University of Dundee

Fetal behavioral responses to the touch of the mother's abdomen

Marx, Viola; Nagy, Emese

Published in:
Infant Behavior and Development

DOI:
10.1016/j.infbeh.2017.03.005

Publication date:
2017

Document Version
Peer reviewed version

Fetal behavioral responses to the touch of the mother's abdomen: A Frame-by-frame analysis

1. Abstract

The aim of the present study was to examine whether fetuses respond to the touching of the mother's abdomen, and if they do, whether they differentiate based on familiarity and the source of the touch, utilizing 3D real-time (4D) sonography. Behavioral responses of 28 fetuses (20th to 33rd week of gestation; N=15 in the 2nd and N=13 in the 3rd trimester) were frame-by-frame coded using a coding system comprising 20 codes and were analyzed in four conditions, during the touch of the (1) mother, (2) the father, (3) the stranger and in a (4) no-touch, control condition.

Fetuses showed differential responses to the touch, in particular in the duration of their reaching out to touch the uterus wall in the four conditions, and self-touch, dependent on the gestational age of the fetus. Fetuses in the 3rd trimester touched the uterus wall significantly longer than fetuses in the 2nd trimester did, when the mother touched compared to the control condition. At the same time, fetuses in the 3rd trimester also touched themselves less during the mother's touch, compared when the stranger touched and also compared to the control condition.

This differential response of the older fetuses might be due to the maturation of the central nervous system, and may indicate the emergence of a proprioceptive self-awareness by the 3rd trimester.

Keywords: fetus, prenatal, fetal development, tactile stimulation, behavioral analysis, fetal behavioral responses

1.1 Acknowledgements

The Authors thank all the mothers who have participated in this study, Edwin Savage for equipment, technical assistance and support, Lisa Korhonen for reliability coding and special thanks to John Morris Chief Technician and Fariad Umar technician for their assistance.

1.2 Funding

This research did not receive any specific grant from funding agencies in the public, commercial, or not-for-profit sectors.

2. Introduction

The first sense to emerge during ontogenesis, around 8 weeks of gestation, is touch (Hooker, 1952; Humphrey & Hooker, 1959; Piontelli et al., 1997).

The developing fetus is constantly touched by its environment, the placenta, the umbilical cord, amniotic fluid, and the uterine surface and touches its body passively or actively as self-initiated movements develop. From 26 weeks of gestation the fetus starts actively responding to vibration stimuli with heart rate acceleration (Kisilevsky, Muir, & Low, 1992) and increased movement rates (Kisilevsky, Gilmour, Stutzman, Hains, & Brown, 2012). Their reactivity to vibration steadily increases and then stabilizes by 32 weeks of gestation.

The fetus prefers to touch body areas that are densely innervated and are more sensitive such as the skin of the face with rich trigeminal innervation. Hand-to-face interaction appears early on (Myowa-Yamakoshi & Takeshita, 2006) and the aim of such movements are becoming goal-oriented (Trevarthen, 1985), that is intentionally initiated by 22 weeks of gestation (Zoia et al., 2007) while other body areas such as the stomach and the thorax are rarely touched.

In the last 4-5 weeks of gestation the fetus increasingly touches the nape, often with both hands (Piontelli, 2015). The feet are another sensitive area and with their disproportionately long arms, fetuses frequently touch their feet and their feet against the uterine wall and mothers often report feeling such movement. Fetuses rarely touch their backs or buttocks actively, but these areas often passively touched or pushed against the uterine wall.

A large body of research shows evidence for the importance of touch and somatosensory stimulation to health, early development and growth. Premature neonates for example show facilitated growth, increased weight gain (Diego, Field, & Hernandez-Reif, 2004; Vickers, Ohlsson, Lacy, & Horsley, 2004; Wang, He, & Zhang, 2013), better sleep (Dieter, Field, Hernandez-Reif, Emory, & Redzepi, 2003), and better cognitive development, orientation, motor skills, and higher state-regulatory and habituation scores on the Brazelton Neonatal Behavioural Assessment Scale (Brazelton, 1973; Field et al., 1986; Mathai, Fernandez, & Mondkar, 2001; Scafidi et al., 1986) after massage. Tactile stimulation was found to be beneficial to the mother as well (Field et al., 1986) and reduces stress levels both in the infant and the mother (Neu, Laudenslager, & Robinson, 2008).

The mother is a special source of somatosensory stimulation during fetal development. It is plausible to assume that mothers' touch of the abdomen during pregnancy affects the fetus directly via external tactile stimulation exerted by the pressure of the hands via the abdomen and via internal maternal muscle and accompanying body movements.

Mothers automatically engage in tactile stimulation of their abdomen, 'rubbing their bellies' in order to feel, to calm, to stimulate, or to interact with the fetus. This abdominal stimulation exerts a slight pressure, and as a result, the abdomen, including the uterine environment move and thus, passively stimulate and touch the fetus. Such stimulation is often related to the mental and emotional state of the mother. Although maternal touching the abdomen during pregnancy is a very common indirect sensory-motor tactile stimulation affecting the fetus, it has been scarcely studied before our recent research (Marx & Nagy, 2015) that reported an initial exploration on fetal responsiveness to maternal voice and touch and found an increase in fetal body movements to maternal touching the abdomen. Fetuses increased their arm, mouth and head movements when the mother touched the abdomen compared to when the mother just spoke or did nothing in a control condition.

The aim of the present study was to first confirm whether fetuses respond to the touching of the mother's abdomen, and if they do, whether they differentiate based on the familiarity and the source of the touch.

There are anecdotal observations that during early pregnancy fetuses tend to move away from stimuli that touch their bodies, whereas later they tend to move towards the stimulation (Hooker, 1952; Valman & Pearson, 1980). Based on the background literature and our previous study, it is expected that fetuses respond to the tactile stimulation with increasing movement, especially later in pregnancy, in the third trimester. Our previous research (Marx & Nagy, 2015) suggests that the fetuses displayed an arousal response to maternal 'tactile stimulation' that is when the mother was touching her abdomen. The present study aims to compare different types of abdominal touch as well as control, no-touch condition. When the mother is touching her abdomen, the stimulation is not only familiar to the fetus (given the mother touched her abdomen numerous times during pregnancy) but is also congruent with the movement that accompanies the maternal abdominal touch.

