Raising Eyebrows and Raising Pitch: How Non-Verbal Uncertainty Cues Influence Assessments of Probability Phrases

Imke Spapens "I.N.A.Spapens@tilburguniversity.edu"
Department of Communication and Cognition, Warandelaan 2, 5037 AB Tilburg

Ruben Vromans "R.D.Vromans@tilburguniversity.edu"
Department of Communication and Cognition, Warandelaan 2, 5037 AB Tilburg

Ruud Koolen "R.M.F.Koolen@tilburguniversity.edu"
Department of Communication and Cognition, Warandelaan 2, 5037 AB Tilburg

Marc Swerts "M.G.J.Swerts@tilburguniversity.edu"
Department of Communication and Cognition, Warandelaan 2, 5037 AB Tilburg

Abstract

In this pre-registered study, we examined how non-verbal uncertainty cues, such as intonation and facial expressions, influence perceived speaker certainty and the interpretation of verbal probability phrases (e.g., "almost never," "probably," "certain"). Prior research on such phrases has focused on written textual cues, whereas communication often includes auditory and visual signals. Using a 2x2 within-subjects experimental design (*N*=100), we found that both rising intonation and marked facial expressions independently reduced perceived speaker certainty. In most, but not all conditions, these cues led to greater variability in how participants assigned numerical values to verbal probability expressions (e.g., interpreting "likely" as anywhere from 10% to 85% likely). Notably, the combination of rising intonation and marked facial expressions produced the lowest perceived certainty, while there was no such additive effect on interpretation variability. These results highlight the importance of non-verbal cues in uncertainty communication, with implications for fields such as health, environmental, and technological risk communication.

Keywords: facial expression; intonation; non-verbal; probability; risk; uncertainty communication

Introduction

People often have to base their decisions on information they receive from others. To this end, they constantly assess the status of conveyed messages, that is, whether information is trustworthy or not. Yet, while much attention is devoted to conveying certainty and clarity in messaging (e.g., Bullock et al., 2019), less emphasis has been placed on how to communicate uncertainty—the aspects of information that remain unknown or ambiguous. Despite its relative neglect, the communication of uncertainty can profoundly influence how information is interpreted, trusted, and acted upon.

In many cases, uncertainty is unavoidable, such as in probabilistic forecasting, medical risk communication, or policy-making, where outcomes cannot be guaranteed. How uncertainty is expressed—whether through words or non-verbal cues—may significantly shape listeners' perceptions of the speaker's confidence and the numerical interpretation of probability phrases. For instance, subtle differences in intonation or facial expressions can imply varying levels of certainty, even when the spoken words remain unchanged. These spoken words, in the context of this study, are probability phrases: qualitative expressions used to convey likelihood, verbal descriptors such as "likely," "possible," or "unlikely." They play a crucial role in how uncertainty is communicated and understood, particularly in situations where precise numbers are either unavailable or may not be easily understood by the audience (Zikmund-Fisher, 2007). For instance, a doctor might tell a patient, "There is a low chance that the treatment will work," to communicate uncertainty about a medical outcome. Similarly, policy-makers may describe the spread of a new virus to the public by saying, "It is very unlikely that the virus will spread." In both cases, the use of probability phrases is critical in shaping how uncertainty is perceived and acted upon. These phrases, however, are prone to interpretation variability. Research shows that numerical interpretations vary, particularly for mid-range probabilities, and even experts may disagree on their interpretation (Budescu & Wallsten, 1985; Willems et al., 2020).

While prior research on non-verbal uncertainty signals (Vromans et al., 2024; Willems et al., 2020) has focused on how prosodic features, such as rising versus falling intonation (auditory uncertainty cues), influence interpretations of verbal probability phrases, the present study focuses on adding a visual dimension (i.e. facial expressions). This dimension has so far been entirely absent, even though this visual element is often an important part of multimodal/spoken communication. Addressing this gap, the present study integrates both auditory and visual cues to explore their individual and combined effects on the perceived speaker certainty and numerical interpretation of verbal probability phrases. By investigating these face-to-face, spoken, multimodal interactions, we aim to deepen our understanding of how uncertainty is communicated and of how it might have (indirect) implications for the way uncertainty is communicated in contexts where risk and chance play an influential role in decision-making.

