, mnemonic effort etc.) are mainly located in the upper part of the face and can originate in the forehead, eyelid and eyebrow muscles. A less significant role is played by the muscles in the lower part of the face, that are responsible of the movements involving the mouth: in some cases the mouth can be shaped into the movement resembling a kiss (lip pucker); in other cases the lips are pressed together (lip tightener or lip presser) or pulled inside (lip suck); finally, we can observe a stretching of the corners of the mouth to produce a sardonic expression (movements similar to those produced in the facial expression that accompanies physical efforts).

De Sanctis concludes his observations by highlighting, at least on a methodological level, the distinction between emotional and "intellectual" expression, recognizing greater complexity and propagation in the former than in the latter, which involves fewer facial movements and which are also less intense and evident than emotional expressions. More recently few contributions concern the facial expression accompanying cognitive process (Ekman, 1979; Fridlund, 1991; Scherer, 1992; Baron-Cohen et al., 1997; Pelachaud & Poggi 2002; Ricci Bitti, *in press*); some of them agree with De Sanctis arguing that the facial expressions of cognitive processes are mainly located in the upper part of the face.

Pio E. Ricci Bitti, Luisa Bonfiglioli, Paolo Melani, Roberto Caterina, Pierluigi Garotti – *Expression and communication of doubt/uncertainty through facial expression*

161

Facial expression and interpersonal communication

It is clear to all that the face takes an active part in the communication processes that occur during conversation, through the gaze direction and the movements of the forehead, eyebrows, eyes, and the lower part of the face (together with other signals not discussed here, such as the position and movement of the head and shoulders, posture, gestures, etc.). Through these movements, the face constantly accompanies both the speaker and the listener as they take turns speaking in a conversation.

The speaker constantly accompanies his/her words with facial expressions that in turn emphasize, underline and modulate the content and meaning of the concomitant verbal language, in the same way as he/she uses an array of hand gestures (Ekman, 1976; Ekman & Friesen 1972; Rimé, 1983). To this end, the movements involving the muscles of the forehead, eyebrows and mouth play a significant part. The eyebrows in particular provide a great deal of information about verbal behavior (Costa & Ricci Bitti, 2003) by lifting, lowering or moving together to varying degree; expressed respectively by Action Unit 1 (AU 1) Inner Brow Raiser; AU 2 Outer Brow Raiser and AU 4 Brow Lowerer as per the FACS (Ekman & Friesen, 1978; Ekman et al., 2002).

From a functional point of view these facial movements, which we can call co-verbal facial expressions, have specific characteristics distinct from emotional facial expressions. They are quicker and appear at the same time as the concomitant verbal behavior.

Despite their apparent resemblance and use of the same underlying muscles, co-verbal and affective (conveying emotions) facial behaviors differ from one another in many ways, such as in their function, form, duration and, probably, in their activation mechanisms. Co-verbal facial expressions are governed by the verbal system; their precise coordination with the word or phrase is crucial in transmitting the message, which is thus completed and/or modulated. They are characterized by rapid and "individual" movements, unlike affective facial expressions which consist most often of combinations of facial actions, which are activated, evolve and end in ways that do not correspond to the clear confines of linguistic units, as is the case with co-verbal expressions with grammatical functions.

The difference between co-verbal facial expressions with linguistic functions and affective expressions is also supported by neuropsychological research. It was demonstrated that the two types of expression involve the activation of different neural structures: affective expression are processed mainly in the right hemisphere, while co-verbal expression with linguistic function are chiefly processed in the left hemisphere. Further proof of these differences is provided by studying

Pio E. Ricci Bitti, Luisa Bonfiglioli, Paolo Melani, Roberto Caterina, Pierluigi Garotti – *Expression and communication of doubt/uncertainty through facial expression*

162

aphasic patients: damage to specific areas of the left hemisphere can cause deterioration of co-verbal facial expressions with linguistic function without interfering with affective facial expressions, while damage to the right hemisphere with consequent deterioration of affective expressions leaves co-verbal facial expressions with linguistic functions intact (Adolphs et al., 1996; Borod et al., 1998; Burt & Perret, 1997; Campbell, 1986).

