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OPINION

# Fetal Consciousness: Four-dimensional Ultrasound Study

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## WHEN IS THE BIRTH OF CONSCIOUSNESS IN HUMANS?

The development of consciousness is a key mystery facing modern science.[1] We define consciousness as awareness of the body, self and world around us.[2] A number of signs of consciousness are shown by newborns, such as being awake and aware of him/herself and the mother. They express primary emotions, such as joy, disgust, surprise, and remember rhythms and vowels to which they have been exposed during fetal life. A newborn infant displays the criteria for a basic level of consciousness, showing awareness of its body and him/herself and, to some extent, the external world. Preterm infants may show limited consciousness from approximately 25 weeks, as thalamocortical connections develop.[3] Do human fetuses have a consciousness, such as feelings and intentions? This is a perennial puzzle that is very interesting but has not yet been solved.

Humans are able to understand the feelings, emotions, and intentions of other people by observing their facial expressions and actions. So, we may be able to document whether fetuses have a consciousness by observing their facial expressions and behaviors *in utero*.[4]

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## FETAL PAIN AND STRESS

Another interesting question is 'Does fetal pain exist?' An overview of current research related to the concept of fetal pain by Van de Velde et al[5] shows contradictory answers. The negative answer is that a fetus definitely cannot feel pain. The positive one is that the fetus reacts to painful stimuli from 24 weeks of gestation, and it is possible that this occurs from 16 weeks' gestation. Katarzyna and Miroslaw[6] speculated that the human fetus is able to feel pain after 24 weeks' gestation, and may feel pain even before that time. Facial scowling, grimacing, or crying as important indicators of fetal pain or distress includes several features, such as brow bulge, eye squeeze, nasolabial furrow and open mouth (Fig. 1).[4,7] Other indicators of fetal pain may be body movements, such as the activity of the arms and legs, clenching of the fists or toes and sudden body movements.[7]

Regarding neonates, stress levels are higher in those exposed to high-risk conditions. Such stress is shown in more marked facial (e.g. rhythmical mouthing) and trunk (e.g. hiccup and back arch) movements compared to nonstressed neonates. Movements, such as rhythmic mouthing, hiccups, and back arch, may indicate neonatal stress.[8]

There has been only one study on the four-dimensional (4D) ultrasound-based evaluation of the fetal response to stress *in utero*.[9] While the stress level was unrelated to the fetal age, the jerkiness of arm movements was significantly correlated with the fetal stress index but not age. This study suggests that jerky arm movements in fetuses are signs of fetal stress. In a case of uterine synechia at 29 weeks and 5 days of gestation, the fetus was trapped in a very small space of the upper part of the uterine cavity. The fetus showed an apparent crying-like facial expression (Fig. 2). Was it a stressful situation for this fetus? Figures 3A and B present the facial expression of one twin fetus after being kicked in the face by the co-twin fetus. After being kicked in the face, this fetus seems to be sad. Reissland et al[9] suggested that the increased frequency of fetal scowling (pain/distress) with advancing gestation might be an adaptive process, which is beneficial after birth.

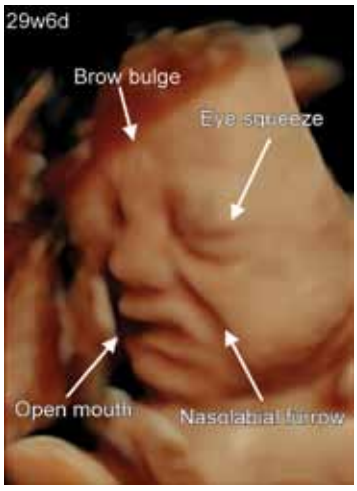
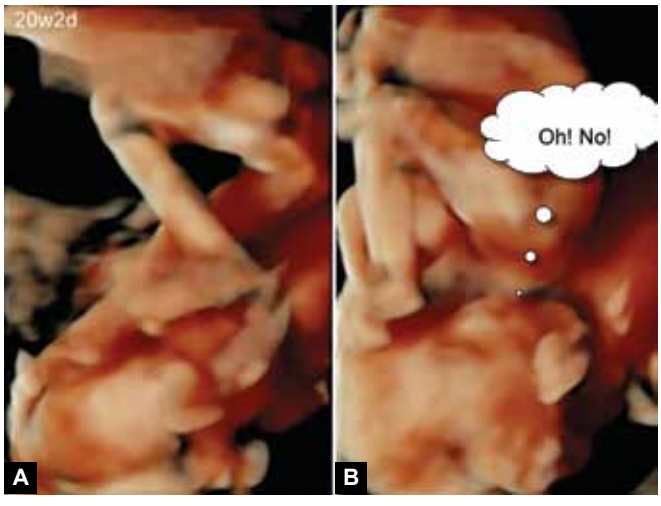



