Title: AUDIOVISUAL PROSODY AND FEELING OF KNOWING

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Abstract

This paper describes two experiments on the role of audiovisual prosody for signalling and detecting meta-cognitive information in question answering. The first study consists of an experiment in which participants are asked factual questions in a conversational setting, while they are being filmed. Statistical analyses bring to light that the speakers' Feeling of Knowing (FOK) is cued by a number of visual and verbal properties. It appears that answers tend to have a higher number of marked auditory and visual cues, including divergences of the neutral facial expression, when the FOK score is low, while the reverse is true for non-answers. The second study is a perception experiment, in which a selection of the utterances from the first study is presented to participants in one of three conditions: vision only, sound only or vision+sound. Results reveal that human observers can reliably distinguish high FOK responses from low FOK responses in all three conditions, be it that answers are easier than non-answers, and that a bimodal presentation of the stimuli is easier than the unimodal counterparts.

Keywords: question answering, feeling of knowing, feeling of another's knowing, tip of the tongue, audiovisual prosody, facial expressions, speech production, speech perception.

Speakers are not always equally confident about or committed to what they are saying. When asked a question, for instance, they can be certain or rather doubtful about the correctness of their answer, and they may be unable to respond at all, even though in some cases it might feel as if the answer lies on the tip of the tongue. It has been shown that such meta-cognitive differences are reflected in the way speakers 'package' their utterances prosodically (Smith & Clark 1993, Brennan & Williams 1995), where *prosody* can broadly be defined as the whole gamut of features that do not determine *what* speakers say, but rather *how* they say it (Bolinger 1985, Cruttenden 1986, Ladd 1996). The prosodic cues may be helpful to addressees, because they can use them to determine whether or not they should interpret incoming sentences with a grain of salt. Sofar, research has focussed primarily on analyses of verbal features, such as particular intonation patterns, that are encoded in the speech signal itself. *Visual* cues, such as a wide range of gaze patterns, gestures, and facial expressions, are a natural and important ingredient of communication as well. It seems a reasonable hypothesis that these might be informative for addressees as well, just as verbal features are, though this issue is largely unexplored. The current paper tries to fill this gap by looking at possible signals of meta-cognitive speaker states on the basis of combinations of verbal and visual features, for which we will use the term *audiovisual prosody* (following e.g. Barkhuysen et al. 2005, Krahmer & Swerts 2004, Munhall et al 2004, Srinivasan & Massaro 2003). Since our work builds on insights of past studies of memory processes in question answering situations (e.g., Smith & Clark 1993, Brennan & Williams 1995), we first discuss such prior work in more detail.

In traditional models of memory, answering factual questions (e.g., "Who wrote Hamlet?") proceeds as follows: when asked a question, a person searches for the answer in memory. If the answer is found, it will be produced, else the person signals search failure by providing a non-answer such as "I don't know." A major deficit of such simple models is that they leave unspecified for how long a person should search for an answer and what triggers the decision to produce a non-answer. For these reasons current models of memory often supplement the *searching component* with a meta-cognitive *monitoring component*, which continuously assesses a person's knowledge. For each potential answer that the searching component retrieves, the monitoring component estimates the confidence in the answer's correctness. If the confidence is high enough, the answer can be produced. If not, the search component can look for more confident answers, provided the meta-memory assessment indicates that a proper answer may still be found (see e.g., Andersen 1999, Koriat 1993, Nelson 1996).

Smith and Clark (1993) emphasize that in a conversational, every day setting, question answering is a social process, which involves *information exchange* as well as *self-presentation*. To account for this, Smith and Clark point out that a further component should be added to a model for question answering, namely a *responding component*, which uses the output of both search *and* monitoring to provide feedback to the questioner. For instance, when a person responds to a question with an answer that has a relatively low confidence score, the person can signal this uncertainty in his or her response; if the answer would turn out to be incorrect later on, the speaker might save face and look less foolish since it was suggested that there was little confidence in the response (Goffman 1967). Smith and Clark (1993) note that signalling uncertainty of an answer can be done, for instance, via explicit commentary, using linguistic *hedges* such as "I guess" or "perhaps", or, more implicitly, by using a rising, question-like intonation (e.g., Bolinger 1985, Morgan 1952). Similarly, speakers may want to account for delays using fillers such as "uh" or "uhm" (e.g., Clark & Fox Tree 2002), when the search has not resulted in an answer yet, even though the meta-memory assessment indicates that an acceptable answer may still be found after a prolonged search.

The resulting 3-fold model of question answering (searching, monitoring and responding) yields a number of testable predictions: if a speaker finds a question difficult, this will result in a longer delay and correspondingly more fillers; and this will also result in more 'marked' answer behavior (hedges, and paralinguistic cues such as rising intonation and fillers). To test these predictions, Smith and Clark (1993) use Hart's (1965) experimental method, a common technique to elicit meta-memory judgements. In this method participants are first asked a series of factual questions in a conversational setting. Then they are asked to rate for each question their feeling that they would recognize the correct answer (i.e., their *Feeling of Knowing* (FOK)). Finally participants take the actual recognition test, i.e., a multiple-choice test in which all the original questions are presented once more. The interesting thing is that this method provides a handle on the Tip of the Tongue (TOT) phenomenon where a speaker is unable to produce an answer, but has the "feeling of knowing" it, perhaps because there was partial access to related information or because the question (cue) seemed familiar (e.g., Koriat 1993, Reder and Ritter 1992). Using this paradigm, Smith & Clark (1993) found that there was a significant difference between two types of responses, answers and non-answers: the lower a speaker's FOK, the slower the answers, but the faster the non-answers. In addition, the lower the FOK, the more often people answered with rising intonation, and added fillers, explicit linguistic hedges and other face-saving comments. It is worth noting that high FOK answers and low FOK non-answers are similar in that both express some form of speaker certainty: in the case of a high FOK answer the speaker is relatively certain of the answer, while a low FOK non-answer indicates that the speaker is relatively certain that he or she does not know the answer. In both cases, the speaker will not embark on a longer memory search, and the reply will tend to contain few paralinguistic cues.

