# Multimodal markers of confidence and doubt: Inferring Feeling of Knowing from facial movements

Jonas Nölle[1], Yichen Wu[1], Pablo Arias[1,2], Yueyao Yang[1], Oliver G.B. Garrod[1], Philippe G. Schyns[1] & Rachael E. Jack[1]

[1]University of Glasgow, jonas.noelle@glasgow.ac.uk [2]Lund University

Questions are essential to gain information and mutual understanding (Clark 1996). When answering questions, people often express a degree of confidence or doubt—called Feeling of Knowing (FoK). A large body of work shows that observers use speech cues to infer FoK (e.g., *uhm* or *maybe*; Caffi & Janney 1994; Jiang & Pell 2017; Goupil et al. 2021; Goupil & Aucouturier 2021). However, it remains unknown whether FoK can also be inferred from nonverbal signals, like facial expressions, that are often used for similar pragmatic functions in conversations (Bavelas & Chovil 2018). Are there specific facial movements that signal confidence and doubt when paired with a spoken answer? And if so, are facial expressions of confidence and doubt culturally variable, as emotions are (e.g., see Jack et al., 2012)? We address this question using a data-driven approach to agnostically generate different facial movements and measure their impact on speaker's perceived confidence or doubt while answering a question. We recruited participants from two cultures with known differences in facial expression perception—Western European and East Asian ($N$ = 22 per culture; Age = 18-35 years, sex-balanced). We constructed multimodal stimuli of speaker's answering a question (i.e., *yes* or *no*) by displaying random combinations of eye/brow facial movements (e.g., AU1-2 Inner & Outer Brow Raiser, AU5 Upper Lid Raiser, Ekman & Friesen, 1978) on different face identities using a generative model of dynamic 3D faces (Yu, Garrod & Schyns 2012) and lip-synchronized recorded utterances using a neural network (Cudeiro et al., 2019). We recorded speech from two Scottish English and two Mandarin native speakers (1 male, 1 female) and created 20 distinct sounding voices by shifting the pitch and spectral envelope. We then paired these with unique face identities on each trial (1800 trials per participant, sex-balanced, same-ethnicity faces). We synchronized the onset of the words *yes* or *no* (fixed at 1s) to the peak of the facial movement. On each trial, participants viewed a question ("Would they make a good leader?") before viewing a speaker answering the question (*yes* or *no*). Participants then rated the confidence of the speaker's answer on a 5-point scale from 'Very doubtful' to 'Very Confident.' To examine whether facial movements influenced participant confidence ratings, we used ordinal logistic regression models with a logit link. Results showed that specific facial movements mark confidence and doubt—participants consistently associated doubt with squinting (e.g., AU6 Cheek Raiser, AU7 Lid Tightener) and frowning (AU4 Brow Lowerer; see also Swerts & Krahmer, 2005) and often associated confidence with raised eyebrows (AU1 Inner Brow, AU2 Outer Brow Raiser) and closed eyes (AU43 Eyes Closed), reflecting existing work showing that long blinks signal understanding (Hömke, Holler & Levinson 2018). Together, our data-driven approach to understanding the role of facial expression in multimodal pragmatics revealed that specific facial movements modulate the perception of confidence and doubt from otherwise neutral speech. Our results will form the basis of new research directions involving the manipulation of both vocal and visual cues to systematically examine how these modalities interact and combine in face-to-face dialogue.

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