Doubt/uncertainty and its communication

Communication of doubt/uncertainty is necessary to mutual understanding in dialogue and develops dynamically and continuously; the analysis of processes and mechanisms underlying communication of interlocutors' uncertainty allows to explain how people detect and resolve misunderstandings (Stone & Oh, 2008). In the developmental psychology, several studies highlight that speaker certainty is an important cue for learning and that nonverbal signals which reflect meta-cognitive aspects are the latest to develop. Empirical studies show that children 3–4 years old are competent at identifying accurate and inaccurate informants (e.g., Bisanz et al., 1975; Koenig et al., 2004).

Doubt/uncertainty: issues from psychological literature. Doubt/uncertainty has recently been examined in various disciplines such as neuroscience (Zaretsky, 2010), informatics (Stone & Oh, 2008), linguistics (Carberry et al., 2002), philosophy (Goldie, 2009). Psychological literature discusses several topics concerning doubt. In particular, different studies try to deepen the following issues:1) is doubt a cognitive rather than an affective or emotional condition?; 2) is doubt associated with affective states (positive or negative)?; 3) how do individuals express doubt ?; 4) how do individuals learn to express and interpret epistemic modality (degrees of certainty) both in mother language and in second language? Moreover, it is suggested to distinguish different types of doubt/uncertainty; we can here consider among others at least three of them: a) the doubt/uncertainty related to the specific internal condition concerning decision making; b) the "doubt condition" that concerns the attitude assumed by the individual in the pursuit of truth or what is right (about philosophical, religious, moral, political issues); c) finally, the doubt/uncertainty associated with a specific case of interpersonal communication, e.g. in case of "Wh questions" (e.g. Where, What, Why, Who, etc.) when the speaker, trying to reply to a question, is not certain to know the answer.

Pio E. Ricci Bitti, Luisa Bonfiglioli, Paolo Melani, Roberto Caterina, Pierluigi Garotti – *Expression and communication of doubt/uncertainty through facial expression*

163

As far as the first kind of doubt/uncertainty related to the specific internal condition concerning decision making, we note that, in this case, the state of doubt/uncertainty can be considered as an attitude with cognitive, affective and behavioral components. Specifically, cognitive component involves thoughts and cognitive activity related to the decision; affective components involves positive or negative emotions related to the doubt/uncertainty and, finally, behavioral/motivational component involves the action tendencies. We can assume that the facial expression of this type of doubt depends both on different emotions and cognitive processes related to the management of doubt. This specific state of doubt/uncertainty, which tends to last a long time until the subject has not taken a decision, doesn't have specific and unambiguous facial expressions. The non-verbal signals depend on both the affective state (e.g., worry, anxiety, etc.) experienced by the individual and the cognitive processes activated in order to manage or resolve the condition of doubt/ uncertainty (e.g., concentration, mental effort, etc.). The communication literature presents several studies concerning the analysis of the relationship among affective and cognitive components in confusion and concentration (Rozin & Cohen, 2003; Ellsworth, 2008); to the contrary, how specific expressions convey uncertainty by signalling specific elements of an interlocutor's cognitive or affective state is a highly debated issue in studies regarding doubt.

Another kind of doubt/uncertainty condition concerns the attitude assumed by the individual in the pursuit of truth or what is right (about philosophical, religious, moral, political issues); in this case the question is cultivated as a method for approaching to the knowledge of the true and tends to persist over time. In this case there are no typical/specific nonverbal signals.