In D. Barner, N.R. Bramley, A. Ruggeri and C.M. Walker (Eds.), *Proceedings of the 47th Annual Conference of the Cognitive Science Society*

Literature Review

Probability Phrases and Uncertainty

Probability is a measure of the likelihood that a given event will occur. Typically, probability quantifies uncertainty in a numerical format, usually expressed as a number between 0 and 1, where 0 indicates impossibility, 1 indicates certainty, and values in between reflect varying degrees of likelihood (Jaynes, 2003; Rosenthal, 2006).

Importantly, prior studies on the interpretation of probability phrases are currently limited by their predominant focus on using written stimuli (Budescu & Wallsten, 1985; Brun & Teigen, 1988; Doupnik & Richter, 2003; Harris et al., 2013; Reagan et al., 1989; Simpson, 1963; Theil, 2002; Timmermans, 1994; Wallsten et al., 1986; Willems et al., 2020). This focus on written text does not do justice to the characteristics of everyday communication, where probability phrases are often delivered in spoken form. Specifically, it neglects the dynamic interplay of verbal and non-verbal cues in face-to-face communication which significantly influence interpretation and perceived speaker certainty (Borràs-Comes et al., 2019; Roseano et al., 2016). Insight into non-verbal cues may also inform theoretical models of probability communication, given that these have so far predominantly focused on written communication (for example, the integrative model of uncertainty tolerance (Han et al., 2019) and the uncertainty communication model (van der Bles et al., 2019).

Non-Verbal Communication and Uncertainty

Auditory Cues: Prosody and Intonation Research on non-verbal uncertainty cues primarily focuses on auditory aspects like prosody (Arnhold et al., 2021; Armstrong & Prieto, 2015; Beach, 2020; Borràs-Comes et al., 2019; Dehé & Wichmann, 2010; Nilsenová, 2006; Prieto & Borràs-Comes, 2018; Rudin, 2022; Swerts & Krahmer, 2005; Tanenhaus et al., 2015; Voyer & Vu, 2016; Vromans et al., 2024). One prominent prosodic cue is rising intonation, which is marked by upward pitch shifts and a question-like pattern. While rising intonation can make listeners perceive the speaker as less certain (Swerts & Krahmer, 2005; Borràs-Comes et al., 2019), falling intonation is usually reserved to mark confidence and commitment.

Recent research highlights that rising intonation combined with filled pauses (e.g., "uh") amplifies uncertainty perception and reduces consensus on numerical interpretations (Vromans et al., 2024). While filled pauses also function as hesitation markers, their influence on perceived uncertainty is weaker than rising intonation. Inspired by Vromans et al. (2024), the current study therefore focuses on rising intonation to investigate prosodic effects on listener interpretation.

Interestingly, vocal cues appear to shift listeners' focus away from the explicit verbal content (e.g., numerical probabilities) and toward the uncertainty conveyed through prosody, explaining why listeners tend to interpret probabilities in a way that brings their estimates closer to a neutral or uncertain middle ground. However, extreme probability phrases (either high or low; e.g., "always" or "never," as discussed in Willems et al., (2020)) are excluded from Vromans et al. (2024), even though these extremities are especially interesting. While rising intonation strongly influences mid-range phrases, it is worth exploring if they have the same effect on more certain verbal content. This helps understand the limits of non-verbal cues' influence: do they still create uncertainty when the message is nearly certain, or highly unlikely? We therefore formulate the following hypothesis:

H1: *Compared to verbal probability phrases spoken with a falling intonation, phrases spoken with a rising intonation will result in (a) lower perceived speaker certainty and (b) less consensus on numerical interpretations.*

Visual Cues: Facial Expressions Next to a manipulation of intonation, this study will analyze facial expressions as potential markers of uncertainty. Our focus is on facial expressions and not other visual uncertainty cues because they are a primary mode of non-verbal communication and are intertwined with how individuals perceive and interpret certainty (Ekman & Friesen, 2003). Expressions such as the "thinking face" (furrowed brow, head tilt), are powerful non-verbal signals of uncertainty and/or cognitive effort.

