CIBM Annual Symposium 2022
Campus Biotech, Geneva | 30th November

Newborn's neural representation of instrumental and vocal music as revealed by fMRI: a dynamic effective brain connectivity study

Serafeim Loukas[1,2,*], Manuela Filippa[1,3,*], Joana Sa de Almeida[1,*], Didier M. Grandjean[3], Dimitri Van De Ville[2,4], and Petra S. Hüppi[1]

[1] Division of Development and Growth, Department of Child and Adolescent, University of Geneva, Geneva, Switzerland
[2] Institute of Bioengineering, École Polytechnique Fédérale de Lausanne (EPFL), Lausanne, Switzerland
[3] Swiss Center for Affective Sciences, Department of Psychology and Educational Sciences, University of Geneva, Geneva, Switzerland
[4] Department of Radiology and Medical Informatics, University of Geneva, Switzerland

BACKGROUND

Already few hours or days after birth, newborns can process speech[1], differences between syllables, discriminate between different speakers, i.e. mother vs stranger [2,3], and they are sensitive to small changes in prosody [4].

Similarly, newborns show early music processing capacities: they detect consonance versus dissonance and minor/major chords changes[5,6], as well as tempo variations in specific cortical regions[7], beat alteration and variation in tones presentation rate[8]. When preterm born infants are exposed to a music during the Neonatal Intensive Care Unit stay they recognize it as familiar and pleasant at term equivalent age[7] and musical memories are consolidated even in the newborn period[9].

There is convincing evidence that, as for adults[10], newborns possess distinctive abilities to process spoken voice and music.

Hypothesis: Singing activates brain regions differently from instrumental music in newborns' brain.

METHODS

- **Population**: n=45 newborns (35 preterm at TEA and 10 full-term infants) were recruited at the neonatal unit of the University Hospitals of Geneva (HUG).
- Newborns underwent a 3T Siemens MRI scan between 37 and 42 weeks gestational age.
- **Stimuli**: During fMRI, newborns were listening to a 8 seconds melody (without words) sang either by the mother's voice, either by a stranger female voice or played by a musical instrument (flute). A silence condition and a noise condition (white noise) completed the five stimuli sequence. The order of the conditions has been randomized.
- **Data analysis**: To explore the dynamic task-based effective connectivity, we employed psychophysiological interaction of co-activation patterns (PPI-CAPs) analysis with both auditory cortices as the seed region to investigate moment-to-moment changes in task-driven modulation of brain activity during an fMRI task involving both instrumental (flute) and voice conditions (mother and stranger voice combined).
- The number of PPI-CAPs (k=5) was determined based on consensus clustering. We explored the K range from 3 to 10 to identify the most stable number of clusters for our data using 10 random subsamples for every k. Finally, permutation testing (2000 permutations) was used to assess the statistical significance of the results using k=5. We report significant results at Bonferroni level alpha=0.05/5= 0.01.

RESULTS

Our findings revealed unique, dynamically occurring, condition-specific, patterns of co-activation (PPI-CAPs) for both singing and instrumental music tasks.

More specifically, in comparison to the instrumental music condition, we found that during the vocal condition the auditory cortex co-activates with the cortical somatomotor, frontoparietal, and attention areas (precuneus/angular gyrus), while the music condition co-activates predominantly with visual areas and the limbic system (orbito-frontal-cortex and temporal pole).

RESULTS

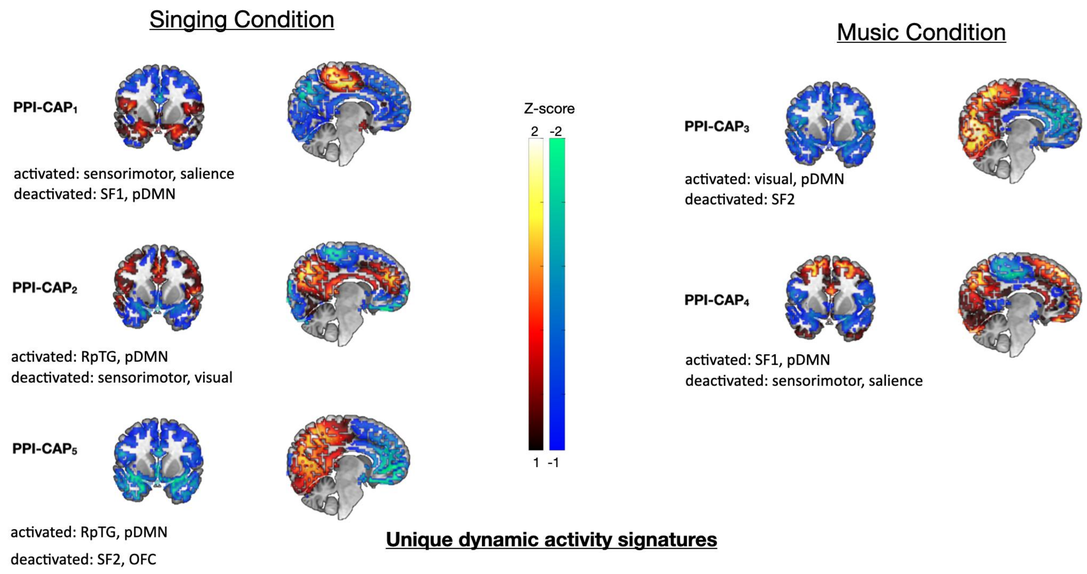

Fig. 1. The 5 PPI-CAPs showing the activations (in red) and deactivation (in blue) patterns