In comparison, the touch by the father of the mother's abdomen is likely also be familiar to the fetus, but the pressure is entirely external, that is not accompanied by congruent movements of the mother, who lays still while the father is touching her abdomen. If, however, a stranger touchers the mother's abdomen, it is neither familiar nor congruent with the movement of the mother.

3. Materials and Methods

3.1 Participants

28 Mothers with singleton pregnancy in their 20-35 gestational weeks (mean = 26.64 weeks, SD = 4.79) took part in the study. Fifteen fetuses were in the second trimester ('younger' fetuses ≤ 27 gestational weeks) and 13 in the third trimester ('older' fetuses >27 gestational weeks).

Mothers were 18 - 35 years old (Mean = 26.64, SD = 4.73), with a normal BMI before pregnancy. None of the mothers reported history of drinking, smoking or use of drugs during the pregnancy and all had the 20-week scan completed confirming that the development and the health of the fetus as well as the pregnancy had no known complications.

All mothers signed the informed consent prior participation and the study was approved by the ethics committee of the University of Dundee (No. UREC 15068).

3.2 Ultrasound methodology

A 'GE Voluson e' Ultrasound System with 'RAB4-8-RS4D' probe and water based conductive ultrasound gel was used to perform the 4D ultrasound scan. The scan was recorded on an Apple 'MacBook Pro' (13 inch, MBP7,1 MC375xx/A) laptop using 'Game Capture HD' software for 'MAC OS X' from Elgato. The laptop was connected to a high definition game recorder, 'Elgato Game Capture HD', which was connected to the 'Voluson e' via VGA to HDMI converter. The signal, via the 'Elgato Game Capture HD' was sent to a 22inch wide screen LCD monitor (DGM L-2254WD) positioned at the end of the scanning bed on a table, which allowed the participants to follow the scan comfortably. A 'Sony HDR CX220E' camera mounted on a tripod was used to record both video and audio of the mothers, fathers, and strangers' interactions framing the participant's face and stomach, to capture tactile stimulation, including the screen of ultrasound system to allow for later synchronization during analysis if it was needed.

3.3 Procedure

The experiment took place in the morning hours in a semi-darkened room of the Developmental Neuropsychological laboratory of the School of Psychology at the University of Dundee. Participants were presented with the participant information sheet that described the procedure in detail, a consent form, and after signing the informed consent, a demographic questionnaire was administered prior to the scan. Participants received no incentive other than a free scan and a copy of the scan on DVD for their participation.

3.4 Calibration of the touch stimulus: training of the stranger and father

This experiment aimed at stimulating the fetus via touching the mother's abdomen by the mothers, fathers, and stranger and comparing these conditions to a control, no touch condition.

Although the 'stranger' was the same throughout the experiment and had a significant experience working with mothers and perinatal infants, and the father might have touched the mother's abdomen numerous times during the pregnancy, they may be completely or partially unfamiliar with how the mother touches her abdomen. The style of the tactile stimulation she uses, the gentle pressure and range of motion applied through the abdominal wall is likely to be unique to every mother. The touch of the stranger and the father therefore were 'calibrated' prior to the experiment in order to ensure that the tactile stimulation was safe and more similar to the pressure and the nature of the touch the mother provided throughout the pregnancy. That also tried to reduce the variability of the stimulation. Mothers were asked to lie on the scanning bed, using a pillow behind their head to achieve a comfortable scanning position and then to touch their abdomen as she would naturally do. The father and the stranger observed the positioning and movement of the touch. More often than not the mother verbally also explained how she was normally ‘stroking’ her abdomen. Following the mothers’ stimulation, that lasted approximately 3-5 seconds, the father and stranger were asked in turn to touch the abdomen the same way and the mother provided feedback on the movement and the pressure. A short break was administered between calibration and experimental procedure.

The experimenter conducting the scan sat next to the scanning bed. Before the experiment began, and after the calibration of the touch was completed, the state and the position of the fetus was assessed utilizing 2D ultrasound. Depending on the fetal position, whenever it was possible 4D scan was administered. During the scan, depending on fetal movements and rotation 4D might have been dispensed and a 2D scan was administered until further 4D acquisition was possible. Therefore, the fetus could be observed throughout the experiment without any interruptions. The acquisition window framed the fetal head and upper torso including face, and arms/ hands at all times.

The experiments consisted of four within-subjects’ conditions (see Figure 1.). Participants were scanned for two minutes without any stimulation in complete silence (pre-stimulus), which was followed by two minutes of stimulation (tactile stimulation by mother, father, stranger) and ended with two minutes of no stimulation (post-stimulus). During the control condition participants were scanned for 6 minutes without stimulation. The total scanning time was 24 minutes.

All conditions were counterbalanced and randomized across participants. Participants received a non-verbal signal from a research assistant, who monitored the start and stop times with a stopwatch. Between conditions the mothers were given a short break before the experiment resumed with the next condition.

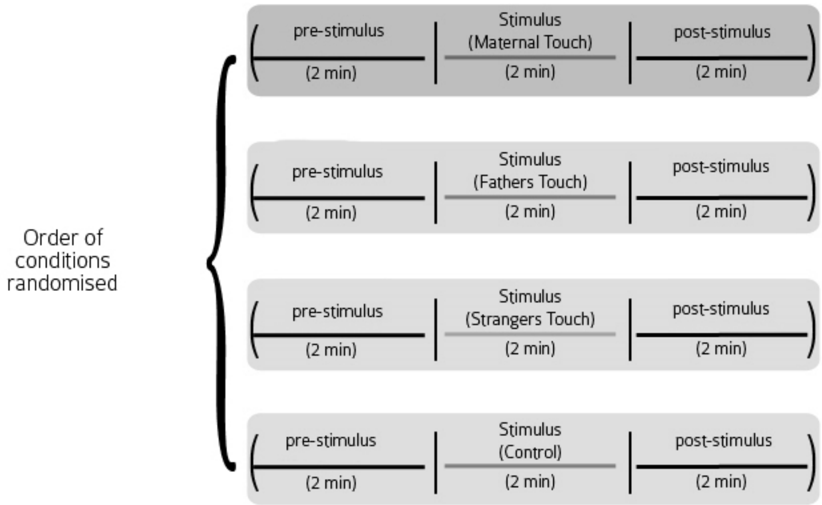

Figure 1. Overview of experimental procedure.

