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Effects of maternal mental health on prenatal movement profiles in twins and singletons

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Abstract

Aim: Prenatal experiences, including maternal stress, depression and anxiety, form crucial building blocks affecting the maturation of the foetal central nervous system. Previous research has examined foetal movements without considering effects of maternal mental health factors critical for healthy foetal development. The aim of this research is to assess the effects of maternal mental health factors on foetal twin compared with singleton movement profiles.

Method: We coded foetal touch and head movements in 56 ultrasound scans, from a prospective opportunity sample of 30 mothers with a healthy pregnancy (mean gestational age 27.8 weeks for singleton and 27.2 for twins). At the ultrasound scan appointment, participants completed questionnaires assessing their stress, depression and anxiety.

Results: Maternal depression increased foetal self-touch significantly. In foetal twins, maternal stress significantly decreased and maternal depression significantly increased other twin touch. Maternal mental health factors affected the head movements of twins significantly more than singletons, with maternal depression decreasing head movement frequency for twins significantly.

Conclusion: These results indicate that maternal mental health might have an impact on types of body schemata formed in utero, in twin compared with singleton pregnancies. Future research needs to examine whether these prenatal effects affect postnatal differences in body awareness.

KEYWORDS
singleton/twin foetus, prenatal movements, maternal stress, depression

1 | INTRODUCTION

Foetal movement profiles, including head turns and prenatal touch behaviours, are markers for the maturation of the central nervous system during pregnancy.[1-4] Because of the plasticity of the developing foetus, the gestational period is a foundation for postnatal behaviour[5] with early experiences in the womb forming crucial building blocks.[6]

Foetal reaction to stimulation such as prenatal reaction to light stimulation,[7] sound stimulation,[8] touch[2,9] and odour[10] as well as

Abbreviations: HADS, Hospital Anxiety and Depression scale; PSS, Perceived Stress Scale; BMUS guidelines, British Medical Ultrasound Society guidelines.

musculoskeletal development contribute to the establishment of sensory-motor organisation.[11] Arguably, this development leads to what has been termed prenatal pre-'consciousness'[12] similarly to what has been called in terms of pre-cognition in the foetus 'implicit' or 'behavioural anticipation'.[3] Movements including head movement and touch behaviour relate to the development of embodied self-awareness at the foetal stage.[13]

During gestation, foetuses explore their body, which is sensitive to touch from around the 8th week of gestation[14] thereby arguably enabling the development of an internal body map. Prenatal movements initiate activity in the developing sensory-motor cortices, from where the somato-topical organisation of the neural representations of the body is organised.[13] Specifically, as pregnancy progresses, the central nervous system matures including the development of the Meissner's touch corpuscles in the fingers, resulting in increasingly discriminatory touch behaviour. From around 24 weeks gestation, foetuses initiate what can be classed an early form of 'affective touch' which has been described as the first step to social communication. This type of affective touch initiates the growth of mechano-sensitive C tactile afferent neurons, which programme the rewarding properties of touch.[15] In sum, prenatal touch is essential, not only for the maturation of body schemata, but also for the development of sensory-motor loops, guiding movement development into infancy and form the basis of the differentiation of self and other.

The study of the development of intrauterine movement profiles provides the basis for a new developmental model. The field of constructive developmental science creates models of the role played by prenatal sensory-motor feedback, in cognitive, social and emotional development with touch encouraging goal-directed behaviour and early affiliative communication.[11]

Prenatal twins provide a unique opportunity to investigate touch behaviour[9,16] with some finding differences and others not. Applying Kurjak's Antenatal Neurodevelopmental Test scoring system on twin and singleton pregnancies, no differences were reported.[17] This contrasts with findings by Castiello et al[16] who reported that in twins the proportion of self- and other-directed movements differed. In twin foetuses, self-directed movements were more frequent at 14 weeks and movements directed at the twin were more frequent at 18 weeks gestation. Hence, according to Castiello et al,[16] twin foetuses, as they mature, seem to direct touch in preference to the other foetus rather than themselves.

Touch in general and twin touch in particular attenuates infant stress responses, reduces crying and enhances quiet sleep.[18] Twin pregnancies provide a unique opportunity to investigate prenatally touch of another human, which might have the potential to accelerate postnatal adaptive behaviours. The beginnings of what we might call prenatal 'social touch' are defined as the type of touch in twin pregnancies, specifically affiliative-touch, namely delivering and receiving human-to-human touch.