Previous research has shown that while audio uncertainty cues have a significant influence on the perception of uncertainty, this effect was by far larger for facial expressions (Dijkstra et al., 2006). Conversely, neutral expressions may convey confidence, resulting in a higher level of perceived speaker certainty (Swerts & Krahmer, 2005; Russell, 1994). Misalignment between verbal and facial cues can create ambiguity, influencing the interpretation of probabilistic messages, and causing a wider spread of these interpretations (Mori & Pell, 2019). This leads to the following hypothesis:

H2: *Compared to verbal probability phrases spoken with a neutral expression, phrases spoken with an expressive facial expression will result in (a) lower perceived speaker certainty and (b) less consensus on numerical interpretations.*

Multimodal Interactions In face-to-face interactions, non-verbal cues such as intonation and facial expressions work together to create a cohesive communicative message (Ekman & Friesen, 1969). While more cues can clarify intent, their interplay may also introduce variability in numerical interpretations of probability, especially when conflicting signals are present (Burgoon et al., 2021; Eppler & Mengis, 2008). Specifically, rising intonation combined with marked facial expressions could amplify uncertainty perception, reducing both perceived speaker certainty and consensus on numerical interpretations (Dohen & Loevenbruck, 2009; Swerts & Krahmer, 2005).

This raises the question of whether these cues act additively to reinforce uncertainty perception or if their combined effect is more nuanced, something that recent work (Vromans et al. 2024; Willems et al., 2020) has not addressed. Moreover, in previous studies it again remains unclear how these effects extend to more extreme probability phrases (e.g., “almost certain” or “highly unlikely”), when the verbal content is less ambiguous than for mid-spectrum expressions (e.g., “probable” or “likely”). The need to further investigate this underscores the importance of this research. Hence, we predict:

H3: *Verbal probability phrases spoken with rising intonation and expressive facial expressions will result in the (a) lowest perceived speaker certainty and (b) least consensus on numerical interpretations*.

Methods

Design

This study partially replicates the methods and analysis of Vromans et al. (2024), extending their methods by incorporating visual non-verbal cues (e.g., facial expressions) alongside auditory cues, namely, intonation. A within-subjects design was used, with participants evaluating combinations of two auditory intonation contours (Rising vs. Falling) and two visual facial expressions (Marked vs. Neutral). The reference condition was predefined as falling intonation paired with neutral facial expressions, as this combination has been shown in prior research (e.g., Vromans et al., 2024) to convey higher perceived speaker certainty.

Dependent variables included perceived speaker certainty and numerical interpretation of verbal probability phrases. Ethical approval was granted by the Research Ethics Committee of [Institution Name] (Approval ID: [Redacted]). The design, hypotheses, and analysis plan were preregistered prior to data collection within the Open Science Framework (https://osf.io/zh5ge/?view_only=e).

Participants

Based on medium effect sizes from Dijkstra et al. (2006) (similar to Vromans et al., 2024) and G*Power, a required sample size of 98 participants ($\alpha = 0.05$, power = 0.95) was determined. Data from 100 participants (73% women, mean age = 21.8, *SD* = 2.6) were collected and analyzed. Participants, recruited via convenience sampling, received course credits as compensation.

Stimulus Materials

Twenty-eight probability phrases adapted from Willems et al. (2020) were selected, following a similar approach to Vromans et al., 2024). To ensure consistency with these previous studies, the majority of the phrases used by Vromans et al. (2024) were included, presented within neutral context sentences. These sentences were chosen to be easily understandable but eliminating any potential biases regarding the expected outcome (e.g., “it is likely that this plan succeeds”). One phrase, “maybe,” was excluded, as it represents the most neutral probability and is therefore less informative in this study compared to more extreme probability phrases. Moreover, using twenty-eight phrases instead of twenty-nine allowed for an even distribution of conditions across participants.