3.5 Coding and coding system

The behavior of the fetuses was coded using frame-by-frame coding with the Noldus Observer System (Noldus Institute Technology, 2003). After initial explorations of the scans, a coding system was designed that consisted of 20 variables such as arm movements, head movements, mouth movements, hands touching the body/face, arms crossed, and yawning. Both frequencies and the durations of the movements were coded and analyzed by the Observer system.

Fetal touch was divided into self-touch of the own body, self-touch of the face and touching of the uterine environment. Self-touch of the body included the fetus touching its body with its hands but not the face. Facial touch describes the fetus touching its head including face with one or both hands. Touching the uterine environment was coded when fetus touched the uterine wall or placenta with either hand. A combined self-touch code was also computed from the summary of the self-touch of the body and the self-touch of the face.

Two common positions of the arms and hands were coded. ’Arms crossed’ describe the crossing of the arms in front of the body or the face. ‘Hands crossed’ was coded when the hands were in front of the face and the fists were touching one another. Hand movements were coded when the hands moved other than crossing, and isolated finger movements were also coded. Body rotation was coded when the body of the fetus was visibly turning towards or away from the probe.

Mouth movements were coded when the fetus was opening and closing its mouth, while yawning was a separate code. Tongue protrusion was coded when the fetus stuck its tongue out. Sucking was coded when repetitive mouth and lip movements were observed. Hiccups were coded when the intercostal muscles and diaphragm contracted accompanied by jerky movements. Fetal breathing was coded when repetitive inward movements of the chest wall were observed accompanied by a simultaneous outward movement of the abdominal wall. Fetal stretch was coded when the fetus erected, ‘stretched’ its torso and tilted its head backwards and this movement lasted for longer than 2 seconds.

Finally, fetal kicking of the legs was coded when it was visible, although often the legs were not visible from the scanning window.

3.6 Reliability coding

11.2% of the entire dataset were reliability coded by a trained second coder. Inter-rater reliabilities for frequency ranged from 82.14% to 100% with an average of 92.27% and Cohen's kappa ranged from 0.80 to 1.00 with an average of .91. Inter-rater reliabilities for duration ranged from 72.02% to 100% with an average of 91.98% and Cohen's kappa ranged from 0.70 to 1.00 with an average of .92.

4. Results

From the coded variables, fetuses touching the uterus and the arms crossed and the combined self-touch duration variables were analyzed and reported here.

A mixed design ANOVA assessed the effect of Condition (Control, Mother, Father, Stranger) and GA on the duration of the fetuses touching the uterus ('Uterus touch'). There was a significant Condition * GA interaction, $F(3, 78) = 3.17$, $p = .029$, $\eta_p^2 = .11$, while no main effects of Condition $F(3, 78) = 1.14$, n.s., or GA $F(1, 26) = 0.01$, n.s. were found.

Post-hoc pairwise comparison showed that older fetuses tended to touch the uterus longer in the 'Mother' (M = 32.99) compared to the 'Control' condition (M = 1.00; p = .095). Also, older fetuses had a tendency to touch the uterus for longer in the 'Stranger' (M = 30.10) compared to the 'Control' condition (M = 1.00; p = .097).

In the 'Stranger' condition older fetuses touched the uterus significantly longer (M = 30.10) compared to younger fetuses (M = 4.69; p = .033) while in the 'Control' condition older fetuses touched the uterus for significantly shorter time (M = 1.00; p = .030) compared to younger fetuses (M = 26.82).

No further effects were found. The means and standard errors can be examined in Table 1 and Figures 2 and 3.

Table 1. Means and standard errors (SE) of fetuses 'Uterus touch' duration across conditions and gestational ages as well as pairwise comparisons.

	Younger Fetuses (<27 weeks GA)		Older Fetuses (=> 28 weeks GA)		Across conditions	
	Mean	SE	Mean	SE	Mean	SE
Across GA	19.13	4.46	19.56	4.79		
Control	26.82	7.68	1.00	8.25	13.91	5.63
Mother	24.66	10.26	32.99	11.02	28.83	7.53
Father	20.33	8.02	14.16	8.62	17.25	5.89
Stranger	4.69	7.70	30.10	8.27	17.39	5.65

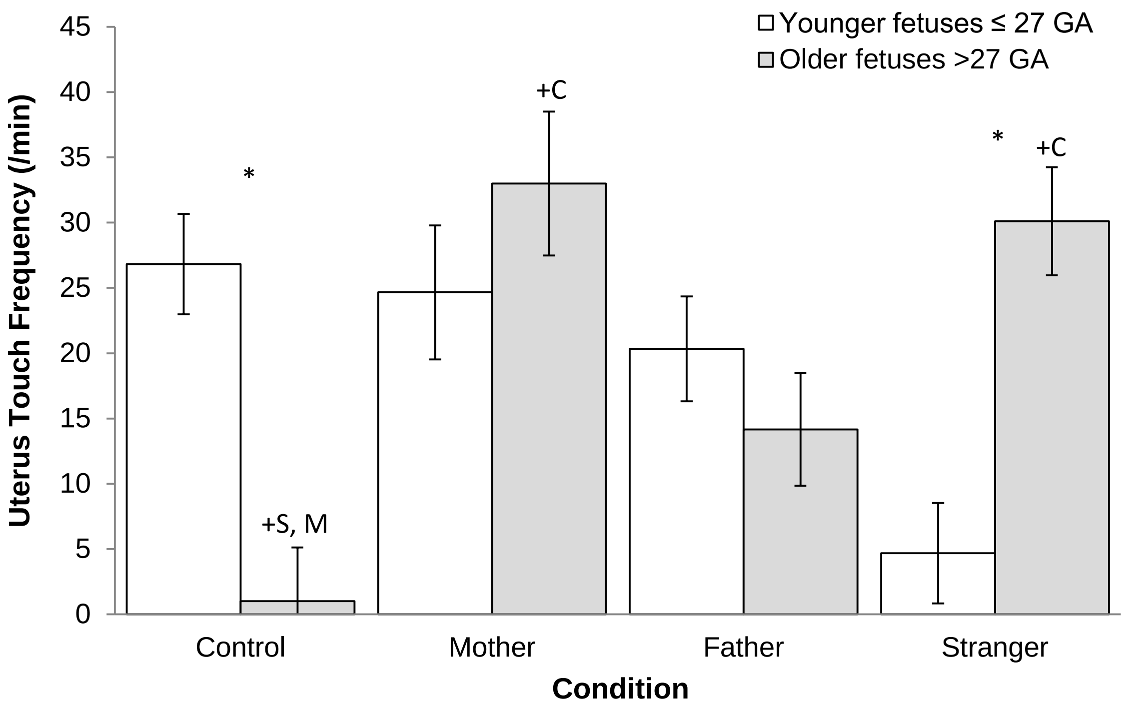

Figure 2. Average 'Uterus touch' duration (in seconds) including standard errors for all four conditions across gestational ages (younger and older fetuses) (+< .10, *<.05).

