Eyebrow Raising, Discourse Structure, and Utterance Function in Face-to-face Dialogue

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Abstract

Some studies have suggested a relationship between eyebrow raising and different aspects of the verbal message, but our knowledge about this link is still very limited. If we could establish and characterise a relation between eyebrow raises and the linguistic signal we could better understand human multimodal communication behaviour. This study investigated eyebrow raising in a corpus of task-oriented English dialogues in relation to discourse structure and utterance function. Based on previous observations of body movement, eyebrow raises were predicted to occur more frequently in utterances starting a new segment in the structure of the dialogue. It was also predicted that they would be more frequent in instructions and in queries than in other types of utterance. Analyses using generalised linear models showed that eyebrow raises occurred more frequently in the initial utterance of high-level discourse segments than in other parts of the dialogue, and more frequently also in instructions than in other types of utterance. The start of a lower level in the discourse structure was not associated with eyebrow raising, nor were utterances with a questioning function. These findings provide tentative evidence of a relation between eyebrow raising and aspects of the linguistic message which is important not only from a psycholinguistic point of view but also for practical applications in the design of multimodal dialogue systems.

Keywords: Psycholinguistics; Multimodal communication.

Introduction

Like many of the subtleties of human communication, the use of the face is something we believe we understand but cannot yet describe. Human facial movements have attracted a great deal of research, but the information we have about the use of the face in multimodal communication is still very limited. Research on facial movements has been largely dominated by the study of the expression of emotion. By contrast, and leaving aside movements that are necessary for the articulation of speech, studies on facial movements in connection with spoken language have been scarce. Observations have, however, been made which suggest possible conversational functions of eyebrow raises in particular, and in recent years a few studies have taken an empirical approach to this issue. The sketchy nature of the evidence for coordination is particularly surprising because other body movements have been shown to have a non-random relation with the speech they accompany. The study reported here investigated possible linguistic functions of eyebrow raising associated with discourse structure and utterance function in face-to-face dialogue.

There have been several studies suggesting a relationship between body movements and **discourse structure**. Kendon (1972, 1980) suggested that common discourse themes will produce gestures with recurring features. Based on this, McNeill et al. (2001) studied possible cues for discourse structure from manual gestures in videotaped conversations. Segmenting the conversations in terms of discourse goals, they found that, indeed, recurring gesture features revealed a discourse organisation that correlated 100% with the hierarchical structure of their segmentation. McClave (2000) looked at head movements in dialogue and, among other functions, she associated changes in head position with a switch in discourse from indirect to direct speech and also with listing or presenting alternatives. In a study by Cassell, Nakano, Bickmore, Sidner, and Rich (2001), body posture shifts were more frequent when starting a new discourse segment which was often at the boundary between turns. From this, Cassell et al. (2001) concluded that posture shifts can signal *boundaries* of units. As for brow raises, Chovil (1991) observed, with an inductive approach, that in her recorded dialogues these sometimes seemed to mark the organizational structure of a dialogue, by marking the beginning, end, or continuation of a topic. The findings above are for English. Cavé, Guaitella, and Santi (2002) found that rapid eyebrow raises could have a role in turn-taking by marking the start of a new speaking turn in French.

In relation to **utterance function**, eyebrow raising has been traditionally associated with questioning. This function was mentioned by Ekman (1979) in a publication that has been very influential in later research even though it was presented as a preliminary observation without empirical evidence. Chovil (1991) also observed this questioning function in her recorded dialogues. More recently, Srinivasan and Massaro (2003) found that both eyebrow raising and head tilting could be used, together with auditory cues, to distinguish echoic questions from statements in perception studies with synthetic stimuli. They reported, however, that participants relied most strongly on the auditory cues, even when the visual cues were enhanced.

In summary, observations in previous research suggest that body movement, including eyebrow raising, could be related to the organization of a discourse into segments. Also, eyebrow raises have been associated with the function of utterances, particularly with questioning. Thus eyebrow raises would appear to have conversational functions, but there is not strong empirical evidence. Research into *when* eyebrow raises occur in dialogue could have important implications for models of speech production and could provide crucial information for the design of embodied animated agents in multimodal dialogue systems.

The current study investigated eyebrow raising as it occurred spontaneously in task-oriented dialogues in English. Considering the question of *when* we raise our eyebrows when we are engaged in conversation, brow raises were predicted to occur more frequently at the start of new segments in the conversation. In particular, and using the structure coding scheme by Carletta et al. (1997), this hypothesis was stated as:

H1: Eyebrow raises will be more frequent in utterances starting conversational games and transactions than in other utterances in the dialogue.