The question naturally arises whether other people can reliably determine the FOK of a speaker. To test this, Brennan and Williams (1996) first performed an experiment which replicated Smith and Clark's earlier findings, and subsequently made a selection of the speakers' responses which were presented to listeners. These were tested on their *Feeling of Another's Knowing* (FOAK) to see if meta-cognitive information was reliably conveyed by the surface form of responses. The results for answers showed that rising intonation and longer latencies led to lower FOAK scores, whereas for non-answers longer latencies led to higher FOAK scores. Brennan and Williams (1996) conclude that listeners can indeed interpret the meta-cognitive information that speakers display about their states of knowledge in question answering.

Even though they stress the interactive and social nature of question answering, both Smith and Clark (1993) and Brennan and Williams (1996) are only concerned with linguistic and prosodic cues to meta-cognition. Arguably, the speaker cues for meta-cognition that they consider in their respective studies are obvious ones, but they are not fully representative of the richness of face-to-face communication, in which gestures and facial expressions play important roles as well. The only study we are aware of in which FOAK judgements were made by people that could actually *see* respondents answering questions is Jameson et al. (1993), but in that study the respondents had to *type* their answers and were not allowed to speak.

There is ample evidence that visual information is a crucial element of face-to-face conversation. Various studies have shown that visual information is beneficial for the understandability of speech (e.g., Jordan & Sergeant 2000, Sumby & Pollack 1954). During face-to-face communication, people pay a lot of attention to gestures (e.g., Kendon 1994, Krauss et al. 1996, McNeill 1992) and facial expressions such as nodding, smiling, and gazing (e.g., Clark and Krych 2004). In these cases the contribution of visual information is primarily *conversational*: they help structure the interaction, for instance by facilitating turn taking, or they support/supplement the information a speaker wants to convey. However, a number of recent studies also link gestures and other non-verbal behaviors more directly to meta-cognitive processes (e.g., Frick-Horbury 2002, Lawrence et al. 2001, Morsella & Krauss 2004). Morsella and Krauss (2004), for instance, explicitly relate the use of gestures to the TOT phenomenon. They point out that mental representations are transient and that retrieving them is effortful (Farah 2000, cf. also Kikyo et al. 2002). As a result, holding them in mind for lengthy intervals (as can occur during question answering) may be difficult; gestures, they argue, facilitate speech production more directly, since they continuously activate the prelinguistic sensorimotor features that are part of semantic representations of target words (Morsella & Krauss 2004 refer to this as the *Gestural Feedback Model*.) Besides gestures, facial cues can be indicative of meta-cognitive processes as well. Goodwin and Goodwin (1986) (see also Clark, 1996) already discussed the communicative relevance of the so-called “thinking face”: it often happens that, during search, a respondent turns away from the questioner with a distant look in the eyes in a stereotypical facial gesture of someone thinking hard. In a similar vein, it has been argued that gaze may be indicative of memory processes (e.g., Glenberg et al. 1998).

Given such earlier work which suggests that visual information may be a cue for meta-cognition, it is interesting to see whether speakers produce visual cues correlating with their feeling of knowing and whether such cues can be perceived by others and used to estimate the feeling of another's knowing. Additionally, an audiovisual study of meta-cognitive information is relevant from the view point of *multisensory perception*. In this field of research, one open question is what the relative contributions are of visual and auditory cues in audiovisual perception and how the two groups of cues interact. On the basis of earlier studies, it can be conjectured that the relative importance of auditory and visual cues differs for different aspects of communication. *Information presentation*, for instance, is traditionally studied from an auditory perspective. At the basic level of understandability the acoustic signal usually provides sufficient information (see e.g., Kohlrausch and van de Par 2005). Visual information tends to influence understandability in, for instance, adverse acoustical conditions (e.g., Benoît et al. 1996, Jordan & Sergeant 2000, Sumby & Pollack 1954) or in the case of incongruencies (as in the well-known *McGurk effect*, where an auditory /ba/ combined with a visual /ga/ is perceived as /da/ by most subjects, McGurk and MacDonald 1976). At the level of prosody a similar dominance of auditory cues can be observed. For instance, a number of prosodic studies that focussed on audiovisual signalling of prominence (indicating which words in an utterance are important) found that, even though facial cues such as head nods and eyebrow movements contribute to perceived prominence, the auditory cues (i.e., pitch accents) dominate (e.g, Keating et al. 2004, Krahmer and Swerts 2004, Swerts and Krahmer 2004). In general, the vast majority of studies have concentrated on verbal prosody, while only recently an interest in audiovisual prosody seems to emerge. When looking at *emotion*, on the other hand, it appears that visual cues (in particular facial expressions) are judged to be more important than auditory cues such as voice information (e.g., Bugenthal et al. 1970, Hess et al. 1988. Mehrabian and Ferris 1967, Walker & Grolnick 1983), and it may be noted that emotion research initially focussed on facial perception (see for instance the work of Paul Ekman and colleagues, e.g., Ekman 1999). Interestingly, various more recent studies have shown that both modalities influence emotion perception of incongruent stimuli, where the visual channel may offer one emotion ('happy') and the auditory channel another ('sad') (e.g., de Gelder & Vroomen 2000, Massaro & Egan 1996). Meta-cognitive information during question answering is an interesting candidate to investigate from this audiovisual perspective, since it shares some characteristics with both emotion (in that it reflects a speakers' internal state) and with information presentation (in the meta-cognitive signalling in the actual response).

In this paper, we describe two experiments which study the role of audiovisual prosody for the production and perception of meta-cognitive information in question answering. We will be particularly interested in combinations of auditory cues (rising intonation, fillers and unfilled pauses) with visual cues (such as gaze, eyebrow movements, and smiles). For Experiment 1, we use Hart's (1965) paradigm to elicit answers and non-answers with different FOK scores, which we then analyze in terms of a number of audiovisual prosodic features. The study by Brennan and Williams (1995) focused on auditory cues alone, while the goal of Experiment 2 is to explore whether observers of speakers' responses (collected in experiment 1) are able to guess these speakers' FOK scores on the basis of visual cues as well. In particular, we are interested in whether a bimodal presentation of stimuli leads to better FOK predictions than the unimodal components in isolation. While we expect that we get the best performance for bimodal stimuli, it is an interesting empirical question whether the auditory or the visual features from the unimodal stimuli are more informative for FOK predictions.

