FOETAL MUSIC PERCEPTION: A COMPARISON STUDY BETWEEN HEART RATE AND MOTOR RESPONSES ASSESSED BY APIB SCALE IN ULTRASOUND EXAMS.

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Abstract

Music perception on foetuses has been described in habituation, categorical perception, sound preferences and recall tests. This study investigated the temporal dimension of rhythm in foetuses of 41 pregnant women evaluating heart rate (HR) and motor response (movement and organization dimensions according to the Assessment of Preterm Infants Behaviour scale) during ultrasound exams. Folkloric lullaby was presented in three ways: from an external source at a slow; then fast pace; and sung by own woman at a slow pace. HR varied significantly between stages and decreased to baseline in response to maternal song. "Organization" was sensitive to the change between the first and last two stages indicating perception of sound source. "Movement" was sensitive when changed between the first and second stage. We conclude that foetuses showed behavioural and physiological response to different sound source and musical rhythm increasing and decreasing organization response and HR according to the pace.

The fascination with the study of perceptual abilities of the foetus started from late 1800, but only in 1885 Preyer carried out the first sensory experiences that detected the hearing ability of the foetuses. However, it was in 1980 the investigations began to be systematically controlled due to the sophisticated technology of ultrasound devices and foetal physiological monitoring, with the record of responses to stimuli that induce behavioural changes, particularly in heart rate and body movements (review in Kisilevsky & Low, 1998).

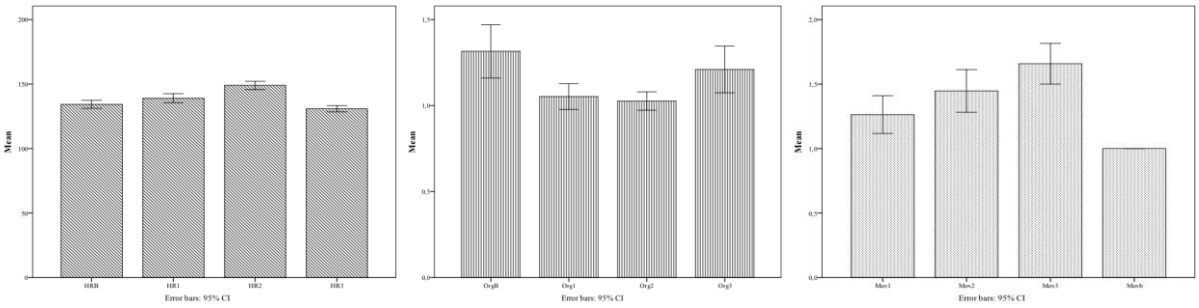
The hearing processing begins with the differentiation of sensory cells and cochlear maturity about 20 gestational weeks. The second phase of this process refers to the cochlea brain-stem auditory cortex axis development, in the third trimester, with its myelination reaching adult-like functioning at the end of the first year of life outside the womb. Hence, there are evidences that the foetuses can hear from the last trimester of pregnancy (Kisilevsky, Pang & Hains, 2000). Within thirty weeks of gestation the foetus has the capacity to respond to white noise of 110db SPL, with variation in heart rate and body movement, estimated that the attenuation caused by the womb environment was around 35dB (Querleu, Renard, Versyp, Paris-Delrue, & Crepin, 1988). Foetuses between 26 and 34 weeks gestation were able to discriminate vowel sounds between 100 and 110 dB (Zimmer et al., 1993). Groome et al. (1999) reported that foetuses between 36 and 40 gestational weeks responded to speech stimuli of 83 to 95 dB SPL, displaying heart rate decelerations to vowel sounds. Near term foetuses could also discriminate the reversal of pairs of consonant to vowel sounds (Lecanuet et al., 1987), as well as a change in gender of the speaker (Lecanuet, Granier-Deferre, Jacquet, Capponi, & Ledru, 1993). The findings show that the closer the end of pregnancy, the greater

the magnitude and frequency response and lower latency (Lecanuet, Granier-Deferre & Busnel, 1995 and reviews by Lecanuet & Schaal, 1996 and Kisilevsky & Low, 1998).