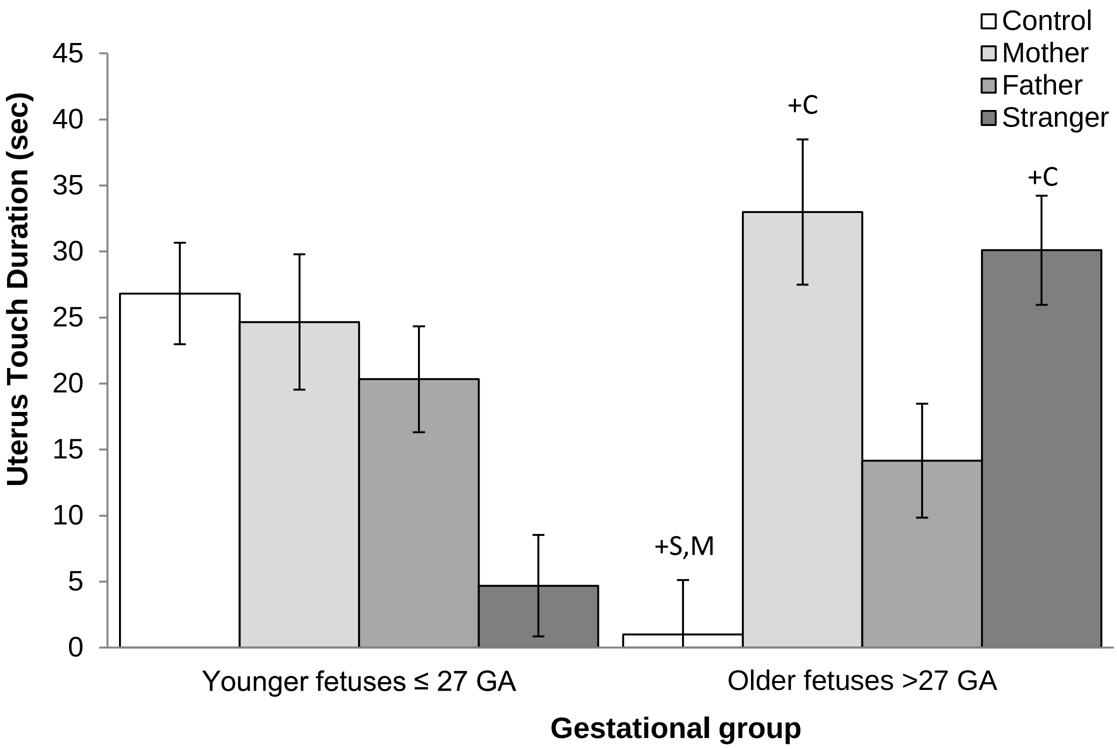

Figure 3. Average 'Uterus touch' duration (in seconds) including standard errors for all four conditions between gestational ages (younger and older fetuses) (+< .10, *<.05).

Further mixed-design ANOVA showed an age-related difference in the length of time fetuses spent with crossed arms $F(1, 26) = 4.99$, $p = .034$, $\eta_p^2 = .16$ but the main effect of Condition did not influence this behavior $F(3, 78) = 1.88$, n.s. and the GA*Condition interaction was not significant $F(3, 78) = 1.73$, n.s..

Post-hoc pairwise comparison of the main effect of GA showed that older fetuses displayed longer 'Arms-crossed' (M = 27.05) behaviors compared to younger fetuses (M = 10.04; $p = .034$). The means and standard errors can be examined in Table 2 and Figure 4.

Table 2. Means and standard errors (SE) of fetuses 'Arms-crossed' duration across conditions and gestational ages as well as pairwise comparisons.

	Younger Fetuses	Older Fetuses

	(<27 weeks GA)		(=> 28 weeks GA)		Across conditions	
	Mean	SE	Mean	SE	Mean	SE
Across GA	10.04	5.19	27.05	5.58		
Control	12.18	9.80	31.67	10.52	21.93	7.19
Mother	8.74	6.16	8.35	6.61	8.55	4.52
Father	11.72	9.02	23.56	9.69	17.64	6.62
Stranger	7.53	9.54	44.63	10.25	26.08	7.00