Although there are a number of studies examining singleton and twin pregnancies (eg [2,9,17,19]), studies describing foetal movement profiles lack the inclusion of maternal mental health factors such as stress, depression and anxiety on foetal movement profiles in general and touch and head movements in particular. The current study adds to the literature by examining potential differences in frequency of self- versus other touch as well as head movements of twins and singletons taking maternal stress, depression and anxiety into account. Given the importance of the prenatal period, the current study investigates whether prenatal experience of touch by another human in twin pregnancies affects the behavioural profile of twin foetuses. Factors including not only the gestational environment, but also the development of touch and other prenatal movements, such as head turns, and the influence of maternal mental health must be tested in the twin context in order to explore the possibility of a twin-specific neurobehavioral trajectory.

Foetal movements allow the singleton foetus to touch their body, called a 'double tactile stimulation' with both touching actions and receiving touch performed by the foetus.[20] This tactile experience is enhanced for twin foetuses where double tactile stimulation exists alongside stimulations by another human, namely twins touching each other. Given the sensory stimulation arising from several sources, foetuses are expected to develop different cortical body maps.[11]

Not only do foetuses with increasing gestational age aim movements towards more sensitive body parts[20] with increasing gestation they are able to 'anticipate' movements, such as opening their mouth before touch with their hand[3] which may be a first step towards action planning and therefore the first steps towards what will develop into postnatally into consciousness.[12] Foetal behaviour already presents some social characteristics observed in neonates including response to the mother's touching her abdomen[21] as well as turning their head towards a visual stimulus.[7]

Missing in most accounts are effects of maternal mental health, which might influence foetal actions and thereby disrupt the normal processes. There are, however, a number of studies, which have shown that maternal mental health will affect foetal outcome (eg [4,22]). Furthermore, prenatal stress results in foetal compromise such as increased heart rate, a dysfunctional hypothalamic pituitary adrenal axis, and increased limb and mouth activity.[23] Maternal depression during prenatal development results in restricted foetal growth and

Key Notes

- Research indicates that maternal mental health factors including stress and depression affect singleton foetuses but studies on multiple pregnancies are lacking.
- In the current study, maternal depression affected the foetal touch and movement behaviours of both singletons and twins with differential effects observed whereas maternal self-reported stress affected other twin touch.
- Effects of maternal mental health on foetal singletons compared with multiples need to be followed up postnatally.

abnormal movement profiles mediated by clinically low dopamine and serotonin levels.[24] However, potentially altered developmental trajectories in twins and singletons have not been systematically investigated. Given that human-to-human touch and head turns affect reactions after birth, the question is whether before birth foetal twin-to-twin touch and head turns might be affected differently in terms of maternal mental health variables compared with foetal singletons who do not have the opportunity to experience direct human-to-human 'interaction' prenatally.

In the current study, we hypothesised that foetal twins compared to foetal singletons would show variations in both self-touch and other touch as well as potentially head movements relative to maternal mental health, including stress, depression and anxiety.

2 | METHOD

2.1 | Participants

An opportunity sample of 30 mothers participated in this prospective study. They were recruited on the basis that their 20-week anomaly scan showed a healthy pregnancy. Medical records confirmed that all foetuses were healthy at their 20-week anomaly scan. 16 of the mothers were pregnant with singletons and 14 with twins. 13 mothers were between 20 and 26 years old, 13 between 27 and 30, and four mothers 30+ years.

Nine mothers were available for ultrasound scans at two time points. This resulted in 56 scans from 44 foetuses (see Table 1).

Twenty two scans from singletons and 34 scans from twins resulted in a total number of 56 scans. Gestational age ranged between 23 and 32 weeks, with mean age of 27.8 (std 2.71) for singleton scans and 27.2 (std 2.59) for scans from twins. Gender of foetuses was obtained from the medical notes or elicited from mothers after birth but was not available for all foetuses. Details of the distribution of gender and pregnancy type are given in Table 2.