Experiment 1

Method

Participants

Twenty participants (11 male, 9 female), colleagues and students from Tilburg University, between 20 and 50 years old, participated as speakers in the experiment on a voluntary basis. None of the participants objected to being recorded, and all granted usage of their data for research and educational purposes.

Materials

The materials consisted of a series of factual questions, taken in part from a Dutch version of the "Wechsler Adult Intelligence Scale" (WAIS), an intelligence test for adults. We selected only those questions which would trigger a one-word response (e.g., Who wrote Hamlet? What is the capital of Switzerland?), and added a supplementary list of questions from the game Trivial Pursuit. The 40 questions in total covered a wide range of topics, like literature, sports, history etc. The list of questions was presented to participants in one of two random orders (see the appendix).

Procedure

Following Smith & Clark (1993), the experimental procedure consisted of three stages. In the first stage, the 40 questions were posed by the experimenter, and the responses by the participant were filmed (front view of head). As in Smith & Clark (1993), participants could not see the experimenter and they were told that this was to avoid the participants from picking up any potential cues the experimenter might give about the correctness of their answers. Participants were told that the experimenter could see them via the digital camera, which was connected to a monitor behind a screen. The experimenter asked the series of 40 questions one by one, and the pace of the experiment was determined by the participant. As an example, here are 5 responses (translated from Dutch) to the question about the name of the person who drew the pictures in “Jip en Janneke”, a famous Dutch book for children written by Annie M.G. Schmidt:

(a.) Fiep Westendorp

(b.) uh Fiep Westen-(short pause)-dorp

(c.) (short pause) Isn’t that Annie M.G. Schmidt?

(d.) no idea

(e.) uh the writer is Fiep Westendorp, but the drawings? No, I don’t know

The example shows cases of correct answers, which could be fluent (a) or hesitant (b), an incorrect answer (c), and a simple (d) and complex (e) case of a non-answer.

In the second stage, the same sequence of questions was again presented to the same participants, but now they had to express on a 7-point scale how sure they were that they would recognize the correct answer if they would have to find it in a multiple-choice test, with 7 meaning “definitely yes” and 1 “absolutely not”. The third stage was a paper-and-pencil test in which the same sequence of questions was now presented in a multiple-choice in which the correct answer was mixed with three plausible alternatives. For instance, the question “What is the capital of Switzerland?” listed Bern (correct) with three other large Swiss cities: Zürich, Genève and Basel.

Participants were unaware of the real purpose of the study, but were told that its goal was to learn more about the average complexity of a series of questions which could be used in future psycholinguistic research. They were warned beforehand that questions were expected to vary in degree of difficulty. In order to encourage them to do their best and guess the correct answer in case of uncertainty, the experiment incorporated an element of competition, where the ‘winner’ (i.e., the person with the highest number of correct answers in the first test) got a small reward (a book token).

Labelling, annotation

All utterances from the first test (800 in total) were transcribed orthographically and manually labelled regarding a number of auditory and visual features by four independent transcribers. The labelling was based on perceptual judgements and features were only marked when clearly present.

Regarding verbal cues, we labelled the presence or absence of the following features:

Delay Whether a speaker responded immediately, or took some time to respond.

High intonation Whether a speaker's utterance ended in a high or a low boundary tone.

Fillers Whether the utterance contained one or more fillers, or whether these were absent.

For simplicity's sake, all three verbal features were treated in a binary way. A clearly perceivable pause before speaking was labelled as a delay while an immediate response was not. We did not measure precise delay durations as Smith and Clark (1993) and Brennan and Williams (1996) did. Concerning high intonation, note that we did not attempt to isolate question intonation, as it turned out to be difficult to consistently differentiate 'real' question intonation from list intonation. Finally, for the labelling of fillers we did not differentiate between 'uh', 'uhm' or 'mm', since the results of the perception study of Brennan & Williams (1995) only revealed minor differences between them.

In addition to these categorical variables, we counted the number of words spoken in the utterance, where family names, like Elvis Presley, were considered to be one word. This count provides a rough measure for the amount and length of linguistic hedges (such as "I guess") used by speakers, where we did not differentiate between the kind of explicit commentary used.

As to the visual cues, we labelled the presence or absence of the following features:

Eyebrow movement If one or more eyebrow movements departed from neutral position during the utterance.

Smile If the speaker smiled (even silently) during the response.

Low Gaze Whether a speaker looked downward during the response.

High Gaze Whether a speaker looked upward during the response.

Diverted Gaze Whether a speaker looked away from the camera (to the left or the right) during the response

Funny face Whether the speaker produced a marked facial expression, which diverted from a neutral expression, during the response.

Note that an utterance may contain multiple marked features. In addition to the isolated features mentioned above, we also counted the number of different **gaze acts**, i.e, combinations of high, low or diverted gaze. In the literature on facial expressions, the features gaze (Argyle and Cook 1976, Gale and Monk 2000, Griffin 2001, Glenberg et al. 1998), smiling (Kraut & Johnson 1979) and brow movements (Ekman 1979, Krahmer and Swerts 2004) are mentioned as informative cues in spoken interaction, and a first inspection of the recordings revealed that they occur relatively frequently in the current data set. The expression we, for want of a better term, called "funny face" can be seen as specific instance of Goodwin & Goodwin's (1986) thinking face, explicitly suggesting uncertainty. Figure 1 contains some representative stills for each of the visual features. The visual features are roughly comparable with Action Units (AUs) described by Ekman & Friesen (1978), though there is not necessarily a one-to-one mapping to these Action Units. The action units form the building blocks of Ekman & Friesen's *Facial Action Coding Systems* which builds on the assumption that facial actions can be described in terms of muscular action. The basic action units correspond with single muscle activities, and more complex facial expressions can be described using these atomic building blocks. Figure 1, in particular, displays examples of marked settings of smile (AU 12, AU 13), gaze (AU 61 to AU 64), and eyebrow raising (AU 1, AU 2). Funny faces typically consist of a combination of AUs such as lip corner depression (AU 15), lip stretching (AU 20) or lip pressing (AU 24), possibly combined with eye widening (AU 5) and eyebrow movement as well.