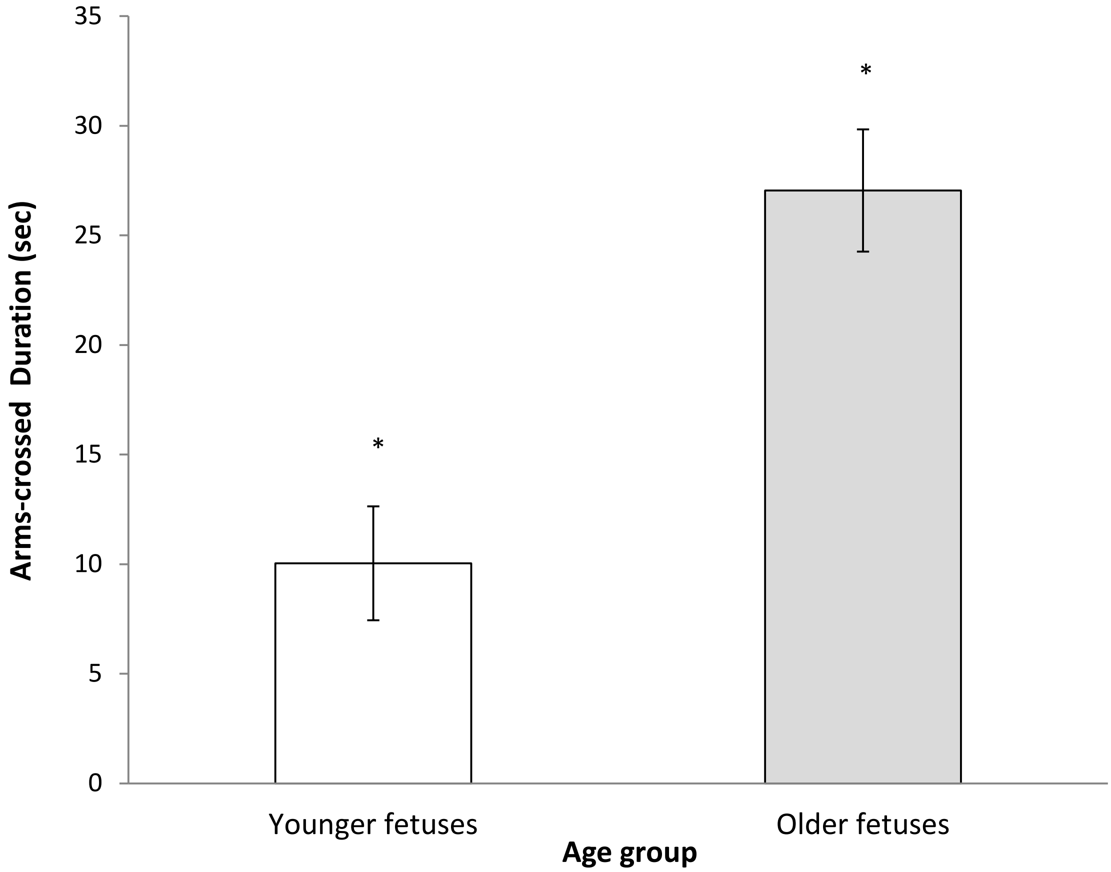

Figure 4. Average ‘Arms-crossed’ duration (in seconds) including standard errors for GA (younger and older fetuses) (*< .05).

A mixed ANOVA was conducted to assess the effect of Condition (Control, Mother, Father, Stranger) and GA on the duration of ‘Self-touch’, computed from the summary of ‘self-touch of the face’ and ‘self-touch of the body’ codes. Results showed a significant interaction between Condition and GA, F (3, 78) = 2.83, p = .044, η_p^2 = .10

and a tendency of main effect of Condition F (3, 78) = 2.19, p = .096, η_p^2 = .08. No main effect of GA F (1, 26) = 0.17, p = .898, $\eta_p^2 < .001$, was found.

Post-hoc pairwise comparison of the interaction between Condition and GA revealed that older fetuses (M = 9.75) engaged in significantly longer 'Self-touch' compared to younger fetuses (M = 7.19, p = .033) in the 'Control' condition, but a significantly shorter duration of 'self-touch' in the 'Stranger' condition (younger fetuses M = 9.27; older foetuses, M = 6.61, p = .034).

When directly cross-comparing the conditions, older foetuses engaged in shorter 'Self-touch' in the 'Mother' (M = 5.87, p = .047) compared to the 'Control' (M = 9.75), and also a had tendency for a shorter 'self-touch in 'Stranger' (M = 6.61) compared to the 'Control' (M = 9.75, p = .069) condition. No further effects were found. The means and standard errors can be examined in Table 3 and Figures 5 and 6.

Table 3. Means and standard errors (SE) of fetuses 'Self-touch' duration across conditions and gestational ages as well as pairwise comparisons.

	Younger Fetuses (<27 weeks GA)		Older Fetuses (=> 28 weeks GA)		Across conditions	
	Mean	SE	Mean	SE	Mean	SE
Across GA	7.45	0.42	7.53	0.45		
Control	7.19	0.78	9.75	0.84	8.47	0.57
Mother	6.49	1.07	5.87	1.15	6.18	0.78
Father	6.83	0.89	7.87	0.95	7.35	0.65
Stranger	9.27	0.81	6.61	0.87	7.94	0.59

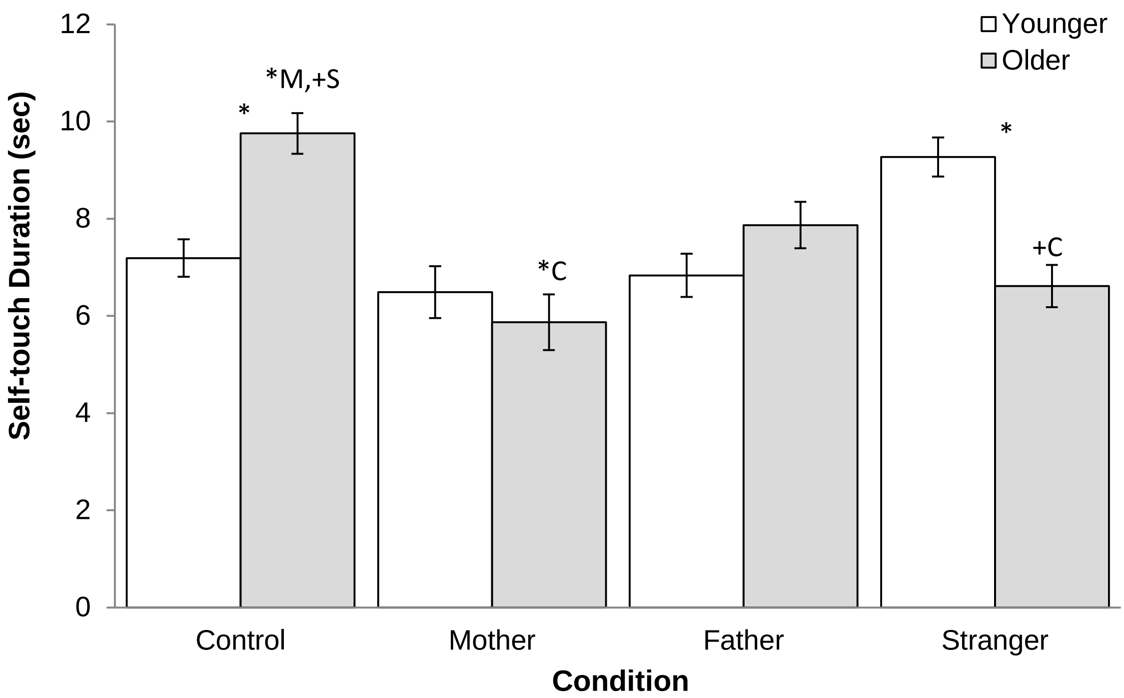

Figure 5. 'Self-touch' duration (Mean, in seconds) and standard errors (SE) for each condition (+< .10, *<.05) in younger and older fetuses.