As for utterance function, the hypothesis was that eyebrow raising is associated with some linguistic communicative functions and it will be unequally distributed across utterances depending on the purpose of such utterances in the dialogue. In the kind of dialogue investigated here instructions were the most important type of utterance for participants to advance the dialogue and complete their task. Additionally, the literature mentioned above suggests that we raise our eyebrows when we ask a question. Thus, queries in the dialogues under investigation were also predicted to have more frequent eyebrow raising:

H2: Eyebrow raises will be more frequent in utterances giving instructions than in other types of utterance

H3: Eyebrow raises will be more frequent in utterances requesting information than in other type of utterance

If, however, eyebrow raises simply occurred at random, then we would expect only effects of the opportunities for brow raises, which would vary as a function of the duration of the sampled unit. Thus, the null hypothesis can be stated as:

H0: Eyebrow raises are a random phenomenon determined only by utterance length. Long utterances will have more brow raises than short ones but uptake of opportunities will not depend on type of utterance or position in discourse.

Method

Corpus collection: The Map Task

A corpus of task-oriented dialogues was recorded using the experimental design of the Map Task (Anderson et al., 1991). In the Map Task, two participants, the *Instruction Giver* (*IG*) and the *Instruction Follower* (*IF*), sit opposite each other with slightly different versions of a simple map. The *IG*'s map has a route navigating a set of labeled landmarks, whereas the *IF*'s has only landmarks. Their task is to draw the *IG*'s route on the *IF*'s map. But their sets of landmarks are not quite identical and they cannot see each other's maps, so both participants must collaborate to perform the task. Thus, they engage in conversation so that the *IG* can describe the route to the *IF*, who in turn can ask any questions or clarifications needed in order to draw that route. In the current corpus four female native speakers of British English participated twice as *IG* to two different *IF*s, yielding a total of eight dialogues. Figure 1 shows a sample frame from one of the recordings, edited for analysis so that it shows a single front view of both speakers.

Materials

The materials for this study came from six of the recorded dialogues with an average duration of 369*sec*. Utterances and brow raises produced by three of the participants (*A1, A2, B2*) in the role of *IG* were analysed.

Figure 1: Sample frame from a video-recorded dialogue, with the *IG* on the left and the *IF* on the right.

Discourse structure The structure of each dialogue was annotated according to the Conversational Games Analysis coding scheme (Carletta et al., 1997), which divides a dialogue according to the speaker's purpose in producing the utterances. There are three conversational levels in this scheme: moves, games, and transactions. These are defined below.

Conversational move: An utterance that communicates an intention and can be classified according to its purpose in the communicative task and according to its form. This is the lowest level of the discourse structure. There are twelve types of move in this coding scheme, which in the current study were reduced to a set of five broader move types: *Instruct*, *Query*, *Explain*, *Reply*, and *Acknowledge*. This classification preserved the basic distinctions between moves' purposes: to make the listener follow an instruction, to acquire some information, to provide some information, and to acknowledge receipt of information.

Conversational game: This is a set of moves starting with an initiation move (*Instruct*, *Query*, or *Explain*) plus any subsequent moves that are produced until the purpose of that first move is fulfilled or abandoned. All moves must be included in at least one game and games can be embedded.

Transaction: This represents the highest level of the dialogue structure. Transactions consist of a set of games that negotiate a section of the map route and so correspond to one step of the task which the dialogue furthers. These sections map onto a speaker's own division of the route into segments that are dealt with in sequence.

Dialogue structure was annotated by the author using the *xlabel* software on *Entropic/Xwaves* which segments the digitised speech signal into labeled units. The annotation was done without acces to the video recordings to avoid a possible bias from facial movements.

Eyebrow raises An eyebrow raise was defined as: any upward movement, from a baseline neutral position, of at least one eyebrow and observable by the annotator on the digital video recordings. This definition, then, included movements of any intensity and also asymmetrical movements in which only one eyebrow was lifted.

The start and end of eyebrow raises produced by the *IG* participants in the dialogues were annotated by the author using the software *SignStream* (version 2.0, Boston University, USA), that allows the frame-stamped segmentation and labeling of digital video data. The annotation was done without sound, to avoid bias from the speech, and also hiding the bottom part of the participant's face, to avoid distraction and bias from articulatory movements from the mouth area.

In order to associate brow raises with a particular conversational move in the dialogue the start of the raising movement was considered. This choice was made because when annotating brow raises their start was generally more marked and perceptually clearer than their end. Thus, a brow raise was associated with the move in which it started. When it did not start within a move, i.e. it started in an inter-move interval, then if it finished after the start of the following move it was associated with that move; if it finished within the inter-move interval, i.e. before the next move's start, then it was excluded from the analysis. The latter occurred in four cases out of 274 brow raises, which left 270 brow raises for the analysis.