FIGURE 1 APPROXIMATELY HERE.

The labelling procedure was as follows. On the basis of a preliminary labelling protocol, utterances from two speakers were labeled collectively. For most cues the labelling was unproblematic, and for the few more difficult cases, mostly involving gaze, a consensus labelling was reached after discussion. This first phase resulted in an explicit labelling protocol with various double checks, after which the labellers proceeded individually by labelling a selection of the cues in the recordings from the remaining 18 speakers. Only the feature gaze was annotated by two persons who labelled the different gaze acts in an utterance (low, high, diverted) in isolation and resolved mismatches via discussion. All features were annotated independently from the FOK score to avoid circularity. Similarly, annotators only looked at answers without taking the question context into account, so that the answer's (in)correctness could not bias the annotator.

Statistical analyses

Our statistical procedure closely follows the ones proposed by Smith and Clark (1993) and Brennan and Williams (1995). We obtained 800 responses, 40 from each of the 20 participants. These responses are not independent so that analyses across the entire data set are inappropriate. Therefore, the following tests are always based on individual analyses per speaker. We computed correlation coefficients for each subject individually, transformed the correlations into Fischer's z_r scores, and tested the average z_r score against zero. The average z_r scores were then transformed back into correlations for reporting in this article. Similarly, when comparing means, we computed a mean for each speaker, and used these composite scores in our analyses. In any individual analysis, we did not include any participant for whom we could not compute an individual correlation or mean, so some of our statistics, as in Smith and Clark (1993), are based on a total n of less than 20. The ANOVA tests reported below compare both means for subjects, and for items.

Results

TABLE 1 APPROXIMATELY HERE.

It appeared that the participants found a majority of the questions very easy, as they gave a maximum FOK score of 7 to 61.1% of the questions, a score of 6 to 13.4% of the questions, and lower scores to the remaining 25.5%. In addition, 71.9% of the questions of the first task were indeed answered correctly and 89.6% of the same list of questions in the multiple-choice test. Table 1 lists the average FOK scores as a function of Question Type (open question versus multiple choice), and the response categories (correct answers, incorrect answers, non-answers).

Speakers' mean FOK ratings were higher when they were able to produce an answer than when they were not (with subjects as random factor, $F1_{(1,17)} = 71.821, p < .001$; with items as random factor, $F2_{(1,23)} = 59.028, p < .001$). The mean FOK ratings were higher for correctly recalled answers than for the incorrect ones ($F1_{(1,19)} = 149.233, p < .001$; $F2_{(1,35)} = 38.086, p < .001$). Speakers also gave higher FOK ratings on average for responses that they later recognized in the multiple choice test ($F1_{(1,18)} = 55.018, p < .001$; $F2_{(1,27)} = 19.714, p < .001$). These data thus show that there is a close correspondence between the FOK scores and the correctness or incorrectness of a response in both the open test and the multiple-choice. The results are similar to those of Smith and Clark (1993) and Brennan and Williams (1995).

TABLE 2 APPROXIMATELY HERE.

In general, it can be observed that participants differ in the extent to which they use different audiovisual features, but these differences do not appear to relate to age or sex of the participants. Table 2 lists the correlation coefficients between the FOK scores and number of words, gaze acts (defined as the sum of low, high and diverted gaze) and marked features (defined as the sum of all features minus words and gaze). It can be seen that there are negative correlations between the FOK scores and these variables for answers, and positive correlations for non-answers. In other words, for answers, higher FOK scores correspond with a lower number of words, gaze acts and marked features, and the opposite relation holds for non-answers, where higher FOK scores correspond with more words, more gaze acts and more marked features.

TABLES 3 AND 4 APPROXIMATELY HERE.

An analogous picture emerges from tables 3 and 4, which give the average FOK scores for presence versus absence of audiovisual features for answers and non-answers, respectively. Table 3 shows that the presence of a verbal feature (filler, delay or high intonation) coincides with a significantly lower FOK score. And similarly for the visual features, where the presence of an eyebrow movement, a smile, a gaze act (high, low and diverted) or a funny face generally is associated with a lower FOK score, which is significant in all cases except for the smile. As expected, the results in Table 4 display the opposite pattern. When a verbal feature is present in a non-answer this corresponds to a significantly *higher* FOK score for filler and delay. Looking at the visual cues, it can be seen that the presence of a marked feature setting is associated with a higher FOK score as well, albeit that the differences are only significant for low and high gaze, partly because the limited number of data points here (reflected by the lower n figures for non-answers). Moreover, non-answers are perhaps inherently less likely to be associated with a high intonation, presumably because speakers do not need to question their own internal state (see e.g., Geluykens 1987), which is reflected in a difference score of only 0.01.

FIGURE 2 APPROXIMATELY HERE.

In order to learn more about the cue value of combinations of features, we also calculated, for answers and non-answers separately, the average FOK scores for responses that differ regarding the number of marked feature settings (minimum: 0, maximum: 7). Note that the theoretical possibility of an utterance containing 8 or 9 marked feature settings did not occur in our data set. The results of this are visualized in Figure

2, which again illustrates opposite trends for the two response categories: for answers, the average FOK score decreases with an increasing number of marked features, while the opposite is true for non-answers (cf. also the last row of Table 2).

TABLE 5 APPROXIMATELY HERE.

Table 5 lists the distribution (in percentages) of cases with a marked setting for our different auditory and visual features as a function of the relative number of marked features present (1 till 7). First, looking at the n values in the left column, this table reveals that there are considerable differences in relative frequency between the different features: the different gaze acts (low, high and especially diverted) and high intonation occur very often, as opposed to the features smile and funny face which are more rarely used. But, in addition, the table also makes it clear that some features can relatively more often be used in isolation or with only one more other feature present (like, low gaze, smile and high intonation), whereas features like funny face and especially delay tend to co-occur with a high number of marked settings for other features.