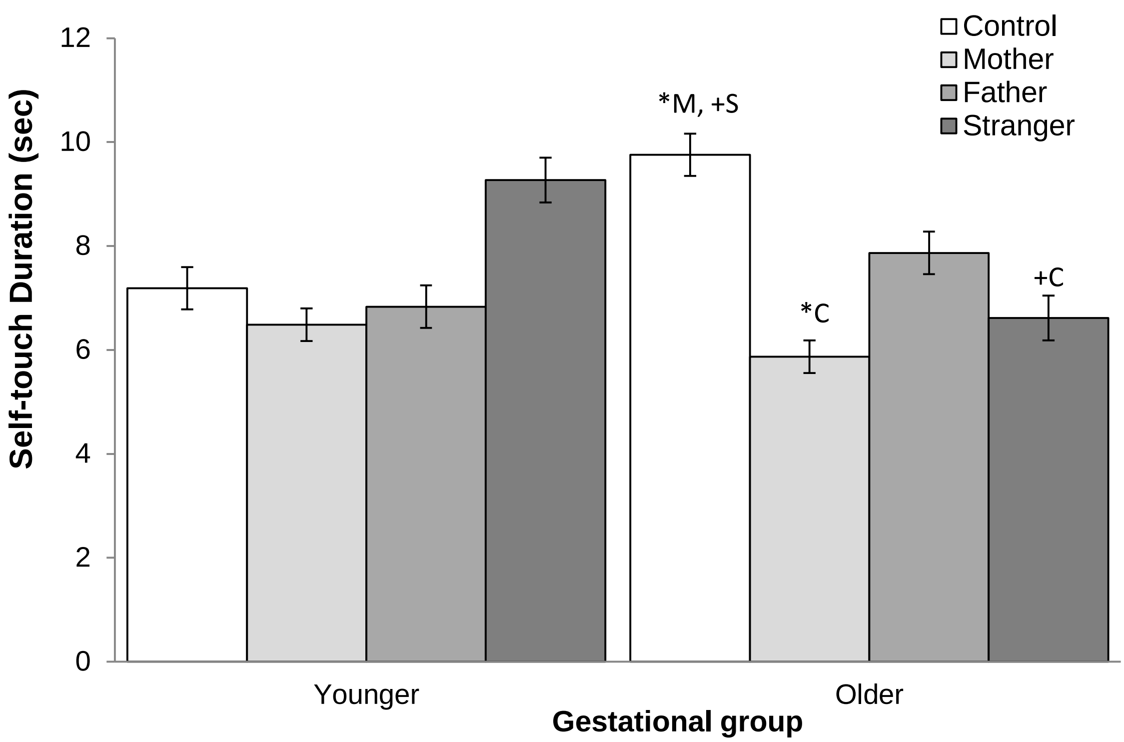

Figure 6. Average 'Self-touch' duration (in seconds) with standard errors for all four conditions in younger and older fetuses (+< .10, *< .05).

5. Discussion

In summary, the results of this study revealed that fetuses, in particular, older fetuses in the third trimester, behaved differently when someone touched the mothers' abdomen compared to when no touch occurred. Fetuses in the third trimester had a tendency to reach out and to touch the uterus wall when the mother touched her abdomen, compared to when there was no touch, in the control condition. Also, when the stranger experimenter touched the mother's abdomen, older fetuses touched the uterus wall significantly longer than young fetuses did. Additionally, fetuses in the third trimester also touched themselves less during the mother's touch, compared when the stranger touched and also compared to the control condition.

Overall, younger, second trimester fetuses seemed to show no differential responses to the presence of the touch on the mother's abdomen. In light of the tendency results for the post-hoc comparisons, it is important to note that the effect sizes for the main effect and the interaction were moderate-to-large, according to Cohen (1988).

These results support the observations by Valman and Pearson (1980) and Hooker (1952) that older fetuses tend to move towards sensory-motor stimulation (Hooker, 1952; Valman & Pearson, 1980). Similarly to these observations older, third trimester, but not the younger, second trimester fetuses reached out to the uterus wall when the mother's abdomen was touched. The results also confirm our previous data that reported that fetuses, in particular in the third trimester increase some of their movements as a response to the touch of the mother's abdomen (Marx & Nagy, 2015). This differential response of the older fetuses might be due to the maturation of the central nervous system (CNS). During the third trimester of pregnancy the CNS continues the maturation, neuronal differentiation, lamination, and the distribution of the thalamocortical axons. It is about between the 26-28th weeks of gestation when the peripheral nervous system connections with the CNS become functional (Craig, 2002; 2011; Kida & Shinohara, 2013; J. J. Marx et al., 2005; McGlone, Wessberg, & Olausson, 2014; Klimach & Cooke, 2008; Kostović, Judas, Rados, & Hrabac, 2002), which in turn, allows the fetus to process and to react to external somatosensory and pressure stimuli.

Mothers often and automatically rub their abdomen so much that this activity often resembles a form of massage. Massage therapy under experimental conditions is usually applied to the hands, feet, neck, head, back in the mothers (Field, Hemandez-Reif, Hart, Theakston, Schanberg, & Kuhn, 2009b) and has been found to be an effective intervention. Massage therapy reduced anxiety in pregnant women, in particular anxiety during labor, decreased the levels of cortisol and norepinephrine (Field, 2010) and symptoms of depression in pregnant women (Field, Diego, Hernandez-Reif, Schanberg, & Kuhn, 2009a). Massage therapy showed to be superior even over relaxation therapies in reducing anxiety, pain, back pain, improving mood and sleep (Field, Diego, Hernandez-Reif, Schanberg, & Kuhn, 2009a). One of the main outcomes of massage therapy during pregnancy was the fewer complications during labor, improved neonatal outcomes as measured by the Neonatal Behavioural Assessment Scale (Brazelton, 1973) and the reduction of premature birth rate. The effects were maintained even when the massage was administered by the partner (Field et al., 2008).