Statistical analysis

The unit of analysis in this study was the conversational move. Multiple linear regression (MLR) analyses were carried out in order to examine a possible relationship between brow raises and both dialogue structure and utterance function, according to the above hypotheses. The dependent variable was the *number of eyebrow raises* per move. The predictor variables were *move type*, *discourse position*, *speaker*, and *move length* (in number of words). *Move type* and *discourse position* were the variables of interest as possible predictors of brow raising. The other variables were included to account for possible effects of individual differences between participants and of the length of utterances. The categorical variables were coded as sets of dummy variables, one for each group within the variable.[1] Then, following standard procedures, all groups minus one, within each variable, were entered into the regression analysis. The group left out in each categorical variable was the reference to which the other groups within that variable were compared. For *move type*, the reference group was *Instruct* and *Query*, one at a time as described below, to which the other move types were compared. For *discourse position* the reference group was *non-initial*. For *speaker*, *A1* was selected as the reference because preliminary observations suggested that she raised her eyebrows more frequently than the other two participants.

Additionally, to confirm results from the MLR analyses, logistic regression analyses were also performed. To do this, *number of brow raises* was reduced to a binary variable indicating whether the conversational move did or did not have a minimum of one brow raise. Since only 6% of the moves had more than one brow raise, the loss of precision was not critical.

Results

There was a total of 682 moves and 270 brow raises. Some descriptives are presented in Tables 1 and 2. Results from the first MLR analysis are reported below and in Table 3, which shows the independent contributions of the significant predictor variables. In this table, for each predictor variable, β indicates how much the number of brow raises will change with a change of one standardised unit in that predictor variable. Since they are expressed in standardised units, β values can be directly compared across predictors. The values for the individual move types and speakers are in comparison to their reference groups: *Instruct* type and speaker *A1*, respectively. Negative β values for those categorical variables indicate that the predictor in question has significantly *fewer* brow raises than the reference group.

Table 1: Mean and SD for *move length* and *number of brow raises (BRs)* by *move type*

		N of words		*N of BRs*	
Move type	(N)	Mean	SD	Mean	SD
Instruct	(284)	10.58	5.54	.65	.821
Explain	(59)	9.10	4.69	.44	.702
Query	(94)	6.40	3.47	.29	.500
Reply	(135)	3.11	3.57	.21	.447
Acknowl.	(110)	1.25	.747	.02	.134
Overall	(682)	6.90	5.74	.39	.675

Table 2: Mean and SD for *move length* and *number of brow raises (BRs)* by *discourse position*

		N of words		*N of BRs*	
Disc. Pos.	(N)	Mean	SD	Mean	SD
Trans-init.	(104)	10.79	5.48	.75	.76
Game-init.	(185)	9.43	5.63	.49	.716
Non-init.	(393)	4.67	4.75	.25	.586
Overall	(682)	6.90	5.75	.39	.675

Overall, the resulting model accounts for 25% of the variance in the number of brow raises per move ($R^2 = .254$; $F_{(8,673)} = 28.655$, $p < .001$). The strongest predictor is the length of the move: the longer the move, the more brow raises it had. The next predictor is the speaker identity, with *A1* raising her eyebrows more frequently than the other two participants. Then with smaller but significant contribution, the next predictor is the type of move, with *Acknowledge* and *Query* types having less brow raises than *Instructs*. Finally, *Transacion-initial* moves had more brow raises than moves in non-initial position.

In the second MLR analysis move types were compared to *Query*, everything else was kept the same. The results are very similar to the previous ones above ($R^2 = .253$; $F_{(7,674)} = 32.639$, $p < .001$). In Table 4 we see the same relation to *Instruct* type, this time expressed in reverse: *Instruct* moves had significantly *more* brow raises than *Query* moves. What is new is that *Query* moves did not appear to have more frequent eyebrow raising than any other move type. That is, it was *Instructs*, all else being equal, which attracted brow raises, not *Queries*.