Discussion

This first study has replicated some of the findings of the research by Smith and Clark (1993), and extended them into the visual domain. It was found that our participants' FOK scores correspond with their performance in the open question and multiple-choice test, and, in addition, particular audiovisual surface forms of the utterances produced by our speakers are indicative of the amount of confidence speakers have about the correctness of their response. For answers, lower scores correlate with occurrences of long delay, fillers and high intonation, as well as a number of gaze features, eyebrow movements, funny faces and smile. In addition, speakers tend to use more words and more gaze acts, when they have a lower FOK. For non-answers, the relationship between FOK scores and the different audiovisual features is the mirror image of the outcome with answers, which is as expected given that both high FOK answers and low FOK non-answers correspond to speaker certainty. If we compare the average

FOK scores with the frequency of occurrence for the various marked settings of audiovisual features, it can be seen that the presence or absence of some highly frequent features such as diverted gaze and high intonation has a relatively small impact on the average FOK score, while this effect is substantial for an infrequent feature such as funny face (especially for answers).

The first study was a speaker-oriented approach to gain insight into audiovisual correlates of FOK. While our analyses revealed that there was a statistical relationship between the two, this in itself does not prove that the audiovisual properties also have communicative relevance. In order to prove this, we performed a perception study, for which we used earlier work by Brennan and Williams (1995) as our main source of inspiration.

Experiment 2

Method

Participants

Participants were 120 native speakers of Dutch, students from the University of Tilburg, none of whom had participated as speaker in the first experiment.

Materials

From the original 800 responses, we selected 60 utterances, of which 30 were answers and 30 non-answers. Of both the answers and the non-answers, 15 had high FOK and 15 low FOK scores. Following Brennan and Williams (1996), only the answer of a question-answer pair was presented to participants, to avoid that participants would unconsciously use their own estimation of the question's difficulty in their perception of the answer. The selection was based on written transcriptions of the responses by someone who had not heard or seen the original responses. Given the individual differences in the use of the FOK scale, we chose to use —per speaker— the two highest scores as instantiations of high FOK scores and the two lowest as low FOK scores. The (in)correctness of the answer was not taken into account when selecting the stimuli, hence both high FOK and low FOK answers could be incorrect. We initially made a random selection of stimuli meeting these restrictions, but utterances were iteratively replaced until the following criteria were met:

1. The original question posed by the experimenter should not appear again in the participants' response.
2. All the answers should be lexically distinct, and should thus not occur twice. This criterion was not applied to the non-answers as they were very similar.
3. The responses should be maximally distributed across speakers. There should be maximally two answers and two non-answers per speaker.

Having applied this procedure on the basis of written transcriptions of the data, we finally replaced a couple of stimuli by others, if the signal-to-noise ratio made them unsuitable for the perception experiment.

Procedure

The selected stimuli were presented to participants in three different conditions as a group experiment: one third of the participants saw the original clips as they were recorded (Vision+Sound), another third saw the same clips but then without the sound (Vision), whereas the last third could only hear the utterances without seeing the image (Sound). In all three conditions, stimuli were presented on a large cinema-like screen with loudspeakers to the right and left over which the sound was played in the Vision+Sound and Sound condition. Both the visual and the auditory information were clearly perceptible for participants. Participants in each condition were first presented with the stimulus ID (1 through 30) followed by the actual stimulus. In case of the sound only stimuli, participants saw a black screen instead of the original video recording. The motivation to present sound-only stimuli also visually, was to make sure that participants were aware of the start of the utterance, in case there was a silent pause in the beginning of the utterance. The interstimulus interval was 3 seconds. Within a condition, participants had to judge recordings in two separate sessions, one with answers as stimuli and one with non-answers. The question to the participants about the answers was whether a person appeared “very uncertain” (1) or “very certain” (7) in his/her response. The question for the non-answer stimuli was whether participants thought the person would recognize the correct answer in a multiple-choice test, with 1 meaning “definitely not” and 7 “definitely yes”. Below, the scores are referred to as the Feeling of Another’s Knowing (FOAK) scores. Each part of the experiment was preceded by a short exercise session with 2 answers and 2 non-answers respectively to make participants acquainted with the kinds of stimulus materials and the procedure.

Statistical analyses

The participants’ responses were statistically tested with a repeated measures ANOVA with the FOAK scores as dependent variable, with original FOK scores and response type as within-subjects factors, and cue modality (Vision, Sound, Vision+Sound) as between-subjects factor. Pairwise comparisons were made with the Tukey HSD method.

Results

TABLE 6 APPROXIMATELY HERE.

Table 6 shows that there were significant effects on the participants’ FOAK scores of original FOK status of the utterance (high FOK utterances receive higher FOAK scores than low FOK utterances) and of response category (answers receive higher FOAK scores than non-answers), while there was no main effect of the cue modality (Vision, Sound, Vision+Sound). However, there were significant 2-way interactions between FOK and cue modality ($F_{(2,117)} = 54.451, p < .001$) and between response and cue modality ($F_{(1,117)} = 241.597, p < .001$), and a significant 3-way interaction between FOK, cue modality and response ($F_{(2,117)} = 3.291, p < .05$). Split analyses showed that these main effects and interactions also hold when looking at the three cue modalities separately. For all cue modalities the difference in FOAK score between high FOK and low FOK utterances was significant (Vision: $F_{(1,39)} = 270.070, p < .001$; Sound: $F_{(1,39)} = 957.515, p < .001$; Vision+Sound: $F_{(1,39)} = 1516.617, p < .001$), and similarly for response category (Vision: $F_{(1,39)} = 16.629, p < .001$; Sound: $F_{(1,39)} = 29.090, p < .001$; Vision+Sound: $F_{(1,39)} = 54.977, p < .001$). There was always a significant interaction between FOK status and response category (Vision: $F_{(1,39)} = 79.179, p < .001$; Sound: $F_{(1,39)} = 41.307, p < .001$; Vision+Sound: $F_{(1,39)} = 161.703, p < .001$).