The third kind of doubt/uncertainty we would like to take in consideration is the doubt/uncertainty associated with a specific case of interpersonal communication, that occurs when the speaker, trying to reply, for example, to a "Wh question", is not certain to know the answer; in this case the facial expression accompanying the verbal message "I am not sure to know it" (or "I doubt to know it or I am uncertain to know it") serves as a conversational signal, that externalizes the cognitive processes related to search/retrieval of a specific information or knowledge.

Communication of doubt/uncertainty and facial expression. Maatman (2005) highlight the importance of *backchannel* signals of listeners that are strictly correlated to speaker behaviour and, into this kind of cues, frown and gaze direction are often linked to speaker communication of doubt/uncertainty.

Pio E. Ricci Bitti, Luisa Bonfiglioli, Paolo Melani, Roberto Caterina, Pierluigi Garotti – *Expression and communication of doubt/uncertainty through facial expression*

164

Eibl-Eibesfeldt (1979) highlighted that eyebrows movements have an important role in interpersonal interaction and examined different meanings of eyebrows raising. In particular, he distinguishes between emotional signals and conversational signals and includes cues associated with doubt, question, and emphasis among conversational signals. Moreover, Eibl-Eibesfeldt considers the original meaning of eyebrow raising as a consequence of eyes opening related to attention and suggests that individuals use this nonverbal signal to display surprise both in the case of negative and positive stimuli.

Poggi and Pelachaud (2000) propose to study eyebrow opening as a polysemous nonverbal signal with a restricted number of different meanings related to attention or violation of expectation. They also outline that, in the specific case of doubt/uncertainty, opening eyebrows is a direct consequence of violation of expectations.

Data collected in a study through judges' rating of a speaker's apparent certainty task, show that there are reliable behavioral cues for degrees of doubt/uncertainty and that these clues seem to be present in the nonverbal behaviors of people detected from video or audio or both (audio-video) but not from information contained in the text only (Oh et al., 2007); Furthermore, these data suggest that both facial movements and head and eye movements linked to cognitive state seem to contribute to viewers' judgments of the degree of certainty/uncertainty of the speaker.

In a developmental perspective, Krahmer and Swerts (2005) have compared the ability in signalling and detecting uncertainty in audio-visual speech by adults (20 –50 years old) and second grade school children (7–8 years old). The study suggests that there are specific cues (e.g., filler usage) that are gradually learned, and not yet fully developed in 7-8 years old children.

Carberry, Lambert, and Schroeder (2002) have analysed the attitude (a disposition, or mental state, toward a particular proposition or situation) of doubt/uncertainty concerning particular proposition expressed by another agent in the framework of studies about artificial agents. They propose that artificial agents are able to "play" a role of cooperative partners in problem-solving and decision-making if they can interact with users in an ecological and natural way; specifically they have to recognize and exhibit the same attitudes (like attitude of doubt) as human agents. Carberry, Lambert, and Schroeder highlight that a collaborative artificial agent must also both recognize a user's attitude toward a proposition expressed in a dialogue and generate an utterance that convey doubt.

Givens (2001) reports several nonverbal cues associated with uncertainty/doubt that include facial expression (frowns, eye movements, lip-pouting, lip-

Pio E. Ricci Bitti, Luisa Bonfiglioli, Paolo Melani, Roberto Caterina, Pierluigi Garotti – *Expression and communication of doubt/uncertainty through facial expression*

165

pursing), head movements (side-to-side head-shakes, head tilts) and gestures like self-touch gestures, palm-up gestures, and the shoulder-shrug.

Swerts and Krahmer (2005) have analysed facial expression of speaker's doubt/uncertainty founding specific visual cues like eyebrow movements, smiling, diverted gaze, and marked facial expressions.