A male, native Dutch speaker recorded all phrases with both falling (certain) and rising (uncertain) intonations, as well as corresponding facial expressions that were either neutral or marked ('thinking face' with a furrowed brow). Subsequently, audio and video segments were edited and combined to create both congruent and incongruent conditions (see Figure 1).

The final corpus included 112 audiovisual files (28 probability phrases x 2 intonation contours x 2 facial expressions). Four randomized experimental versions ensured exposure to all conditions in equal degree while mitigating fatigue effects. Stimuli were presented via Qualtrics in soundproof lab booths using headphones.

Measurements

Perceived speaker certainty was assessed with the item “How certain does the speaker seem about the accuracy of his statement?” on a 7-point Likert scale (1=very uncertain, 7=very certain). Numerical interpretation was measured using the item “What do you think is the probability (expressed as a percentage) that this plan will succeed?” on a sliding scale (0–100%).

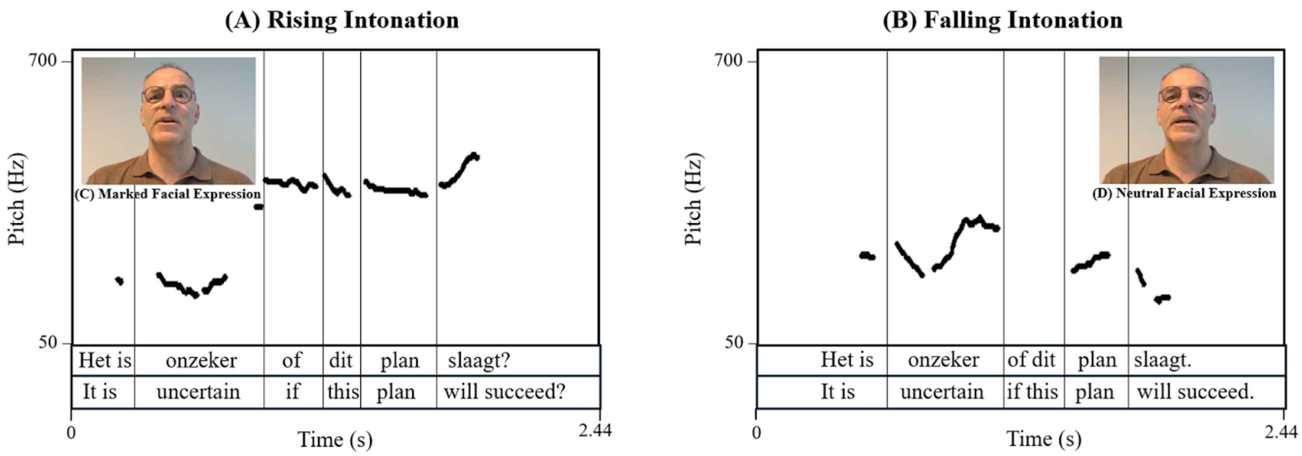

Figure 1: Illustration of experimental stimuli including the depiction of the (A) rising vs. (B) falling intonation contours and marked (C) vs. (D) neutral facial expressions utilized in the study.