The hypothesis that the foetus recognizes and stores human voices and language to which he is exposed during pregnancy is confirmed by studies on the preference of the baby. Newborns prefer their mother's voice to that of a strange woman (DeCasper & Fifer, 1980), a story told by the mother during late pregnancy compared to a new story (DeCasper & Spence, 1986), and their native language compared to a foreign language (Moon, Cooper, & Fifer, 1993). As the foetus can hear at about thirty weeks, the music played in the external environment can be recognizable by him in the intra uterine environment (Querleu, Renard Boutteville & Crepin, 1988). Some studies have examined the effects of music on foetal behaviour using long periods of stimulation. Sontag, Steele and Lewis (1969) exposed 11 pregnant women at 28 weeks gestation to 10 minutes of their favourite-recorded songs listened at ear level with an average intensity of 75 dB (range 65 dB to 100 dB). They observed an increased foetuses heart rate of about five beats per minute occurred 90 seconds after the beginning of the song. There were no changes in foetal body movements and no change in maternal heart rate. The foetal heart rate returned to baseline levels within two minutes of the beginning of the song. Since the beginning of the response was late and there was no change in activity, the authors speculated that the foetal response was mediated through the mother's emotional reaction. Similarly, Zimmer et al (1982) postulated that changes in foetal behaviour in pregnant women between 34 and 40 weeks of pregnancy are mediated by hormonal changes, the same way as when exposed to music through headphones, the sound stimulus being masked to the foetus, it was observed that they showed a decrease in respiratory activity and increased body movement, as the mother listened to their favourite type of music, classical or rock. In short, there are evidences that the foetuses are able to respond to sound stimuli in the intra-uterine environment and heartbeat is one of the most consistent measurements used in studies. However, the measure of intra-uterus motor responses remains poorly defined.

Among the tools used for the study of sensory and perceptual behaviour of foetuses Doppler ultrasound has often been used and heart rate measurement has shown to be more consistent with the observation of the overall foetal movement (Fernando et al, 2003). However, it was not found in the literature, reports of wide application of motor behaviour study of the foetal response to musical stimuli. Among the scales that allow the study of the motor behaviour of the foetus or premature newborn there is the Assessment of Preterm Infants Behavior, called APIB (Als, 1988). The APIB, based on the Brazelton Newborn Behavioral Assessment Scale (NBAS, Brazelton & Nugent, 1995), provides further refinement of the identification of infants' self-regulatory efforts and thresholds to disorganization as viewed through aspects of the infant's behaviours referred to as subsystem interactions. In this scale the subsystems of the infant are formally observed and considered in terms of their organization and the items include factors such as autonomic, motor, state, attention, and self-regulation. In newborns, the exam proceeds through a series of manoeuvres that increase in vigour as well as tactile and vestibular demand. Further, the assessment examines the integrity of the infant's sleep organization, systematically elicited movement repertoire, and availability and quality of social interaction. The stability and organization of the infant's subsystems are continuously evaluated in their mutual interplay with each other, and in turn in their interplay with the examination's graded demands.

There are at least two important methodological limitations to the use of APIB and Doppler-ultrasound to the study of foetus's behavioural response that must be considered. The application of this scale while the foetus is inside the womb is limited to items based in global motor response to auditory stimulation that may represent both, auditory and attention skills.



(a) (b) (c)

Figure 1 – Mean score of the performance of the three parameters HR (a), organization (b) and movement (c) to four stages: baseline and the three categories of stimulus presentation.
Notes: HR= heart rate; Org= organization; Mov= movement; and the following B, 1, 2 and 3 indicate the basal level, first, second and third stimuli stage presentation, respectively.