Field and her colleagues proposed a model (Field, Diego, Hernandez-Reif, Schanberg, & Kuhn, 2009a; Morris & Weinstein, 1981) that explains how massage increases the level of serotonin and decreases norepinephrine and cortisol levels and in turn, decreases symptoms of depression, reduces leg and back pain, and anxiety. Such biochemical changes are suggested to lead to a lower rate of prematurity in the baby as one of the main outcomes of massage therapy research in pregnant women.

The nature of the touch however, is also important. A reason the present study employed 'calibration' of the touch was that previous research found significant differences in the effects of light versus moderate pressure massage (Diego et al., 2004; Field, Diego, Hernandez-Reif, Schanberg, & Kuhn, 2009a). Moderate but not light pressure stimulation activates the vagal nerve, and via vagal stimulation, influences the cardio-respiratory and gastro-intestinal system, including increased absorption and motility (Field, Diego, Hernandez-Reif, Schanberg, & Kuhn, 2009a). The evolutionary newer branches of the vagal nerve also have a hypothesized function in promoting social affiliation and attachment (Porges, 1995). It is likely that mothers naturally use an optimally moderate pressure that is adjusted to their weight, body type and perhaps the stage of pregnancy, thus the feedback from the mother was essential to reduce the variability of the touch by the stranger and the father.

Although it is plausible to assume that fetuses would selectively respond to maternal touch via the abdomen and differently to the touch of the father and stranger, this assumption was not fully supported by the data. Fetuses reacted differently to the control condition compared to both when mother and stranger touched but not when the father touched the mother's abdomen. It is possible that the stranger, confederate experimenter, learned to rub the mother's abdomen quickly as she gained experience throughout the experiment – thus she was quicker in learning and adapting to different types and styles of touches the mothers taught her. It is likely that fathers slipped back into their usual style of touch they have always used when touching the mother's abdomen. It is also likely that the strength of the pressure differed and might not have consistently reached 'moderately' strong pressure to have an effect on the fetus.

Overall, older but not younger fetuses responded to the touch, rubbing of the maternal abdomen by moving towards the stimulus and touching the uterine wall. Older fetuses therefore were more capable of reacting differentially to stimulation versus no stimulation, compared to younger fetuses. This general difference in the activity between age groups gave support to our earlier report (Marx & Nagy, 2015) that found that older fetuses spent a longer time with crossed arms, suggesting less motor activity, longer quiet periods overall.

Generally, touch is a basic sense that lays the foundations of the body schema and the neurophysiological bases of the sense of self via me – not me discrimination (de Preester & Knockaert, 2005; Gallagher, 1995) from very early in the development. This body schema is suggested to be an unconscious awareness of the own body in space, in relation to posture and movements. Gallager (1995) argues that in the most primitive way, proprioceptive awareness is possibly developed by the third trimester of pregnancy and is a form of self-consciousness of the embodied-self (Gallagher, 1995). Via touch, the mother and the fetus are sharing one another's embodied vitality as a form of shared sympathy a meaning shared with others (Trevarthen, 2012).

Although the study attempted to control for the inexperience of the stranger and the father, by 'calibrating' the touch, that is training them to apply touch that is likely to be perceived by the fetus but not too strong or even dangerous or unusual; this effort might have flattened any results that could be due to fetus' familiarity to the touch of the father, as opposed to the touch of the stranger, who has never touched the mother's abdomen before. Future studies need to systematically explore the possible effects of familiarity, the effect of the contingency of the maternal touch and the developmental stage in the behavioural responses of the fetuses.

References

Brazelton, T. B. (1973). Neonatal Behavioral Assessment Scale. Philadelphia Heinemann. http://doi.org/10.1016/j.neuro.2009.04.001

Craig, A. D. (2002). How do you feel? Interoception: the sense of the physiological condition of the body. *Nature Reviews Neuroscience*, *3*(8), 655–666. http://doi.org/10.1038/nrn894

Craig, A. D. B. (2011). Significance of the insula for the evolution of human awareness of feelings from the body. *Annals of the New York Academy of Sciences*, *1225*, 72–82. http://doi.org/10.1111/j.1749-6632.2011.05990.x

de Preester, H., & Knockaert, V. (2005). Body Image and Body Schema. John Benjamins Publishing.

Diego, M., Field, T., & Hernandez-Reif, M. (2004). Fetal responses to foot and hand massage of pregnant women. *In Early Child Development*.

Dieter, J. N. I., Field, T., Hernandez-Reif, M., Emory, E. K., & Redzepi, M. (2003). Stable preterm infants gain more weight and sleep less after five days of massage therapy. *Journal of Pediatric Psychology*, *28*(6), 403–411. http://doi.org/10.1093/jpepsy/jsg030

Field, T. (2010). Developmental Review. *Developmental Review*, *30*(4), 367–383. http://doi.org/10.1016/j.dr.2011.01.001

Field, T. M., Schanberg, S. M., Scafidi, F., Bauer, C. R., Vega-Lahr, N., Garcia, R., et al. (1986). Tactile/kinesthetic stimulation effects on preterm neonates. *Pediatrics*, *77*(5), 654–658.

Field, T., Diego, M. A., Hernandez-Reif, M., Schanberg, S., & Kuhn, C. (2009a). Massage therapy effects on depressed pregnant women. *Journal of Psychosomatic Obstetrics & Gynecology*, *25*(2), 115–122. http://doi.org/10.1080/01674820412331282231

Field, T., Figueiredo, B., Hernandez-Reif, M., Diego, M., Deeds, O., & Ascencio, A. (2008). Massage therapy reduces pain in pregnant women, alleviates prenatal depression in both parents and improves their relationships. *Journal of Bodywork and Movement Therapies*, *12*(2), 146–150. http://doi.org/10.1016/j.jbmt.2007.06.003

Field, T., Hemandez-Reif, M., Hart, S., Theakston, H., Schanberg, S., & Kuhn, C. (2009b). Pregnant women benefit from massage therapy. *Journal of*