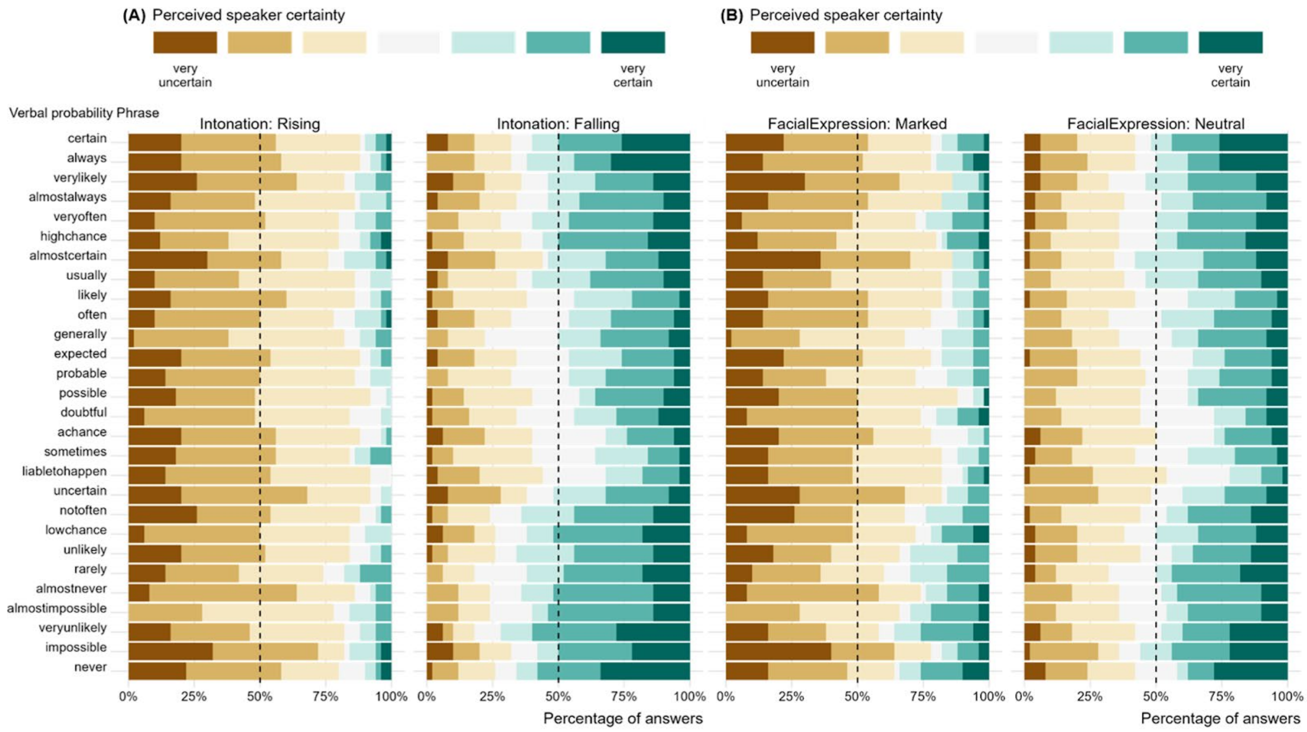

Figure 2: Stacked bar charts of the perceived certainty of a speaker when uttering verbal probability phrases with either a (A) rising or falling intonation, or a (B) marked or neutral facial expression.