The observation of the foetus' response to auditory stimuli throughout the Doppler ultrasound is complicated as the generated visual outputs often are blurred images and depends on trained professional to decipher and categorize them, turning difficult the operational definition and the application of inter-ratter concordance tests. Also, the accuracy of the motor response is limited to the register of presence or absence of global movements like startles or body dislocations that can be interpreted as to align, to go forth or back to the sound source. This study aims to compare the foetal response to musical stimuli by heart rate variability with foetal global movements and the reactions of approach items of APIB scale. The hypothesis of this study is that whether foetuses perceive the changing rhythm of the music they will be able to respond in terms of increased or decreased motor activity and the pursuit of sound source. The scores of the factors "global movement" and signs of "attention organization" will be correlated with the rate of heartbeat and analyzed to the experimental conditions.

Method

The sample consisted of 41 adult pregnant women, who attended the outpatient department of Obstetrics and Gynaecology in monitoring the pregnancy by a routine ultrasound. The average gestational age was 34,7 weeks (2,4 Standard Deviation, minimum and maximum of 30 and 40 gestational weeks). Foetuses showed no evidence of chromosomal, congenital, neurological abnormalities, or nutritional disorders. Not included were pregnant women whose foetuses show signs of foetal distress.

The record of movement and foetal heart rate was obtained by Doppler-ultrasound (Sonoline Versa Pro, Siemens, Germany), the examinations were performed by the same physician in a hospital room, in the context of ultrasound monitoring of clinical care in pregnancy following the protocol of maternal and child health program. The scale APIB was used to score the foetal behavioural response and were used two behavioural dimensions of this scale likely to be observed by ultrasound: motor organization (movement indicator) and atencional organization (organization indicator) considering, for the record, the frequency of the motor response and the presence of atencional response (aligning, approach or avoidance from the sound source). To establish the baseline of foetal behaviour, each patient was instructed to be silent for 90 seconds. The beginning of the presentation of all categories of sound stimuli was given only after there is no record of foetal movement and stabilization of heart rate for at least 90 seconds.

Sound stimuli were composed of three categories of voices singing a folk popular Brazilian music to children of public domain sung by: 1. adult male voice in slow pace (*Adagio*); 2. adult male voice at a fast pace (*Allegro*); and 3. pregnant women voice in the slow pace (*Adagio*). A stringed musical instrument (*cavaquinho*) accompanied all the voices sound stimuli. The *cavaquinhos*'s spectrum of acoustic frequencies varies between 1000 and 4000 Hz, similarly to the female voice (Richards, 2008). This arrangement using a musical instrument background stimulated a minimum of uniformity in rhythm and tone to all singers in such a way to minimize the effect of gender of voice and personal style of singing. The room's noise level was initially measured in a silence condition during one ultrasound procedure. The sound source, male voice and musical instrument, was at a distance of 30 cm from the abdomen and were issued at an average intensity of 80 dB in an environment with ambient noise level around 40 dB. Considering the level of internal and external noise, the external sound stimuli were issued in intensity noise level of offsetting the general (average intensity of both internal and external noise), with higher intensity than at least 40 dB of overall noise level. Each category of stimuli lasted a maximum of 90 seconds when the end all variables were measured.

Results and Discussion

The three indicators measured during the test, heart rate (HR), organization (O) and movement (M), showed a clear difference in patterns of response all over the four stages, basal (B) and the three experimental conditions (1, 2 and 3), as it can be seen at the Figure 1. The heart rate seems to keep in pace with the rhythm of the stimuli accelerating as the male voice accelerated and decreasing to lower level to the *adagio* mother's voice. The indicator organization showed an intriguing pattern of decrement to the male voice independent of the rhythm, and increasing to the *adagio* mother's voice, but still in levels bellow the baseline. Meanwhile, the indicator movement increased linearly with the session presentation schema. No significant correlation was found between indicators, but a poor negative one between the variables heart rate (HR3) and movement (M3) (r= -.33, p= .043) at the *adagio* mother's voice, indicating that there was an increment in movement and a decrement in heart rate when the mother's voice started.