TABLE 1 Distribution of mothers over pregnancy type and number of scans taken

	Mothers of singletons	Mothers of twins
Mothers available for one scan	10	11
Mothers available for two scans	6	3

Note: Note that the sum of the values in the table is 30 (mothers), leading to the production of 10 + 11 × 2 + 6 × 2 + 3 × 4 = 56 scans from (10 + 6) + (11 + 3) × 2 = 44 foetuses.

TABLE 2 Distribution of foetuses over pregnancy type and gender of the foetus

	Female	Male	n.a.
Singleton	9	4	3
Twin	12	14	2

Note: Note that the sum of the values in the table is 44 (foetuses).

Measurements of head circumference were available for 14 out 22 singleton scans (mean 26.32, std 2.49), and for 18 out of 34 scans for twins (mean 25.71, std 2.87). Measurements of femur length were available for 11 of the singleton scans (mean = 5.32, std. 0.58) and 20 of the scans for twins (mean 5.03, std 0.63). All pregnant women were healthy non-smokers, with a BMI of 18–30. To assure confidential analysis, we assigned an anonymous code to each foetus.

2.2 | Ethics

Pregnant women were recruited from the North East of England via posting advertisements to pregnancy-related Facebook groups. All women received ultrasound scans in private ultrasound clinics. This study was conducted in accordance with the Declaration of Helsinki. Ethical permission was granted by Durham University: ref PSYCH-2019–09-06T10_23_46-dps0nr. Once mothers had been fully informed about the aims and procedures of the research and provided their informed consent, they underwent their ultrasound scan perfomed by a trained professional sonographer.

2.3 | Scanning procedure and materials

Before the scan, women completed questionnaires, assessing anxiety and depression levels[25] and perceived stress.[26] The scanning room was darkened, and the pregnant women were made comfortable in a reclined position on either their side or their back for around 15 minutes following BMUS guidelines. The scans were recorded for offline analysis. All participants received a copy of their scan.

2.4 | Coding

Before coding began, the scans were reviewed to establish foetal positioning in the womb. Using the Observer®, frequency of head movements, self-touch and twin-to-twin touch was coded for each foetus frame by frame based on the Fetal Observable Movement System.[27]

2.5 | Reliability

In order to ensure that the coding of the scans was reliable, an independent coder blind to the aims of the study coded 10% of the scans. There was very good agreement of the behaviours coded with mean Cohen's Kappa scores ranging between 0.89 and 0.98.

2.6 | Analysis

Because of variability of codable scan time across scans, data were transformed into rates. For example, if a foetus exhibited a number of self-touches throughout the scan, this frequency was divided by the seconds in which self-touch for this foetus was visible.

3 | RESULTS

For details of the statistical methodology of the results presented in this section, we refer to Appendix S1 (https://www.maths.dur.ac.uk/~dma0je/Software/twins-appendix-S1.pdf) where we also include graphical representations of the data and analyses.

3.1 | Correlation analysis

Mental health scores of the participating mothers were moderately but positively correlated. The correlations of anxiety and stress, and anxiety and depression, were significantly different from 0, and stress and depression correlation was borderline significant at the 5% level (see Table 3). It is noted that, even where variables are significantly correlated, their impact on the outcome variable (head turns or touches) needs to be tested.

3.2 | Two-sample t tests

3.2.1 | *Head movements*

For the relative number of head turns, a two-sample t test for pregnancy effects (Singleton versus Twin) did not show any effect ($p > 0.8$). The same was true for gender effects ($p > 0.3$).

3.2.2 | Touch

For the relative number of self-touch, neither a two-sample t test for pregnancy effects ($p > 0.8$) nor for gender effects ($p > 0.5$) were significant. However, for other twin touch, a two-sample t test for gender effects did show a significant result ($p = 0.0428$), with female twins touching the other twin less frequently.

3.3 | Modelling

In order to model the three touch and movement types (head movements, self-touch and other twin touch), negative binomial mixed models were fitted. Response and covariates were related through a log-link, and the scan length was incorporated in the form of an additive logarithmic offset. A random effect was included for each foetus, in order to account for the fact that some foetuses received two ultrasound scans, at different gestational ages. As covariates, we used an indicator variable for being twin or singleton, the three maternal mental health scores, and gestational age, as well as terms involving gender or interactions where adequate. The potential covariates of head circumference and femur length, and maternal age group, were excluded from consideration following a preliminary analysis, for the former two variables due to the large number of missing values, and for the latter due to an obvious lack of significant effects. Also, maternal anxiety was included in all models but never reached significance. Models were fitted using R function glmmTMB, and effects considered significant for model coefficients with p-value < 0.05 (see Appendix S1).