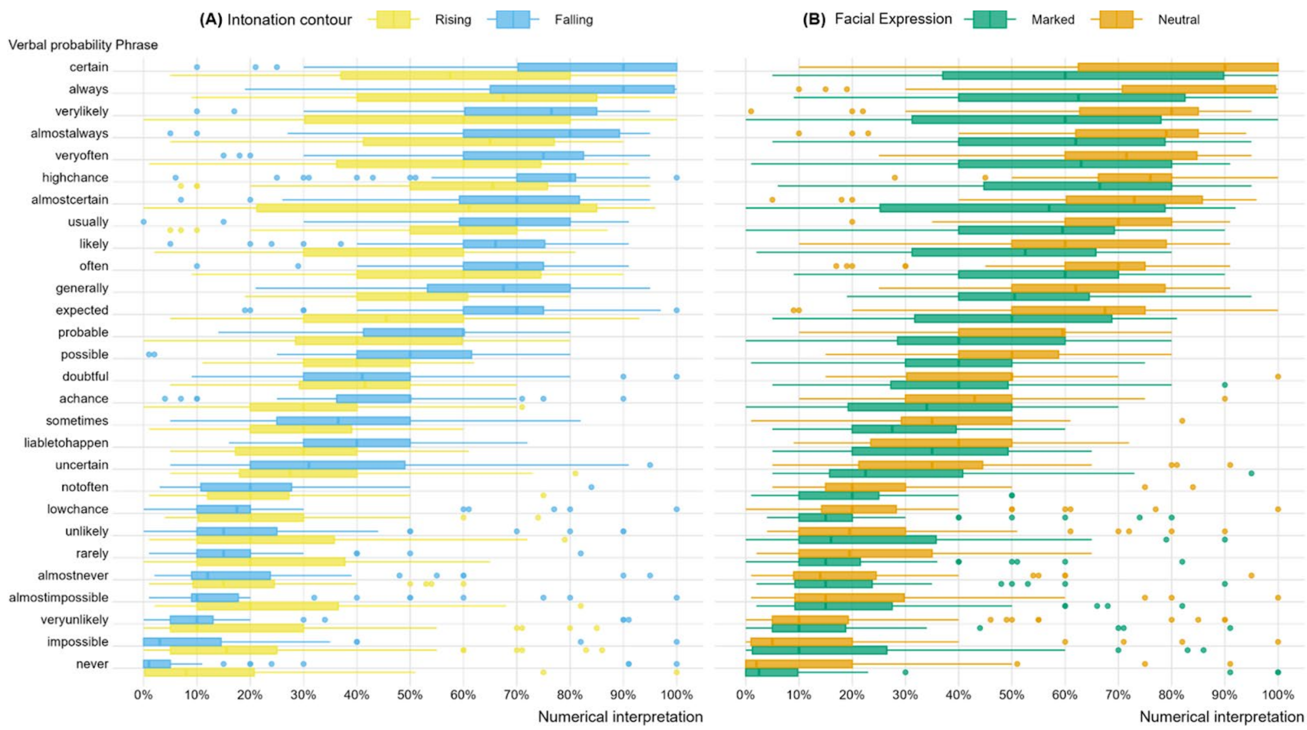

Figure 3: Box plots numeric interpretation of probability phrases when the phrase is uttered with either a (A) rising (yellow) or falling (blue) intonation contour, or a (B) marked (green) or neutral (orange) facial expression.

Procedure

Participants were instructed about the task, provided consent, and were randomly assigned to experimental versions. The participants evaluated audiovisual stimuli, responding to perceived certainty and probability interpretation items. A demographic survey (gender, age, education level; to sketch an accurate description of the participant pool) followed. Sessions lasted ~15 minutes, and data collection occurred in October and November of 2024.

Statistical Analyses

Data visualization provided an initial overview of the hypotheses, followed by validation using statistical tests. Analyses were conducted in RStudio (version 2024.12.0+467) using the following packages: haven (Wickham & Miller, 2023); tools from the tidyverse such as tidyr, dplyr, and readr (Wickham et al., 2023); ggplot2 (Wickham, 2016), ggridges (Wilke, 2023); patchwork (Pedersen, 2023); knitr (Xie, 2015); papaja (Aust & Barth, 2023); psych (Revelle, 2023); tableone (Yoshida & Bohn, 2023); parameters (Lüdecke et al., 2023); foreign (R Core Team, 2023); and lme4 (Bates et al., 2015).

Results

Effect of a Rising Intonation (H1)

Figure 2A shows a significant decrease in perceived speaker certainty when a rising intonation is used instead of a falling one. A falling intonation correlates with high perceived certainty (scores of 6-7), while a rising intonation leads to lower certainty (scores of 1-2). A linear mixed-effects model confirmed this effect, showing a reduction of 1.52 points in perceived certainty (β = -1.52, *SE* = 0.06, $p < .001$). The baseline perceived certainty for the reference condition was 3.67 (β = 3.67, *SE* = 0.08, $p < .001$).

The box plots in Figure 3A show that rising intonation leads to less extreme numerical interpretations and greater variability in responses, as confirmed by a Fligner-Killeen test ($\chi^2(1,115) = 61.30$, $p < .001$).