**Fig. 1:** HDlive image of fetal expression of pain at 29 weeks and 6 days of gestation. Facial expressions as important indicators of fetal pain may include several features, such as brow bulge, eye squeeze, nasolabial furrow and open mouth (*Courtesy*: Reprinted with permission from Hata T et al)[4]


**Fig. 2:** A case of uterine synechia (S) at 29 weeks and 5 days of gestation. The fetus is located in a very small space in the upper part of the uterine cavity. This fetus shows a crying-like facial expression. Is it stressful for this fetus?




**Figs 3A and B:** HDlive presents the facial expression of a fetus after being kicked in the face by its co-twin at 20 weeks and 2 days of gestation (A and B). How does this fetus feel? It seems to be sad

## FOUR-DIMENSIONAL ULTRASOUND STUDY OF FETAL CONSCIOUSNESS

Arm-to-face and hand-to-face movements were examined in 27 fetuses at 19 to 35 weeks of gestation using 4D ultrasound. Hand touching of the mouth, either directly or indirectly, was observed in more than half of the cases. Moreover, opening of the mouth preceded hand-to-mouth movements. This anticipatory behavior of the fetus suggests that human fetuses probably realize how they should move their hands in order to make contact with their mouths. These movements are based on knowledge of intersensorimotor relations in fetal bodies.[10]

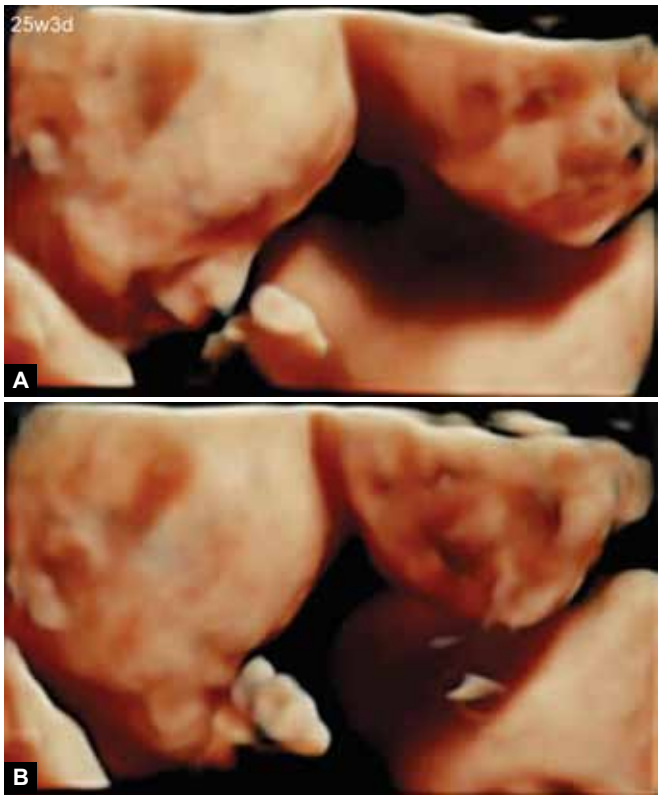
On employing 4D ultrasound, the movements of hands toward the mouth and eyes were assessed in eight singleton fetuses at 14, 18 and 22 gestational weeks, in order to examine whether such movements are deliberate and how they are performed. At 22 weeks, the fetus appears to understand that the mouth is bigger and less delicate than the eyes. Therefore, the fetus may have learned that the eye is smaller and more delicate, suggesting the presence of somatosensory sensitivity, by 22 gestational weeks. At this time, the movements suggest deliberate actions, with kinematic patterns that depend on the reason for the action, which would represent a markedly advanced level of motor planning.[11]