3.4 | Head movements

Overall, maternal depression leads to a decreased number of head turns ($p = 0.0500$). There is evidence to suggest that this effect is different for twins and singletons: While for singletons, there is no significant effect detectable ($p > 0.5$), for twins the effect is very strong ($p = 0.0128$). Gestational age is also shown to relate positively to increased head turns ($p = 0.0132$), with no significant difference between twins and singletons.

3.5 | Touch

Maternal depression leads to significantly more self-touch ($p = 0.0225$). There is no evidence to suggest that this effect is different for twins compared to singletons.

For twins, maternal depression leads to significantly more touch of the other twin ($p = 0.0207$), and maternal stress leads to less touch of the other twin ($p = 0.0268$). Under consideration of this modelling, and in spite of the previous result of the two-sample t test, there is no significant effect of gender on self- or other twin touches.

4 | DISCUSSION

It is widely acknowledged that touching and being touched attenuates infant stress responses[18] and is crucial for neuro-cognitive postnatal development.[20,22,24] Prenatal maternal mental health specifically anxiety and depression potentially contribute 10–15%

TABLE 3 Pearson and Spearman correlation coefficients with associated p-values

Coefficient (p-value)	Anxiety/Stress	Anxiety/Depression	Stress/ Depression
Pearson	0.50 (0.0012)	0.68 (<0.0001)	0.32 (0.0446)
Spearman	0.48 (0.0020)	0.60 (<0.0001)	0.29 (0.0727)

to postnatal outcomes as measured by behavioural and emotional developmental factors such as those found in Attention Deficit Hyperactivity Disorder.[22]

Regarding multiple pregnancies, known to carry more medical risks compared to singleton pregnancies, we found in our study that twins were not only affected medically but also psychologically by maternal mental health. This could represent a vulnerability in twins to the transmission of maternal stress and depression. Another interpretation could be that twins compared to singletons use touch more frequently as a coping mechanism given that they have the human-to-human touch experience which is lacking in the singleton. These hypotheses need to be tested in a larger sample. Self-touch is an act of coping with stressful and/or harmful situations through a mechanism of passive avoidance, which Kikuchi & Noriuchi[28] argued, is automatically realised in the human brain for self-protection. When examining self-touch behaviours in our group of twin and singleton foetuses, we did not find any difference in relative frequencies of self-touch. When taking maternal mental health, specifically depression, as a mediating factor into account, foetuses significantly increased their self-touch behaviours hence supporting the argument of self-protection even at this very early age. With regard to head movements, a measure which has been previously related to prenatal pre-cognition,[7] in twin foetuses we found that maternal depression was negatively correlated with relative frequency of head movements: the more depressed the mother the fewer head movements were shown by foetuses ($p = 0.013$).

In sum, in the prenatal period, twins seem to be affected by maternal depression in terms of both head movements as well as increased other touch behaviours potentially as a soothing mechanism.

Although there are no conclusive findings about the exact developmental timing of the emergence of the sense of a bodily self, studies of brain responses to touch stimulation in neonates born preterm and at term have suggested that a somatotopic cortical pattern develops prenatally.[29] Studies on the ontogeny of human body perception in infants suggest that a pre-reflective, non-conceptual form of bodily self-awareness, a primitive sense of self or 'minimal self', is already present in the first months of life[30] and that the minimal self-development might be influenced by prenatal experiences including maternal stress, depression and anxiety.

The current study indicates differential neurobehavioral trajectories for twins compared to singletons. Specifically, twin foetuses seem more vulnerable to adverse maternal mental health factors, indicating a need for mothers with a multiple pregnancy to have greater mental health support. Furthermore, the study also reaffirms that maternal mental health, namely stress and depression, affects the way foetuses experience prenatal touch. In summary, this study provides the basis for the beginnings of a differentiated development of 'self-perception' in twins and singletons. Future studies need to follow-up with postnatal behavioural analyses to assess how maternal mental health factors may exert influences on embodied self-awareness into infancy and childhood.

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CONFLICT OF INTEREST

None.

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SUPPORTING INFORMATION

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