These results support **H1a** and **H1b**, demonstrating that rising intonation reduces perceived speaker certainty and decreases consensus in the numerical interpretation of probability phrases.

Effect of a Marked Facial Expressions (H2)

Marked facial expressions also reduced perceived speaker certainty compared to neutral expressions (Figure 2B). A linear mixed-effects model showed that neutral expressions increased certainty by 1.80 points (β = 1.80, *SE* = 0.06, $p < .001$). Box plots in Figure 3B show that marked expressions lead to less extreme numerical interpretations and increase variability, confirmed by a Fligner-Killeen test ($\chi^2(1,115) = 13.20$, $p < .001$).

These findings support **H2a** and **H2b**, indicating that neutral facial expressions enhance perceived speaker certainty and promote consensus in numerical interpretations compared to marked expressions.

Combined Impact of Rising Intonation and Marked Facial Expressions (H3)

The combination of rising intonation and marked facial expressions resulted in the lowest perceived speaker certainty (β = -0.85, *SE* = 0.09, $p < .001$). However, it did not significantly amplify variability in numerical interpretations compared to either condition alone ($\chi^2(1,115) = 0.61$, $p = .436$).

These results support **H3a**, indicating that the combination of rising intonation and marked facial expressions leads to the lowest perceived speaker certainty. However, **H3b** is not supported, as this combination does not significantly reduce variability in numerical interpretations compared to other conditions.

Discussion

Main Findings

This study investigated the impact of intonation and facial expressions on perceived speaker certainty and the numerical interpretation of verbal probability phrases. Both non-verbal cues independently reduced perceived certainty and increased variability in interpretations. The combined effect of these cues on interpretative variability was more nuanced: adding marked facial expressions to rising intonation did not significantly alter the overall variability in numerical interpretations or further reduce perceived certainty compared to rising intonation alone. This could stem from a "ceiling effect," where the strong impact of one cue (e.g., rising intonation) leaves little room for additional cues (e.g., marked facial expressions) to further influence variability. As Swerts and Krahmer (2005) note, intonation alone can effectively signal uncertainty, potentially making other cues redundant. Redundancy, in this context, occurs when multiple cues convey the same message, as noted by Burgoon et al. (2021). Furthermore, auditory and visual cues might interact in non-linear ways, where one strong cue may overrule the effect of another one (Holler & Beattie, 2003; Swerts & Krahmer, 2005).

One possible explanation for the lack of an additive effect between prosodic and visual cues on interpretative variability is that such an effect was, in fact, present for perceived speaker certainty. Specifically, the combination of rising intonation and marked facial expressions significantly lowered perceived certainty, even though it did not further increase variability in numerical interpretations. This suggests that while these cues effectively signaled uncertainty, their combined effect may have made the speaker's intent more explicit, reducing interpretive variability by leading listeners to converge on a common interpretation. Notably, this lack of an additive effect was specific to rising intonation, as the combination of falling intonation and marked facial expressions showed context-dependent variability.

All in all, the lack of a significant additive effect between rising intonation and marked facial expressions on interpretative variability suggests that while marked facial expressions can amplify variability in certain contexts, rising intonation alone may introduce enough ambiguity to make additional cues less impactful. Future research could examine whether combinations of cues, such as gestures or gaze, amplify or mitigate variability when paired with intonation and facial expressions. Additionally, the timing of cues (e.g., sequential vs. simultaneous) and individual differences, such as cognitive load or cultural background, may significantly shape interpretations (Eppler & Mengis, 2008; Vromans et al., 2024). Future research could further investigate these dynamics in real-world communicative settings. For instance, in patient-doctor interactions, understanding how rising intonation and marked facial expressions influence a patient's interpretation of probabilistic statements (e.g., "It's likely that this treatment will work") could help refine strategies for conveying uncertainty and improving trust. Similarly, exploring these cues in high-stakes environments, such as legal or financial advising, could provide insights into their broader applications.