Stone and Oh (2008) have examined displays of uncertainty in face-to-face conversation to simulate those behaviors in the Rutgers University talking Head (RUTH), an ECA (Embodied Conversational Agent) that represents a real-time facial animation system able to animate conversational facial displays and head movements in synchrony with speech and lip movements. Results show that movements of the head and eyes seem to signal what an interlocutor is doing to contribute to the conversation (e.g., listening, planning an utterance, presenting information, questioning or revising previous contributions) while other displays seem to serve to appraise how well that on-going activity is proceeding. They also suggest that head and eye movements are indicators of uncertainty and highlight the presence of a specific nonverbal signals used by participants to communicate uncertainty: the "facial shrug" formed by "pressing the lips together and raising the chin, arching the upper lip and allowing the lower lip to bulge outward" (Stone & Oh, 2008, pag. 67).

Aim

This study concerns the facial expression that accompanies the communication of doubt/uncertainty; in particular we have analysed the facial expressions involved in case a person communicates doubt/uncertainty related to a specific information or knowledge of her/his own in answering a question of this kind: "Do you know what…?", "Do you know who...?", "Do you know whether…?", "Do you know when…?", "Do you know where…?". The aim of this study was to analyse facial expression and other non-verbal signals involved in two different cases of doubt/uncertainty communication:

1. "I don't know" as: "I'm sure that I don't know!"; (in this case the answer does not communicate a doubt but rather a certainty; the certainty of not knowing the answer).
2. "I don't know" as: " I'm not sure to know it, ...may be I could know… I can try to retrieve this information…" .

Pio E. Ricci Bitti, Luisa Bonfiglioli, Paolo Melani, Roberto Caterina, Pierluigi Garotti – *Expression and communication of doubt/uncertainty through facial expression*

166

Our hypothesis is that the two types of facial expression share the same AU combination (AUc) in the inferior part of the face, but show differential facial actions in the upper face, that has the specific function to express the involved cognitive processes.

Method and procedure

Since we considered two possible nonverbal answers that correspond to the verbal answer "I do not know….." in front of different "Wh questions", we realized a four steps study, where we adopted a combination of encoding and decoding procedure.

First step

In this step, with the help of 12 volunteer encoders (6 Females and 6 Males; mean age 41.2; range 34-68) we carried out an individual session of role playing, lasted approximately 10 minutes where we got facial expressions accompanying answers like, "I don't know"… "I am not sure to know it"… "I doubt to know it"… "I am uncertain to know it"… "I don't know but I can try to retrieve this information…" in response to 5 "Wh questions". Our interest was focused only on facial expression; other nonverbal signals take part in fact in this kind of communications differentiating the two types of answer: e.g., in the first type of answer the facial expression can be accompanied by the head shake, as negation signal. Out of the 60 photos 36 respond to the including criterion. Twenty-four answers were unable to produce minimum required technical characteristics (E.g. the participants move partially out of the shot angles of the camera…).

Second step

We presented the 36 facial expressions to 30 decoders (19 females and 11 males; mean age 36.3; range 24-41), that evaluated them through two different tasks: in the first case they had to evaluate each expression through a free verbal answer (during the pre-set time of 10 second); the analysis of the different free verbal definitions of the facial expressions found out three possible "families" of feelings/attitudes expression:

Pio E. Ricci Bitti, Luisa Bonfiglioli, Paolo Melani, Roberto Caterina, Pierluigi Garotti – *Expression and communication of doubt/uncertainty through facial expression*

167

1. "I don't know": that means certainty of not knowing.
2. "I'm not sure": that really means uncertainty.
3. "I am thinking about it": that means "I am uncertain, but I can try to retrieve this information in my mind".

In the second task they had to assess the degree of correspondence of each facial expression, on a five points likert scale (from 1-Absolutely disagree to 5-Absolutely agree), to the three "families" of answers listed above.

On the basis of the results, we chose 4 images (2 males and 2 female) of facial expressions for each of the three meanings above mentioned; we selected the images with the highest correspondence to the three "families" of meaning (see table 1).

