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Can the Fetal Face Reveal Early Affective States? Insights from 4D Ultrasound, Neurodevelopment, and Artificial Intelligence

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Objectives

To evaluate whether structured fetal facial expressions observed using four-dimensional (4D) ultrasound may reflect early affective responses within maternal-fetal neurobehavioral interaction.

Methods

An integrative evidence synthesis using a modified PRISMA framework searched PubMed, Scopus, and Web of Science (2000–2025) for studies on fetal facial behaviour, prenatal development of emotional neural circuitry, maternal-fetal affective interaction, and artificial intelligence (AI) analysis of ultrasound imaging. Studies of human fetuses at 20–40 weeks' gestation reporting facial movements, maternal emotional correlates, or computational facial analysis were included. Evidence was synthesized across neurodevelopmental, imaging, and machine-learning domains.

Results

Seventy-eight studies met the inclusion criteria. Limbic structures involved in affective processing, including the amygdala, insula, and anterior cingulate cortex, begin forming functional networks during the late second trimester. Concurrently, **4D ultrasound demonstrates increasingly organized fetal facial movements between 24–34 weeks' gestation, including brow lowering, eye squeezing, and lip puckering that form reproducible patterns.** Some studies report **associations between maternal emotional state and fetal behavioural responses.** Machine-learning analyses further identify clusters of facial configurations potentially corresponding to neutral, calm, or stress-related states.

Conclusions

Advances in 4D ultrasound and AI analysis suggest **fetal facial behaviour may reflect early affective responsiveness to the intrauterine environment** and offer new approaches for assessing fetal neurobehavior.

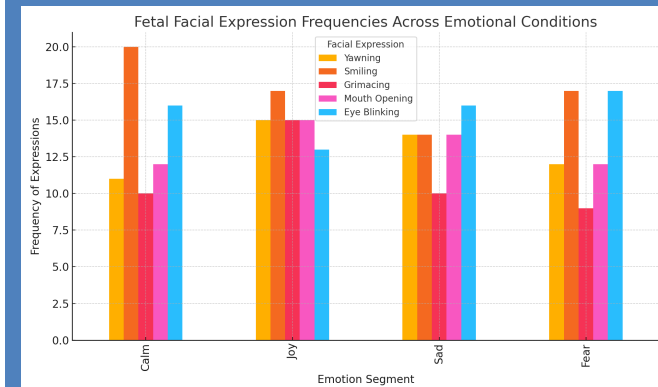


Figure 1. This bar chart displays the total frequency of five distinct fetal facial expressions—yawning, smiling, grimacing, mouth opening, and eye blinking—observed during each maternal emotional condition.

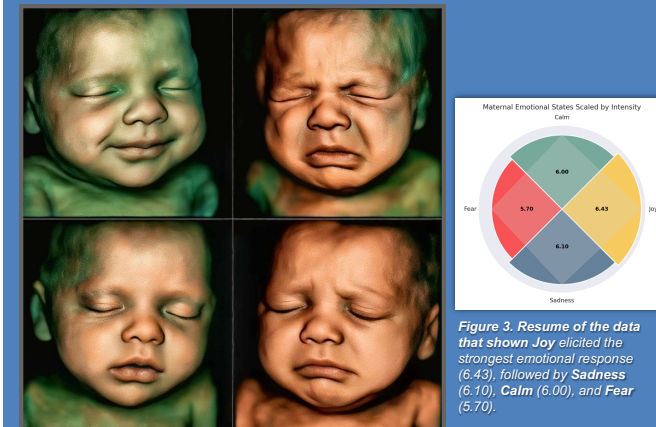


Figure 2. each illustrating a distinct fetal facial expression observed in response to different maternal emotional conditions. The figure presents a panel of four 4D ultrasound AI enhanced imaging still images: joy (top left), fear (top right), calm (bottom left), sad (bottom right).