Self-touch of the fetal face/head was scored over a period of 10 minutes at 24, 28, 32, and 36 gestational weeks, and the rate of using left and right hands to touch their face was determined. Hand preference showed marked variability. However, no significant increase in the rate of right-handed touches was noted with fetal age progression. No sex differences were noted in handedness. Maternally reported stress levels were significantly positively correlated with fetal self-touches with the left hand (odds ratio 0.915; $p < 0.0001$).[12]

Profiles of kinematic movements involving five pairs of twin fetuses were assessed with 4D ultrasound at 14 and 18 gestational weeks. Analysis revealed that the duration of movement and deceleration time were extended for other-directed movements on comparison with those directed toward the uterine wall. In the study, similar kinematic profiles regarding movements toward the co-twin and self-directed ones toward the eye-region were noted, i.e. the most delicate body area. It was concluded that movements directed at the co-twin are not coincidental: twin fetuses already perform movements aimed at the co-twin from the 14th gestational week[13] (Figs 4 and 5).

In previous studies using 4D ultrasound, 'the application of this technique to the examination of fetal facial movements revealed the existence of a full range of facial


**Fig. 4:** HDlive image of monochorionic diamniotic twins at 17 weeks and 6 days of gestation. One twin fetus looks like he/she is whispering to the co-twin fetus. Is there communication between them? Is this a fetal conversation between twins?




**Figs 5A and B:** HDlive shows fetal twin behaviors at 25 weeks and 3 days of gestation (A and B). One twin fetus (left) seems to be sad, and the co-twin fetus (right) turns his/her face to the left twin

expressions similar to emotional expressions in adults'.[14] 'Different facial expressions and movements depicted by 4D ultrasound might represent fetal awareness'.[15]

### Do Fetuses have a Consciousness?

Most of fetal facial expressions may simply constitute a reflexive behavior on the part of the fetus. However, fetal facial expressions and emotion-like behaviors observed by 4D ultrasound may represent some kind of fetal emotion and awareness. These facial emotion-like expressions or emotion-like behaviors may represent a reliable behavior or some emotional state of the fetus *in utero*.[16] For example, fetuses may be able to feel pain and change their facial expression, such as 'frown' or 'show a sad look' when they feel stressed and 'smile' in a comfortable environment. Furthermore, one of twin fetuses may recognize the other twin as a person and behave based on this recognition from an early stage of pregnancy. In other words, fetuses may have a consciousness. Trevarthen and Delafield-Butt[17] suggested that expressions of fetuses, in addition to twisting movements of distress and tentative exploration by touch, provide supporting evidence of emotions of discomfort, curiosity, or pleasure, adapted for communication of interests and feelings. Reissland et al[18] also stated that fetal facial expressions depicted by 4D ultrasound in the third trimester develop into complexes that define a 'cry-face-gestalt' or a 'laughter-gestalt', expressing emotions that will communicate powerfully immediately after birth in the regulation of parental care. Moreover, maternal hunger with depletion of the energy supply to the fetus drives 'anxious' patterns of fetal movements. The mother and fetus are already affectively connected. These discoveries prompted a revolution in psychological theory and medical ethics.[17] So, 'there is a consensus in modern pediatrics that by 24 weeks, the fetus should be considered a conscious entity deserving the same standard of sympathetic medical care as adults'.[19] We also always think of a 'fetus as a patient'. However, memories of such experiences in the fetal period may be lost when babies are born. Of course, there is an opposite opinion against these comments. 'The fetus shows some signs of consciousness, but it is mainly asleep and probably not aware of itself or its environment. Thus, it is hard to believe that it is conscious'.[2] In our opinion, however, it is important to bear in mind that a fetus is a human being with consciousness.

## CONCLUSION

The introduction of 4D ultrasound has opened the door to new academic disciplines, such as 'fetal neurology' or 'fetal psychology', and fetal behavioral science is at the dawn of a new era. We hope that knowledge on fetal brain and central nervous system functions (including whether or not they have a consciousness) will be advanced through fetal behavioral research using this technology.

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