Table 1. *Degree of correspondence to the three "families" of meaning.*

	I don't know		I'm not sure		I am thinking about it	
	Mean	(SD)	Mean	(SD)	Mean	(SD)
Female Images	4,11	1,07	4,47	0,87	4,53	0,50
Female Images	4,03	0,99	4,42	0,76	4,42	0,79
Male Images	4,03	0,55	4,31	1,10	4,64	0,48
Male Images	4,00	1,43	4,25	0,95	4,19	0,99

Third step

The 12 images of facial expressions were included in random order in a set of 36 images; the other 24 images represented male and female encoders expressing by facial movements the following six emotions: anger, disgust, fear, happiness, sadness, surprise. Then we realized two decoding sessions where we administered these 36 images of facial expressions to two groups of decoders recruited voluntarily among psychology university students':

• the first group of 66 decoders (53 females and 13 males, mean age 22.3; range 19-44) had the task to evaluate and describe each facial expression through a free verbal label (adjectives, nouns, sentences ...);

• the second group of 66 decoders (54 females and 12 males, mean age 21.9; range 19-41) had the task to attribute to each facial expression a specific mean-

Pio E. Ricci Bitti, Luisa Bonfiglioli, Paolo Melani, Roberto Caterina, Pierluigi Garotti – *Expression and communication of doubt/uncertainty through facial expression*

168

ing through one of the following verbal labels: anger, disgust, doubt/uncertainty, fear, happiness, sadness, surprise.

Fourth step

In the last step of the study we analyzed the three types of facial expression obtained in the second step through the Facial Action Coding System (FACS; Ekman & Friesen 1978; Ekman et al., 2002); two independent judges decoded the different Action Units (AUs) involved in the 12 facial expressions.

Results and discussion

The verbal labels (adjectives, nouns, sentences, etc.) attributed to the 12 facial expressions in the free label task of the second step of the study were grouped by "families"; e.g., in relation to "doubt/uncertainty", we grouped terms such as: doubt, doubtful, uncertain, hesitant, uncertainty, indecisive, without conviction, I do not know, no idea, indecision, irresolute…

The degree of recognition concerning the 12 facial expressions of doubt/uncertainty through the task with free verbal definition was 63.51% (see figure 1), which is particularly high, significantly higher than chance accuracy and not substantially lower than the degree of recognition obtained in the same task by the facial expressions of basic emotions (mean percentage: 71.02%).
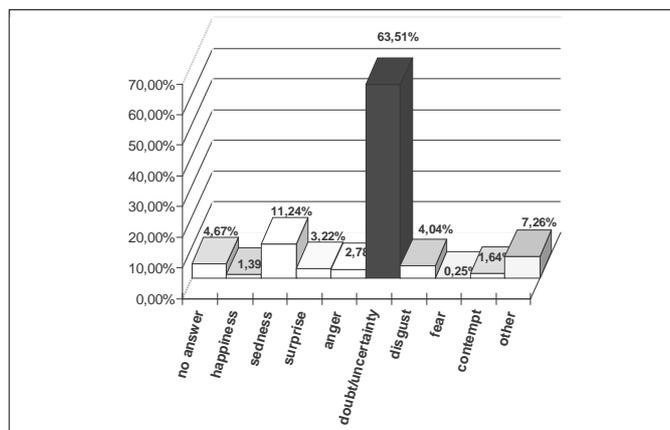

Figure 1. *Free label task: recognition degree (%)*

Pio E. Ricci Bitti, Luisa Bonfiglioli, Paolo Melani, Roberto Caterina, Pierluigi Garotti – *Expression and communication of doubt/uncertainty through facial expression*