Two-way ANOVA was run analyzing all variables having gestational age and basal heart rate as co-factors. Gestational age didn't have effect upon the variables and basal heart rate was only related to variations at heart rate of the male *allegro* pace (HR2) and *adagio* mother's voice (HR3) (Table 1). This last result was expected as the three indicators have had different patterns, as said above. However, it's noticeable that the basal level of heart rate (HRB) did not have significant effect upon the variables of the first stimuli presentation in this analyse.

Table 1. ANOVA of tested variables presenting only the variables that achieved significant levels with basal heart rate as factor.

		Sum of Squares	df	Mean Square	F	Sig.
HR2	Between Groups	1734,178	10	173,418	2,165	,050
	Within Groups	2402,798	30	80,093		
	Total	4136,976	40			
HR3	Between Groups	1329,343	10	132,934	3,615	,003
	Within Groups	1103,048	30	36,768		
	Total	2432,390	40			

Notes: HR2= heart rate experimental condition 2; HR3= heart rate experimental condition 3.

Table 2. Friedman Test comparing the four stages of the test by each indicator.

	Heart rate	Organization	Movement
N	41	38	38
Chi-square	59,451	16,424	37,556
df	3	3	3
Asymp. Sig.	,000	,001	,000

Table 3 - Wilcoxon Signed Ranks Test comparing each indicator in pairs of stages, subtracting the later minus the former.

	HR1 – HRB	HR2 – HR1	HR3 – HR2	O1 – OB	O2 – O1	O3 – O2	M1 – MB	M2 – M1	M3 – M2
Z	-2,082[a]	-5,021[a]	-5,264[b]	-2,887[b]	-1,000[b]	-2,333[a]	-3,162[a]	-1,807[a]	-1,789[a]
Asy. Sig. (2-tailed)	,037	,000	,000	,004	,317	,020	,002	,071	,074

a. Based on negative ranks; b. Based on positive ranks

Notes: O= organization; M= movement; and the following B, 1, 2 and 3 indicate the basal level, first, second and third stimuli stage presentation, respectively.

Considering each indicator independently, all had a significant variation all over the session (Table 2) being the heart rate the strongest parameter followed by movement and organization. The comparison between pairs of subsequent stimuli of each indicator shows a different result (Table 3). The indicator heart rate appears to be significantly different between all stages of stimuli presentation. Organization was significantly different between the basal level (OB) and the first presentation (O1) (*adagio* male voice) and between the second (O2) and the third stage (O3) (*allegro* male voice *versus adagio* mother's voice). Movement was only significant between the basal (MB) level and the first presentation (M1).

Conclusion

The data indicated that the rate of heart rate was confirmed as a strong parameter in this kind of study as it varied significantly between all stages of the test returning to baseline levels in response to maternal voice. Moreover, this indicator seems to follow the pace of the song at the stage 1 and 2. An interpretative doubt remains about the return to basal levels in stage 3, when the mothers sang the song, possible meaning a recognition ability to the mothers' voice or a decrement in the heart rate as the pace of the music also decreased. The organization indicator was sensitive only between the first two and last two stages possibly indicating a differential perception of sound source. Movement was sensitive only to the change between the basal and first second stage, despite of the fact that there was a general increment in movement. The kind of movement was unclear, though, not allowing the observation of possible different categories of fine movements as hand to mouth, sucking, swallowing, etc. Gestational age showed no significant effect on the variables studied indicating that the chosen range of gestational week was appropriated to this study. We conclude that foetuses showed behavioural and physiological response to different sound source and change of musical rhythm. The APIB factors that were investigated in this study are suitable as a measuring tool to study the foetal behaviour in the last 10 weeks of gestation and can be used as parameter for research in music perception in foetuses.

References

Als, H., Duffy, F.U., & McAnulty G.B. (1988). The APIB, an assessment of functional competence in preterm and full-term newborns regardless of gestational age at birth: II. *Infant Behavior and Development, 11*, 319-331.