TABLES 7 AND 8 APPROXIMATELY HERE.

The 2-way interactions can easily be understood when we look at the average scores for combinations of FOK and cue modality, and response and cue modality (see Tables 7 and 8, respectively). The first table shows that the difference in scores for low and high FOK scores is more extreme in the Vision+Sound condition, than in the unimodal conditions, meaning that the participants' ratings were more accurate when participants had access to both sound and vision. Notice that this explains why no main effect of experimental condition was found: the differences in FOAK scores between high FOK and low FOK stimuli change, while the overall FOAK averages stay the same (see Table 6). The second table shows that the difference between high and low FOK scores is —as expected— easier to perceive in answers than in non-answers. A separate analysis of variance revealed that the differences between FOAK scores for high FOK and low FOK stimuli were significantly different for the different cue modalities ($F_{(2,237)} = 46.248, p < .001$). Post hoc pairwise comparisons using Tukey HSD tests showed that the differences in FOAK ratings between high FOK and low FOK stimuli for a given cue modality was significantly different from the differences in ratings for any of the other two cue modalities.

Discussion

The results of the second perception test are consistent with the findings of the first analysis of speaker's expression of uncertainty. It appears that participants are able to differentiate low FOK responses from high FOK responses in the unimodal experimental conditions, but they clearly performed most accurately in a bimodal condition. This suggests that the addition of visual information, which was not present in the aforementioned FOK and FOAK studies, is beneficial for detecting uncertainty. While we had seen that answers and non-answers exhibit opposite audiovisual features, human participants are able to adapt their judgments: they are able to tell the difference between low and high FOK for both response categories, be it that the performance for non-answers drops compared to answers, in line with previous observations of Brennan and Williams (1995). In conclusion, this study brought to light that the audiovisual features of our original utterances have communicative relevance as they can be interpreted by listeners as cues of a speakers' level of confidence.

Since only high and low FOK stimuli were used in experiment 2, it would be interesting to see whether the FOAK effect persists for middle range FOK stimuli. We hypothesize that participants would indeed note that speakers are relatively uncertain when uttering a medium FOK answer, since, generally, a lower FOK answer corresponds to more audiovisual marked cues (cf. Figure 2), but *how* uncertain remains an open question. Additionally, the current experiment is a judgement study in which participants are specifically asked to rate the perceived FOK of a speaker's utterance. It would be interesting to see if and how people actually *use* audiovisual prosody as a cue for FOK during natural conversations. We conjecture that such cues will also be picked up and interpreted correctly during 'on line' communication, and hope to address this in future research.

General discussion

In response to a question, speakers are not always equally confident about the correctness of their answer. It has been shown that speakers may signal this using verbal prosody (Brennan & Williams 1995, Smith & Clark 1993). For instance, a response to the question “Who wrote Hamlet?” might be “[pause] uh Shakespeare?”, where the delay signals a prolonged memory search, and the filler and the high (question-like) intonation both signal relatively low confidence from the meta-cognitive monitoring component.

In this paper we have described two experiments which extend these observations into the visual domain, showing that there are clear visual cues for a speaker’s feeling of knowing and that listeners are better capable to estimate their feeling of another’s knowing on the basis of combined auditory and visual information than on the basis of auditory information alone. In the first experiment we used Hart’s (1965) paradigm to elicit speaker utterances plus their accompanying FOK scores. The data collected in this way were analysed in terms of a number of audiovisual cues. This analysis confirmed earlier work by Smith and Clark (1993) and Brennan and Williams (1996) in that low FOK answers are typically longer than high FOK answers, and tend to contain more marked auditory cues (fillers, longer delay, high intonation). Interestingly, we found that the visual features show a comparable pattern. Focussing first on answers, we found that marked facial expressions (diverging from the ‘neutral’ face) such as smiles, gaze acts, eyebrow movements and ‘funny faces’ are more likely to occur in low than in high FOK answers. In general, when a speaker gives a high FOK answer to a question, this response is produced in a straightforward way, and marked audiovisual cues are not produced. When a speaker is uncertain of the answer or has difficulty retrieving it, however, various things may happen in parallel; low FOK answers tend to require a longer search, which may trigger a filler, but may also be accompanied by various gaze acts. Both fillers and gaze acts tend to occur during memory search, before the actual answer is uttered. The gazing might partly be explainable from the common observation that it is easier to ‘think’ when not looking at a communication partner. We found that gazing typically occurred in various directions both along the left-right and up-down axis; in these data no single gaze act appeared to fulfil a designated function. That a speaker is uncertain about the correctness of a retrieved answer can be indicated auditorily, via a rising, question-like intonation, but also visually, for instance by raising the eyebrows (which has been interpreted as the visual counterpart to a rising intonation, see e.g., Bolinger 1985). Similarly, the presence of a 'funny face' (often, but not always, timed immediately after the answer has been uttered) was also typically associated with a lower FOK score, clearly functioning as a cue for speaker uncertainty. Smiles, however, appeared to be more ambiguous in this respect as some of our speakers smiled when they were asked an 'easy' answer for which they had no difficulty retrieving the answer, while others smiled in response to questions they considered 'extremely' difficult or for which they felt they *should* know the answer.

The earlier studies by Smith and Clark (1993) and Brennan and Williams (1996) revealed an asymmetry between answers and non-answers in that low FOK answers look similar to high FOK non-answers (in both cases the speaker is uncertain on a meta-cognitive level) and that high FOK answers look similar to low FOK non-answers, both in prosodic terms (in both cases the speaker is certain). The current experiment confirmed this asymmetry, and extended it into the visual realm. Thus, the presence of smiles, brow movements, gaze acts and a funny face is less likely for high FOK answers and for low FOK non-answers. Data sparseness presumably resulted in less significant effects for the non-answers than for the answers (in addition, non-answers are lexically more similar than answers and are perhaps inherently less likely to end on a high boundary tone).