The degree of recognition obtained by the second group of decoders was 79.61% (see figure 2), which is significantly higher than chance accuracy and not substantially lower than the degree of recognition obtained in the same task by the facial expressions of basic emotions (mean percentage: 85.00%).
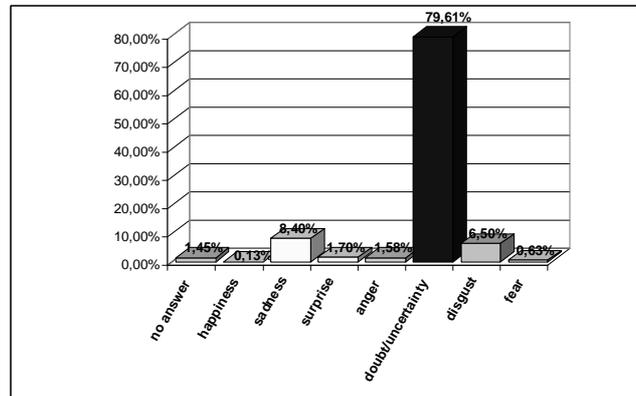

Figure 2. *Fixed label task: recognition degree (%)*

Chi square analysis through the three different types of facial expression of doubt/uncertainty (1. "I don't know"; 2. "I'm not sure"; 3. "I am thinking about it") showed significant differences between the first type and the other two; $\chi^2(2)$ = 19.229, p= .000 (see figure 3). This result confirms that these two facial expressions are considered more specific representation of doubt/uncertainty.
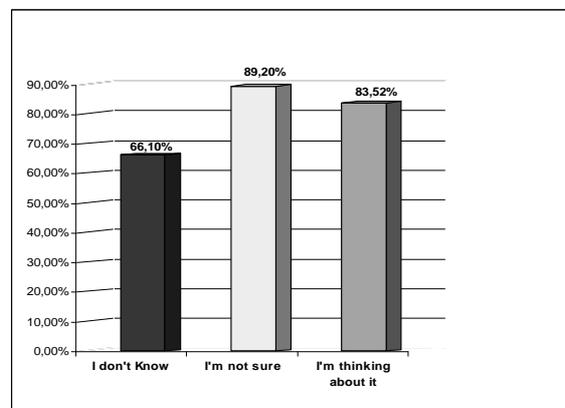

Figure 3. *Comparison of the three expressions of doubt/uncertainty*

Pio E. Ricci Bitti, Luisa Bonfiglioli, Paolo Melani, Roberto Caterina, Pierluigi Garotti – *Expression and communication of doubt/uncertainty through facial expression*

170

The FACS analysis of the three types of facial expressions of doubt/uncertainty was performed by two independent FACS coders. Scoring agreement was quantified with Cohen's Kappa for the presence of single AU in the three types of doubt/uncertainty (see table 2).

Table 2. *Kappa's coefficients means value for single Action Units in the 12 selected images*

Single Action Units	I don't know Occurrence	I'm not sure Occurrence	I'm thinking about it Occurrence
AU1	Np*	0.88	0.73
AU2	Np*	0.89	0.75
AU4	Np*	Np*	0.88
AU7	Np*	Np*	0.79
AU15	0.90	0.91	0.89
AU17	0.87	0.92	0.93

Not present

Conclusions

These results partially confirmed our hypothesis, identifying two typical facial expressions of doubt/uncertainty, which share the same facial actions in the inferior part of the face and show different facial actions in the upper face. In the lower part of the face all the three types of expression involved the presence of the AUc 15+17 (Lip Corner Depressor + Chin Raiser); in the upper part of the face we found the following differences: while the first type of expression (corresponding to the verbal message "I do not know, and I am certain I do not know") does not present any specific AU (see figure 4), the second type of expression (corresponding to the verbal message "I am not certain to know it") shows the AUc 1+2 (Inner Brow Raiser + Outer Brow Raiser; see figure 5); finally the third type of expression (corresponding to the verbal message "I do not know, but I can try to retrieve this information…") shows in addition to the AUc 1+2 also the AUc 4+7 (Brow Lowerer + Lid Tightener) and a deviation of gaze direction that are both signal of mental concentration (see figure 6).
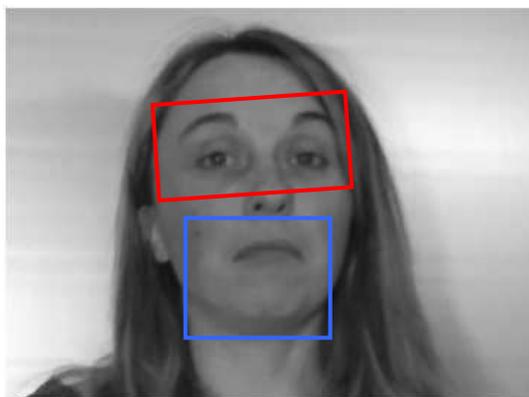
Our results show that the communication of doubt/uncertainty activates mostly the facial expressions involved in cognitive processes and that the study of facial