In both analyses *move length* is by far the best predictor

[1] *Move type* was coded as *Instruct, Explain, Query, Reply,* and *Acknowledge*. *Discourse position* was coded as *Transaction initial, Game initial, Non-initial*. And *speaker* was coded as *A1, A2, B2*

Table 3: Independent contribution of the significant predictors of *Number of brow raises* (move types compared to *Instruct*)

Predictor	β	Sig.
Acknowledge	−.105	.020
Query	−.095	.012
Trans. initial	.101	.006
Speaker A2	−.178	< .001
Speaker B2	−.204	< .001
Move length	.379	< .001

Table 4: Independent contribution of the significant predictors of *Number of brow raises* (move types compared to *Query*)

Predictor	β	Sig.
Instruct	.108	.015
Trans. initial	.092	.009
Speaker A2	−.184	< .001
Speaker B2	−.208	< .001
Move length	.372	< .001

of the number of brow raises, whereas *move type* and *discourse position* contribute much less to explaining the variance in that dependent variable. Nevertheless, their contribution is significant. This was confirmed by the general linear test statistic[2]. This test confirmed the significance of the increase in R^2 when adding the variable *move type* to a reduced model without it ($F_{(3,673)} = 2.920, p < .05$), and when adding *discourse position* to a reduced model without it ($F_{(1,673)} = 7.612, p < .001$). Some diagnostics were also used to detect whether there was multicollinearity between the predictors: measures of association, the variance inflation factor (VIF), and tolerance values. These showed that the predictors were not too highly associated between them, and also that the VIF and tolerance values in the regression analyses presented above were acceptable, even considering the conservative cutoff values suggested by some researchers (all VIF values were < 4, and tolerance values were $> .2$).

The dependent variable above was skewed. This was not a problem for the MLR analyses because the data size was considerably large. Nevertheless, as mentioned earlier, logistic regression analyses were also performed which confirmed the results. The same significant predictors appeared and in the same pattern. For example, the odds of a brow raise occurring in an *Instruct* move were 2.5 times greater than the odds of it occurring in a *Query* move (95% C.I. from 1.2 to 3.9).

Discussion and conclusion

In this study Conversational Games Analysis (Carletta et al., 1997) was applied to six Map Task dialogues in order to investigate whether eyebrow raises produced by speakers were related to the structure of the dialogue and to utterance function. One of the predictions was that brow raises would occur more frequently in moves starting conversational transactions and conversational games than in other positions in the structure of the dialogue (H1). Also, brow raises were predicted to occur more frequently in *Instruct* (H2) and *Query* moves (H3) than in other types of move. H1 and H2 were partially supported by the results of analyses using generalised linear models. Brow raises were found to relate most strongly to the length of the utterance. As the number of words in a move increased, so did the number of brow raises. If this had been the only relationship found, eyebrow raising would have seemed a random phenomenon with simply more opportunities to occur in long utterances. However, other relations appeared that were independent of move length. Supporting H1 partly, speakers raised their eyebrows more frequently in transaction-initial moves than in non-initial moves. This seemed to indicate that they used eyebrow raising when starting a new task-related section of the discourse. This tendency was not present at a lower discourse level: game-initial moves that were not transaction-initial did not have more eyebrow raises than non-initial moves. As for utterance function, brow raises were also found to occur more frequently in *Instruct* moves than in *Query* and *Acknowledge* moves,[3] lending some support to H2 above. However, contrary to the prediction in H3, *Query* moves did not have more frequent eyebrow raising than any other type of move. In fact, interestingly, the only relation between *Query* and other move types was, as we just saw, that speakers raised their eyebrows *less* frequently when asking questions than when giving an instruction. Apart from these results, speakers differed significantly in terms of number of eyebrow raises per conversational move. One speaker produced more eyebrow raises per move than the other two speakers did. Large variability between participants is very often found in this type of research and can be a problem for the interpretation of findings. In this study, the influence of one speaker on the frequency of brow raising was stronger than the influence of the variables of interest, namely *move type* and *discourse position*. However, the reported statistical significance for the latter is still valid, because the contribution of each variable was assessed independently of the contribution made by the others. So, those variables did influence the frequency of brow raising, even if the influence of the speaker identity was larger. Similarly, although *move length* was the strongest predictor, its influence was controlled when evaluating the other potential predictors. It is important to point out though, that the predictive power of the whole model was not very strong. Putting together the influence of the significant predictors, only 25% of the variance in brow raising was accounted for. Therefore, if the majority of this accounted variance is explained by the duration of the utterance and by the identity of the speaker, then the influence of the type of utterance and its position across the discourse is significant but relatively small. Being aware of this limitation, we could interpret the results as described below.