In the second experiment, participants watched speaker utterances in one of three conditions (Sound only, Vision only, Vision+Sound) and had to judge the speaker's FOK. It turned out that overall participants are good at estimating the FOK of other speakers, where the resulting FOAK scores are somewhat more accurate for answers (high FOK answers receive high FOAK scores and low FOK answers receive low FOAK scores) than for non-answers. Interestingly, FOAK judgments are significantly more accurate in the bimodal (Vision+Sound) condition than in the respective unimodal ones. This indicates that the presence of visual information is actually beneficial for FOAK judges. If we compare the results for the Sound only and the Vision only experiment, it appears that overall subjects made better use of auditory than of visual cues for the perception of uncertainty. However, it should be noted that visual expressions such as funny faces and eyebrow movements occurred relatively infrequently in the second experiment, but when they did occur they seem to offer a very strong cue for FOAK estimations. Based on this observation we recently performed an additional perception experiment, only consisting of incongruent stimuli combining low FOK facial expressions (funny faces) with high FOK speech prosody and vice versa. Participants were asked how certain the speaker appeared in his or her response. The results indicate that for these incongruent stimuli the facial expression in most cases has the largest impact on the FOAK score.

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Appendix

English translations of the Dutch questions used in the first experiment, as they were presented to participants in one of the two random orders.

1. How does one call the sticks used in golf?
2. Who made the drawings for “Jip and Janneke”?
3. The sahara lies in which continent?
4. Which novel about a knight is the most reprinted book after the Bible?
5. How many months does it take the moon to circle the earth?
6. What does the abbreviation ‘Fl’ for the Dutch guilder stand for?
7. What is the largest mammal?
8. What is the name of the gang of robbers that terrorized Limburg in the 18th century?
9. Who, according to legend, was the bishop of Myra?
10. In which Dutch quiz show are the contestants awarded with a toy monkey for each good answer?
11. What is the highest mountain of the Alps?
12. Who wrote Faust?
13. What is the chemical symbol of water?
14. What does the word ‘Jihad’ mean?
15. What color of light is used on the starboard side of a boat?
16. What is Rembrandt’s last name?

17. Which television series is about the Forrester and Spectra families?

18. Guide Gezelle was a famous man. What was his occupation?

19. What is the boiling temperature for water?

20. In which wind-direction does one travel from Amsterdam to Brussel?

21. What is the name of the cartoon character who owns the dog Pluto?

22. Egypt lies in which continent?

23. Who is the head of state of the Vatican?

24. Who wrote “The discovery of heaven”?

25. What is a “Friese doorloper”?

26. Brazil lies in which continent?

27. What is the pseudonym of the Mexican Don Diego de la Vega?

28. Who wrote Hamlet?

29. Which rocker is also known as “The King”?

30. How many darts is a player allowed to throw in one turn?

31. In which wind-direction does one travel from London to Berlin?

32. Which disease was known during the Middle Ages as “The Black Death”?

33. What is the capital of Switzerland?

34. Supporters of which football club sing “Geen woorden maar daden”?

35. How many degrees are in a circle?

36. Approximately, how many people live in the Netherlands and Belgium?

37. In which country did the Inca’s live?

38. Which person from the Bible went to look for mustard?

39. Which Dutch soap series has been running on television for the longest period?

40. Who wrote the Iliad?

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Table 1: *Average FOK scores (and standard deviations) for different response categories.*

Experiment	Response	FOK
Open Question	All answers (n=704)	6.32 (1.27)
	Correct Answers (n=575)	6.55 (1.00)
	Incorrect Answers (n=129)	5.29 (1.72)
	All Nonanswers (n=96)	3.03 (2.12)
Multiple Choice	Correct Answers (n=717)	6.17 (1.53)
	Incorrect Answers (n=83)	3.84 (2.18)

Table 2: *Pearson correlation coefficients of FOK scores with number of words, gaze acts and marked features. The n indicates for how many participants an individual correlation could be computed.*

Correlations of FOK scores with	Response	
	Answers ($n = 20$)	Non-answers ($n = 13$)
Words	–.265***	.695***
Gaze acts	–.325***	.630***
Marked features	–.410***	.690***

*** $p < .001$

Table 3: *Average FOK scores (and standard deviations) for answers as a function of presence or absence of audiovisual features. Statistics are based on paired T-test analyses. The* n *indicates the number of participants for which individual means could be computed. The Diff. score is obtained by subtracting the average Absent FOK score from the average Present FOK score.*

		Present (1)	Absent (2)	Diff. (1)-(2)
Auditory	Filler ($n = 19$)	5.70 (1.00)	6.53 (0.32)	–0.83***
	Delay ($n = 20$)	5.23 (0.80)	6.53 (0.27)	–1.30***
	High Intonation ($n = 19$)	5.91 (0.80)	6.40 (0.27)	–0.49*
Visual	Eyebrow ($n = 19$)	5.78 (0.87)	6.46 (0.26)	–0.69***
	Smile ($n = 17$)	5.69 (1.36)	6.36 (0.35)	–0.67
	Low gaze ($n = 20$)	6.05 (0.61)	6.47 (0.33)	–0.42**
	High gaze ($n = 19$)	5.72 (0.98)	6.52 (0.34)	–0.80***
	Diverted gaze ($n = 20$)	5.96 (0.57)	6.64 (0.38)	–0.68***
	Funny Face ($n = 10$)	4.78 (1.19)	6.38 (0.43)	–1.60**

* $p < .05$; ** $p < .01$; *** $p < .001$

Table 4: *Average FOK scores (and standard deviations) for non-answers as a function of presence or absence of a audiovisual features. Statistics are based on paired T-test analyses. The* n *indicates the number of participants for which individual means could be computed. The Diff. score is obtained by subtracting the average Absent FOK score from the average Present FOK score.*