Brazelton, T.B., Nugent, J.K. (1995). The Neonatal Behavioural Assessment Scale. Third edition. *Clinics in Developmental Medicine 137*. London: MacKeith Press,CUP.

DeCasper, A.J., & Fifer, W.P. (1980). Of human bonding: Newborns prefer their mothers' voices. *Science, 208,* 1174–1176. DeCasper, A.J., & Spence, M.J. (1986). Prenatal maternal speech influences newborns' perception of speech sounds. *Infant Behavior and Development, 9,* 133–150. Moon, C., Cooper, R.P., & Fifer, W.P. (1993). Two-day-olds prefer their native language. *Infant Behavior and Development,16,* 495–500.

Fernando K.L.; Mathews V.J.; Varner M.W.; et al (2003). Robust estimation of fetal heart rate variability using Doppler ultrasound. *2003 IEEE International Conference On Acoustics, Speech, And Signal Processing, Vol II*, Proceedings: Speech II; Industry Technology Tracks; Design & Implementation of Signal Processing Systems; Neural Networks for Signal Processing Book Series: International Conference on Acoustics Speech and Signal Processing (ICASSP): 257-260.

Groome, L.J., Mooney, D.M., Holland, S.B., Smith, L.A., Atterbury, J.L., & Dykman, R.A. (1999). Behavioral state affects heart rate response to low-intensity sound in human fetuses. *Early Human Development, 54*, 39–54.

Kisilevsky, B.S., Pang, L.-H., & Hains, S.M.J. (2000). Maturation of human fetal responses to airborne sound in low- and high-risk fetuses. *Early Human Development, 58*, 179–195.

Kisilevsky, B.S., & Low, J.A. (1998). Human fetal behavior: 100 years of study. *Developmental Review, 18*, 1–29.

Lecanuet, J.-P., Granier-Deferre, C., & Busnel, M.-C. (1995). Human fetal auditory perception. In J.P.Lecanuet, W.P.Fifer, N.A.Krasnegor, & W.P.Smotherman (Eds.), *Fetal development: A psychobiological perspective* (pp. 239–262). Hillsdale, NJ: Lawrence Erlbaum Associates.

Lecanuet, J.-P., Granier-Deferre, C., DeCasper, A.J., Maugeais, R., Andrieu, A.-J., & Busnel, M.-C. (1987). Perception et discrimination foetales de stimuli langagiers, mise en évidence à partir de la réactivité cardiaque, résultants préliminaires. *Compte-Rendus de l'Académie des Sciences, Paris (III), 305*, 161–164.

Lecanuet, J.-P., Granier-Deferre, C., Jacquet, A.-Y., Capponi, I., & Ledru, L. (1993). Prenatal discrimination of a male and female voice uttering the same sentence. *Early Development and Parenting, 2*, 217–228.

Querleu, D., Renard, X., Versyp, F., Paris-Delrue, L. & Crépin, G.. (1988). Fetal hearing. *European Journal of Obstetrics and Reproductive Biology, 29*, 191-212.

Richards, T.A. (2008). *The Cavaquinho Chord Bible: DGBD Standard Tuning 1,728 Chords*. United Kingdom: Cabot Books.

Sontag, L.W.; Steele, W. G.; Lewis, M. (1969). The fetal and maternal cardiac response to environmental stress. Human Development, 12(1), 1-9.

Zimmer, E.Z., Fifer, W.P., Kim, Y.-I., Rey, H.R., Chao, C.R., & Myers, M.M. (1993). Response of the premature fetus to stimulation by speech sounds. *Early Human Development, 33*, 207–215.

Zimmer, E.Z.; Divon, M.Y.; Vilensky, A.; Sarna, Z.; Peretz, B.A.; Paldi, E. (1982). Maternal exposure to music and fetal activity. *European Journal of Obstetrics Gynecology and Reproductive Biology*, *13*: 4; 209-213.