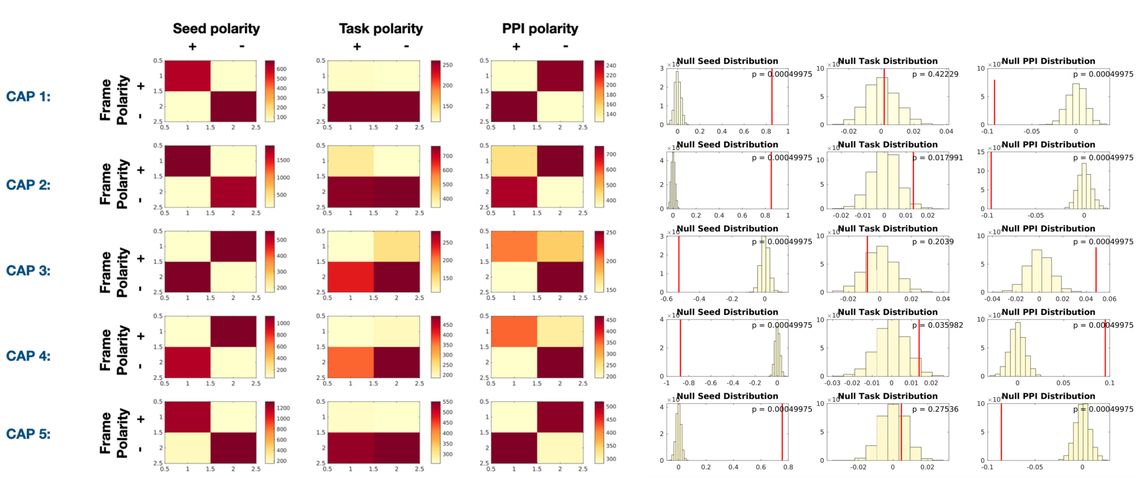

Fig. 2. Left: The 5 PPI-CAPs showing the activations (in red) and deactivation (in blue) patterns. Right: The null distribution of the effects based on the permutation testing. Significant results are reported after Bonferroni correction at a=0.05/5.

CONCLUSION

In line with adult studies, the singing voice condition, activating the somatomotor network, evokes body, proprioceptive, and motor aspects of the auditory perception, while the musical instrument activates more areas dedicated to visual and limbic stimuli processing.

The dynamic aspects of the melody seem thus activating a body experience when presented by the voice and a visual one when played by a musical instrument.

Moreover, attention regions are solicited by voice, while the limbic system, which supports a variety of functions including emotion, is specifically activated by the melody when played by an instrument.
This study confirms that infants have early, specialized auditory processing, discriminating singing from instrumental melody, and highlights the relevance of dynamic approaches to studying brain function in newborn populations.

REFERENCES

1. Dehaene-Lambertz, G., Montavont, A., Jobert, A., Allirol, L., Dubois, J., Hertz-Pannier, L., & Dehaene, S. (2010). Language or music, mother or Mozart? Structural and environmental influences on infants' language networks. Brain and language, 114(2), 53-65.
2. Adam-Darque, A., Pittet, M. P., Grouiller, F., Rihs, T. A., Leuchter, R. H. V., Lazeyras, F., ... & Hüppi, P. S. (2020). Neural correlates of voice perception in newborns and the influence of preterm birth. Cerebral Cortex, 30(11), 5717-5730.
3. Virtala, P., Huotilainen, M., Partanen, E., Fellman, V., & Tervaniemi, M. (2013). Newborn infants' auditory system is sensitive to Western music chord categories. Frontiers in psychology, 4, 492. https://doi.org/10.3389/fpsyg.2013.00492
4. Sambeth, A., Ruohio, K., Alku, P., Fellman, V. & Huotilainen, M. Sleeping newborns extract prosody from continuous speech. Clin. Neurophysiol. 119, 332–341, (2008).
5. Virtala, P., Huotilainen, M., Partanen, E., Fellman, V. & Tervaniemi, M. Newborn infants' auditory system is sensitive to Western music chord categories. Front. Psychol. 4, 492 (2013).
6. Perani, D. et al. Functional specializations for music processing in the human newborn brain. Proc. Natl Acad. Sci. USA 107, 4758–4763 (2010).
7. Lordier, L., Loukas, S., Grouiller, F., Vollenweider, A., Vasung, L., Meskaldij, D. E., ... & Hüppi, P. S. (2019). Music processing in preterm and full-term newborns: a psychophysiological interaction (PPI) approach in neonatal fMRI. Neuroimage, 185, 857-864.
8. Winkler, I., Háden, G. P., Ladinig, O., Sziller, I. & Honing, H. Newborn infants detect the beat in music. Proc. Natl Acad. Sci. USA 106, 2468–2471 (2009).
9. Loukas, S., Lordier, L., Meskaldji, D. E., Filippa, M., Sa de Almeida, J., Van De Ville, D., & Hüppi, P. S. (2021). Musical memories in newborns: A resting-state functional connectivity study. Human brain mapping.
10. Schirmer, A., Fox, P. M., & Grandjean, D. (2012). On the spatial organization of sound processing in the human temporal lobe: a meta-analysis. Neuroimage, 63(1), 137-147.
11. Freitas, L. G., Bolton, T. A., Krikler, B. E., Jochaut, D., Giraud, A. L., Hüppi, P. S., & Van De Ville, D. (2020). Time-resolved effective connectivity in task fMRI: Psychophysiological interactions of Co-Activation patterns. Neuroimage, 212, 116635.

Financial support: Funding from the Swiss National Science Foundation, FNS. (PI P Hüppi). We also thank the Art-Thérapie and Prim'Enfance Foundations for supporting the project.