Speakers in the dialogues under investigation raised their eyebrows more frequently in the first utterance of a transac-

[2] See e.g. Neter, Wasserman, and Kutner (1996)

[3] *Instructs* also had more brow raises than *Explain* and *Reply* moves, but this tendency did not reach significance

tion than elsewhere in the dialogue. In Map Task dialogues transactions represent the highest level of the discourse structure, and they reveal the speakers' mental organisation of the description of the route into segments. Eyebrow raises at the start of these segments could mark the introduction of a new coherent section of the description. Looking at the research literature this has some similarities with the findings reported by Chovil (1991). In both cases the speaker is introducing a new segment with a new "theme". The current finding could also be compared to that by Cassell et al. (2001) who found that participants made a body posture shift when starting the discussion of a new assigned topic, again marking the start of a high-level discourse segment. Cavé et al. (2002) reported that in French brow raises seemed to mark the start of turns. This would suggest that body movement marked boundaries not only at high-levels in the structure of a conversation. However, in the current dialogues eyebrow raising did not mark the start of segments at a lower level than transactions, namely conversational games. This is probably because the change from one game to the next is not as marked as a change from one transaction to another. The start of a game marks the initiation of a new purpose in the conversation, for example, to provide some instruction or some information, or to acquire some information from the other participant. While this implies a change in the conversation, those games are still linked by a coherent "topic" within the same transaction, that is, they have in common the fact that they discuss or negotiate the same part of the route. Considering previous findings in the literature and those here, a general conclusion could be made that a change in body movement can signal a change from one segment of the discourse to another. More in particular, we could conclude that in the task-oriented dialogues under investigation speakers' eyebrow raises seemed to have a discourse function by marking the *start* of *high-level* discourse units in the conversation.

In relation to utterance function, the fact that queries did not have more eyebrow raises than any other type of utterance disagrees with previous observations that associated brow raising with questioning (Ekman, 1979; Chovil, 1991; Srinivasan & Massaro, 2003). It would seem, then, that eyebrow raises do not mark questions as had been claimed. Alternatively it could be that in the type of dialogues investigated here, eyebrow raises provided a questioning meaning to utterances that would not be perceived as questions when only listening to the speech without watching the speakers. However, considering the report by Srinivasan and Massaro (2003) that visual cues had a much weaker effect than auditory cues in their perception experiments, it seems unlikely that the finding in the current study would be due to wrong assignment of some questions to a category other than *Query*. It could be possible, however, that brow raises *added* a questioning meaning to utterances with a different main purpose, such as an instruction. This will be discussed further below.

As for *instruct* moves, the fact that they had more brow raises than other types of utterances could be due to their importance in the dialogues under investigation, since it is mainly these instructions that allow the interlocutor to draw the route on her map. Therefore, instructions must be conveyed clearly and efficiently by the speaker in order to succeed in the completion of their task. Eyebrow raises may play a role here by reinforcing the content of these utterances and setting them apart. In a different kind of dialogue, another type of utterance could carry the key information that would be marked by eyebrow raising. Another interpretation, in connection with the discussion in the previous paragraph, is that eyebrow raising was associated to *Instructs* in order to add a questioning meaning to the instructions, as if simultaneously asking *'ok?'*, *'are you with me?'*. It is possible that this function, of checking that the interlocutor is following the conversation, can be achieved sometimes by an explicit utterance and other times by means of eyebrow raising accompanying the instructions. It would be interesting, in future research, to study the interlocutor's (*IF*) behaviour, to see how many times they produce an *Acknowledge* or *Reply*, immediately following a brow raise by the *IG* speaker in a non-query move, as if the *IF* had felt prompted to provide a reply or a sign that a message had been successfully conveyed.

To summarise, this study provides tentative evidence of a relation between eyebrow raising and the linguistic message, which can be interpreted as an indication that eyebrow raises may have conversational functions. These functions would be to signal the beginning of high-level discourse segments and to emphasise information in the utterances with the most important role in the dialogue. A question arises as to whether these are intended signals that can add meaning to the linguistic message or whether brow raises are not intended and are just a by-product of the speech production process. There has been a long debate about this issue in the field of gesture study and it is still ongoing. In any case, if eyebrow raises are correlated with certain aspects of the linguistic signal, an interlocutor would be able to attribute meaning to them and interpret them as a signal even if originally not intended as such.

A relation between brow raises and prosodic phenomena has also been reported (e.g. Krahmer & Swerts, 2004; Flecha-Garcia, 2006), supporting the hypothesis that eyebrow raising is not a random behaviour and may be linked to the linguistic signal. Although the findings in the current study are preliminary, they make an important contribution by encouraging further research in this area. A larger-scale study, including more participants and different types of dialogue, may confirm the conversational functions of eyebrow raising in English. Perhaps certain eyebrow raises and other movements, such as head movements, would be found to derive from the same speech production system as other linguistic phenomena. Apart from its relevance for psycholinguistic theories of speech production, this type of research has applications in the area of multimodal dialogue systems. If we can determine when these movements occur in natural interactions, we could provide important guidelines for the design of embodied conversational agents that are hampered by poor coordination between the speech and the movements of the animated agent.

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