Psychosomatic Obstetrics & Gynecology, *20*(1), 31–38. http://doi.org/10.3109/01674829909075574
Gallagher, S. (1995). Body schema and intentionality. In J. L. Bermundez, A. J. Marcel, & N. Eilan (Eds.), *The Body and the Self* (2nd ed., pp. 225–244). Cambridge, Massachusets: MIT Press. Retrieved from http://books.google.com/books?hl=en&lr=&id=hwBh9nDDDFQC&oi=fnd&pg=PA225&dq=Body+schema+and+intentionality+body+schema+and+intentionality&ots=Y-bDdbFDSF&sig=_lNoW3hJa-aZCrOa0IvSjV-Eo_c
Hooker, D. (1952). Early human fetal activity. *The Anatomical Record*, *113*(4), 503–504.
Humphrey, T., & Hooker, D. (1959). Double simultaneous stimulation of human fetuses and the anatomical patterns underlying the reflexes elicited. *The Journal of Comparative Neurology*, *112*, 75–102. http://doi.org/10.1002/cne.901120110
Kida, T., & Shinohara, K. (2013). Gentle touch activates the prefrontal cortex in infancy: an NIRS study. *Neuroscience Letters*, *541*, 63–66. http://doi.org/10.1016/j.neulet.2013.01.048
Kisilevsky, B. S., Gilmour, A., Stutzman, S. S., Hains, S. M. J., & Brown, C. A. (2012). Atypical fetal response to the mother's voice in diabetic compared with overweight pregnancies. *Journal of Developmental and Behavioral Pediatrics : JDBP*, *33*(1), 55–61. http://doi.org/10.1097/DBP.0b013e31823e791e
Kisilevsky, B. S., Muir, D. W., & Low, J. A. (1992). Maturation of Human Fetal Responses to Vibroacoustic Stimulation. *Child Development*, *63*(6), 1497–1508. http://doi.org/10.1111/j.1467-8624.1992.tb01710.x
Klimach, V. J., & Cooke, R. W. I. (2008). Maturation of the neonatal somatosensory evoked response preterm infants. *Developmental Medicine & Child Neurology*, *30*(2), 208–214. http://doi.org/10.1111/j.1469-8749.1988.tb04752.x
Kostović, I., Judas, M., Rados, M., & Hrabac, P. (2002). Laminar organization of the human fetal cerebrum revealed by histochemical markers and magnetic resonance imaging. *Cerebral Cortex (New York, N.Y. : 1991)*, *12*(5), 536–544. http://doi.org/10.1093/cercor/12.5.536
Marx, J. J., Iannetti, G. D., Thömke, F., Fitzek, S., Urban, P. P., Stoeter, P., et al. (2005). Somatotopic organization of the corticospinal tract in the human brainstem: a MRI-based mapping analysis. *Annals of Neurology*, *57*(6), 824–831. http://doi.org/10.1002/ana.20487
Marx, V., & Nagy, E. (2015). Fetal Behavioural Responses to Maternal Voice and Touch. *PLoS ONE*, *10*(6), e0129118–15. http://doi.org/10.1371/journal.pone.0129118
Mathai, S., Fernandez, A., & Mondkar, J. (2001). Effects of tactile-kinesthetic stimulation in preterms-A contolled trial. *Indian Pediatrics*.
McGlone, F., Wessberg, J., & Olausson, H. (2014). Discriminative and affective touch: sensing and feeling. *Neuron*, *82*(4), 737–755. http://doi.org/10.1016/j.neuron.2014.05.001
Morris, M. B., & Weinstein, L. (1981). Maternal caffeine intake may affect the fetus. *American Journal of Obstetrics and Gynecology*, *140*(607), 10–10. http://doi.org/10.1007/BF03313643
Neu, M., Laudenslager, M. L., & Robinson, J. (2008). Coregulation in Salivary Cortisol During Maternal Holding of Premature Infants. *Biological Research*

for Nursing, *10*(3), 226–240. http://doi.org/10.1177/1099800408327789
Noldus Institute Technology. (2003). *The Observer 5.0 Reference Manual*. Wageningen, The Netherlands.
Piontelli, A. (2015). Development of Normal Fetal Movements. Milano: Springer. http://doi.org/10.1007/978-88-470-5373-1
Piontelli, A., Bocconi, L., Kustermann, A., Tassis, B., Zoppini, C., & Nicolini, U. (1997). Patterns of evoked behaviour in twin pregnancies during the first 22 weeks of gestation. *Early Human Development*, *50*(1), 39–45. http://doi.org/10.1016/S0378-3782(97)00091-1
Porges, S. W. (1995). Orienting in a defensive world: mammalian modifications of our evolutionary heritage. A Polyvagal Theory. *Psychophysiology*, *32*(4), 301–318.
Scafidi, F. A., Field, T. M., Schanberg, S. M., Bauer, C. R., Vega-Lahr, N., Garcia, R., et al. (1986). Effects of tactile/kinesthetic stimulation on the clinical course and sleep/wake behavior of preterm neonates. *Infant Behavior and Development*, *9*(1), 91–105. http://doi.org/10.1016/0163-6383(86)90041-X
Trevarthen, C. (2012). Natural Sources of meaning in human sympathetic vitality. *Moving Ourselves*.
Trevarthen, C. B. (1985). Neuroembryology and the Development of Perceptual Mechanisms. In *Postnatal Growth Neurobiology* (pp. 301–383). Boston, MA: Springer US. http://doi.org/10.1007/978-1-4899-0522-2_13
Valman, H. B., & Pearson, J. F. (1980). What the fetus feels. *British Medical Journal*, *280*(6209), 233–234.
Vickers, A., Ohlsson, A., Lacy, J., & Horsley, A. (2004). Massage for promoting growth and development of preterm and/or low birth-weight infants. (A. Vickers, Ed.). Chichester, UK: John Wiley & Sons, Ltd. http://doi.org/10.1002/14651858.CD000390.pub2
Wang, L., He, J. L., & Zhang, X. H. (2013). The efficacy of massage on preterm infants: a meta-analysis. *American Journal of Perinatology*, *30*(9), 731–738. http://doi.org/10.1055/s-0032-1332801
Zoia, S., Blason, L., D'Ottavio, G., Bulgheroni, M., Pezzetta, E., Scabar, A., & Castiello, U. (2007). Evidence of early development of action planning in the human foetus: a kinematic study. *Experimental Brain Research*, *176*(2), 217–226. http://doi.org/10.1007/s00221-006-0607-3