		Present (1)	Absent (2)	Diff. (1)-(2)
Auditory	Filler ($n = 9$)	4.98 (2.05)	2.60 (1.20)	+2.38**
	Delay ($n = 12$)	4.21 (2.22)	2.20 (1.16)	+2.01*
	High Intonation ($n = 5$)	3.67 (1.70)	3.66 (1.21)	+0.01
Visual	Eyebrow ($n = 8$)	3.76 (1.99)	2.41 (0.92)	+1.35
	Smile ($n = 12$)	3.69 (2.33)	2.70 (1.13)	+0.99
	Low gaze ($n = 14$)	3.96 (2.05)	2.49 (1.21)	+1.47**
	High gaze ($n = 10$)	4.00 (1.75)	2.25 (1.50)	+1.75*
	Diverted gaze ($n = 9$)	3.43 (1.44)	2.79 (2.14)	+0.64
	Funny Face ($n = 4$)	3.75 (2.63)	2.85 (1.44)	+0.90

* $p < .05$; ** $p < .01$; *** $p < .001$

Table 5: *Percentage of marked settings for different audiovisual features as a function of the relative number of marked prosodic features. (minimum = 1, maximum = 7; combinations of 8 or more features do not occur.)*

		Number of marked feature settings						
		1	2	3	4	5	6	7
Auditory	Filler ($n = 191$)	6.3	15.7	18.8	17.8	18.8	13.6	8.9
	Delay ($n = 161$)	0.6	5.0	17.4	24.8	23.0	17.4	11.2
	High Intonation ($n = 232$)	13.8	20.7	25.0	15.5	10.8	8.2	5.6
Visual	Eyebrow ($n = 154$)	11.0	15.6	14.3	22.7	14.9	12.3	8.4
	Smile ($n = 98$)	15.3	17.3	10.2	17.3	17.3	14.3	7.1
	Low gaze ($n = 280$)	22.1	22.5	18.2	10.0	12.1	8.6	6.1
	High gaze ($n = 232$)	3.9	21.1	21.1	20.7	13.4	12.5	6.9
	Diverted gaze ($n = 409$)	12.5	24.9	20.5	17.4	12.0	8.1	4.4
	Funny Face ($n = 36$)	0	8.3	11.1	19.4	22.2	16.7	19.4

Table 6: *ANOVA results (main effects) for perception experiment: average FOAK scores as a function of FOK, response category and experimental condition.*

	Factor	Level	FOAK (std. error)	F-stats
Within Subjects	FOK	High	4.792 (0.035)	$F_{(1,117)} = 2229.886$,
		Low	2.646 (0.035)	$p < .0001$
	Response	Answer	3.922 (0.030)	$F_{(1,117)} = 90.477$,
		Non-answer	3.516 (0.038)	$p < .0001$
Between Subjects	Cue modality	Vision	3.779 (0.047)	$F_{(2,117)} = 1.424$,
		Sound	3.669 (0.047)	$p = .245$
		Vision+Sound	3.709 (0.047)	

Table 7: *FOAK scores (and std. errors) for high FOK and low FOK stimuli in different experimental conditions.*

Cue modality	high FOK (1)	low FOK (2)	Diff. (1)-(2)
Vision	4.434 (0.061)	2.903 (0.061)	1.531
Sound	4.890 (0.061)	2.668 (0.061)	2.222
Vision+Sound	5.052 (0.061)	2.367 (0.061)	2.685

Table 8: *FOAK scores (and std. errors) for high FOK and low FOK stimuli for answers and non-answers.*

Response	high FOK (1)	low FOK (2)	Diff. (1)-(2)
Answer	5.231 (0.044)	2.614 (0.035)	2.617
Non-answer	4.353 (0.045)	2.678 (0.051)	1.675

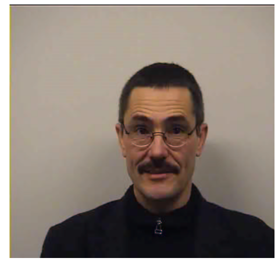
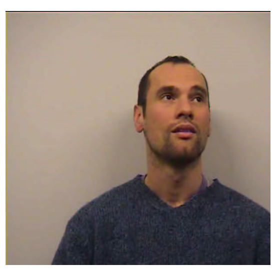
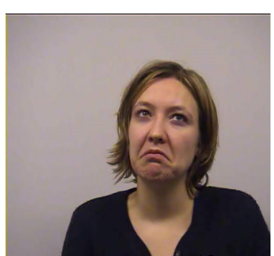
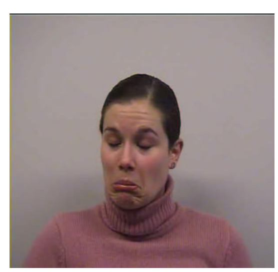
Label	Definition and example
Eyebrow movement	Speaker raises one or two eyebrows from neutral position
	 
Smile	Speaker produces a clearly visible smile or laugh
	 
Gaze	Speaker diverts eye gaze from its position at onset, relative to the position of the head
	 
Funny face	Speaker produces a marked facial expression
	 

Figure 1: *Stills illustrating a number of annotated visual features; the description and examples represent the marked settings for each feature.*

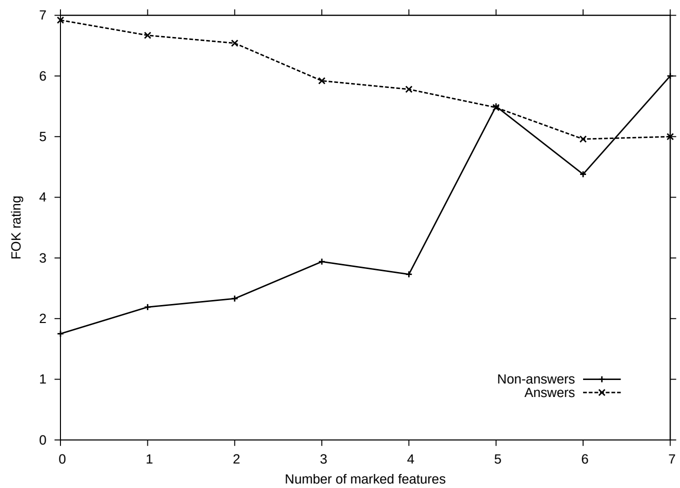


Figure 2: *Average FOK scores for answers and non-answers as a function of the relative number of marked prosodic features (minimum = 0, maximum = 7; combinations of 8 or more features do not occur.)*