Pio E. Ricci Bitti, Luisa Bonfiglioli, Paolo Melani, Roberto Caterina, Pierluigi Garotti – *Expression and communication of doubt/uncertainty through facial expression*

171

expression must devote more attention to expressions involved in conversation and externalization of cognitive processes.

Figure 4. *Facial expression for "I do not know".*

Figure 5. *Facial expression for "I am not sure to know it".*

Pio E. Ricci Bitti, Luisa Bonfiglioli, Paolo Melani, Roberto Caterina, Pierluigi Garotti – *Expression and communication of doubt/uncertainty through facial expression*
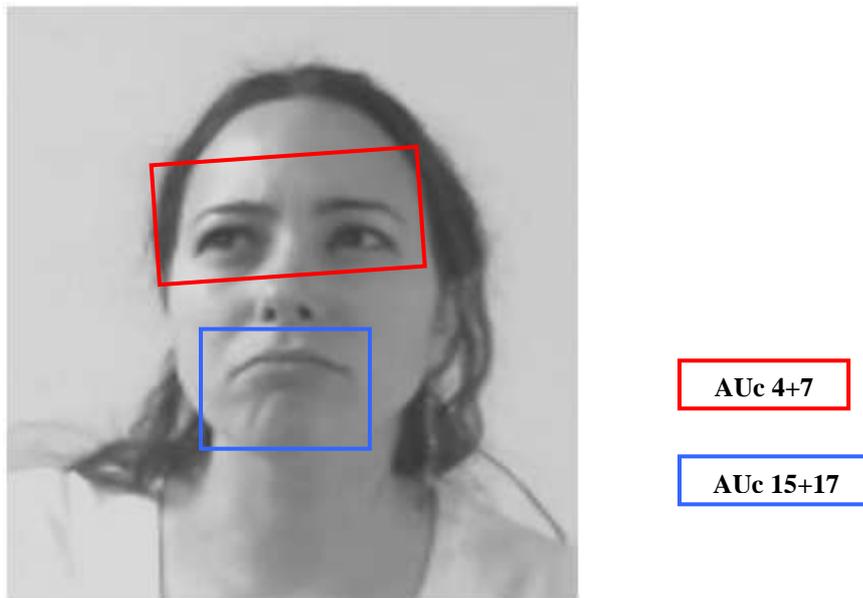
172

Figure 6. *Facial expression for "I do not know, but I can try to retrieve this information".*

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Pio E. Ricci Bitti, Luisa Bonfiglioli, Paolo Melani, Roberto Caterina, Pierluigi Garotti – *Expression and communication of doubt/uncertainty through facial expression*

173

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Pio E. Ricci Bitti, Luisa Bonfiglioli, Paolo Melani, Roberto Caterina, Pierluigi Garotti – *Expression and communication of doubt/uncertainty through facial expression*

174

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Pio E. Ricci Bitti, Luisa Bonfiglioli, Paolo Melani, Roberto Caterina, Pierluigi Garotti – *Expression and communication of doubt/uncertainty through facial expression*

175

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Pio E. Ricci Bitti, Luisa Bonfiglioli, Paolo Melani, Roberto Caterina, Pierluigi Garotti – *Expression and communication of doubt/uncertainty through facial expression*

176

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