Theoretical Implications

Our findings confirm that probability phrases are inherently ambiguous, and non-verbal cues play a crucial role in shaping their interpretation. This study extends Willems et al. (2020) and Vromans et al. (2024) by showing how non-verbal cues shape perceptions. While Willems et al. highlighted variability in numerical interpretations of verbal probability phrases, our findings emphasize that non-verbal cues amplify this variability, particularly for mid-range probabilities. Similarly, Vromans et al.'s findings on prosody and uncertainty are enriched here by the inclusion of facial expressions, showing that these cues signal uncertainty even when combined, although redundancy/cognitive overload may limit additive effects.

From a cognitive perspective, the findings align with theories of ambiguity and uncertainty processing, suggesting that rising intonation and marked facial expressions introduce uncertainty heuristics. These cues appear to trigger a conservative processing strategy, leading listeners to adopt more moderate interpretations of verbal probability phrases—a pattern consistent with the broader literature on cognitive effort reduction during ambiguity (e.g., Kahneman, 2011; Swerts & Krahmer, 2005).

Additionally, the study highlights the importance of applying broader theories of non-verbal communication specifically to probability phrases. Unlike plain numbers, verbally communicated probability phrases depend heavily on contextual and non-verbal cues for interpretation. This makes them particularly susceptible to the dynamic interplay of auditory and visual signals, as demonstrated by the observed shifts in numerical interpretations toward central probabilities. These findings underscore the need for future models of uncertainty communication to integrate multimodal cues and their unique effects on probabilistic reasoning.

The results support the need to integrate auditory and visual cues into models of uncertainty communication by demonstrating that auditory and visual cues interact in non-linear ways, with rising intonation and marked facial expressions reducing perceived speaker certainty and influencing numerical interpretations. This reinforces the importance of extending existing theoretical models of uncertainty representation that mainly focus on written communication, such as the integrative model of uncertainty tolerance (Han et al., 2019) and the uncertainty communication model (van der Bles et al., 2019), to include multimodal dynamics that are more representative of daily face-to-face interactions.

Practical Implications

Effective uncertainty communication requires attention to both verbal and non-verbal cues. In fields like healthcare, professionals should be aware of the effects of facial expressions and tone of voice on the way uncertainty is perceived and interpreted, to hopefully minimize misinterpretation and anxiety about, for example, the probability of certain treatment side effects. Training programs should incorporate guidance on managing non-verbal signals to improve patient understanding and decision-making.

Limitations

This study employed a controlled experimental design featuring a single speaker and facial expression ("thinking face"), which constrains ecological validity and limits the generalizability of the findings. The exclusive focus on one expression may not capture the diverse effects that other facial cues could have on communication. Additionally, utilizing only one speaker restricts the variability in vocal and facial expressions, potentially leading participants to adapt to the speaker's style over time, thereby affecting their responses.

The absence of filler items in the experimental design may have rendered the study's purpose more apparent to participants, increasing the risk of response bias. Furthermore, the participant pool lacked diversity in terms of age and cultural background, which is crucial given that cultural norms and age-related factors can significantly influence the interpretation of non-verbal cues (Liu et al., 2021).

The study's focus on neutral contexts excluded emotional and situational influences that are prevalent in real-world scenarios. This limitation hinders the applicability of the findings to everyday communication, where emotions and context play a pivotal role.

Conclusion

This study underscores the critical role of non-verbal cues in uncertainty communication. Rising intonation and marked facial expressions reduce perceived certainty and, in some cases, increase interpretative variability. These findings highlight the need for theoretical models on risk and uncertainty communication to include non-verbal elements and encourage further research into their broader applications and implications in high-stakes contexts such as patient-doctor interactions or public climate change communication.

Acknowledgements

The authors would like to thank prof. dr. Emiel Krahmer for his valuable assistance in creating the experimental stimuli and Jorge Macarulla Trell for his support in debugging the R scripts used for data cleaning and analysis. Their contributions greatly enhanced the quality and efficiency of this research.

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