Musical Training is Associated with Better Reading and Differences in Resting State Functional Connectivity in Adults

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Introduction

- Musical training has been shown to drive both structural and functional neural plasticity [1].
- Musicians tend to have better phonological awareness [2, 3], as well as increased language and reading skills [4], compared to non-musicians.
- Musicians have higher intrinsic brain activity in several well-defined neural networks, including sensorimotor, visual, auditory, and salience networks [5, 6].
- The underlying mechanisms of better reding skills in musicians are largely unknown
- Few studies have focused on neural mechanisms underlying these advantages using functional connectivity methods.
- We had two objectives in this study:
  1. Add to the growing corpus of resting state functional connectivity studies in musicians.
  2. Investigate the neural correlates of improved reading and language performance in musicians.

Materials and Methods

- We recruited **36 subjects** (see Table 1).

Sex	N	Age (SD)	Musicians (years trained +/- SD)
Males	18	27.44 (5.52)	4 (7.25 +/- 5.73)
Females	18	24.06 (5.94)	8 (7.31 +/- 3.95)

Table 1: Cohort statistics

- Questionnaires assessed subjects' musicianship, socioeconomic status (SES), level of education, and self-reported reading / language abilities.
- There were no significant differences in the levels of maternal (T(34) = 1.01, p = 0.32) or paternal (T(34) = 1.26, p = 0.22) education between musicians and non-musicians.
- We administered a battery of language and reading tests (see Table 2). One musician and one non-musician did not complete behavioral testing.

Test	Measure
Gray Oral Reading Tests (GORT-5) [7]	Passage reading
Comprehensive Test of Phonological Processing (CTOPP-2) [8]	Phonological processing
Kaufman Brief Intelligence Test (KBIT-2) [9]	Non-verbal IQ

Table 2: Summary of language and reading tests

- We collected structural and resting-state functional MRI.
- Using the CONN toolbox for MATLAB [10], we conducted ROI-to-ROI connectivity analyses to identify neural networks that were more highly correlated in rest for musicians than in non-musicians ($p < 0.05$, FDR-corrected).
- We looked at domain-specific regions for language and reading, as well as domain-general networks.
- We used networks and ROIs from the Power atlas [11] and a meta-analysis of functional imaging studies of musicians from Neurosynth (https://neurosynth.org/analyses/terms/musicians/).

Behavioral Results

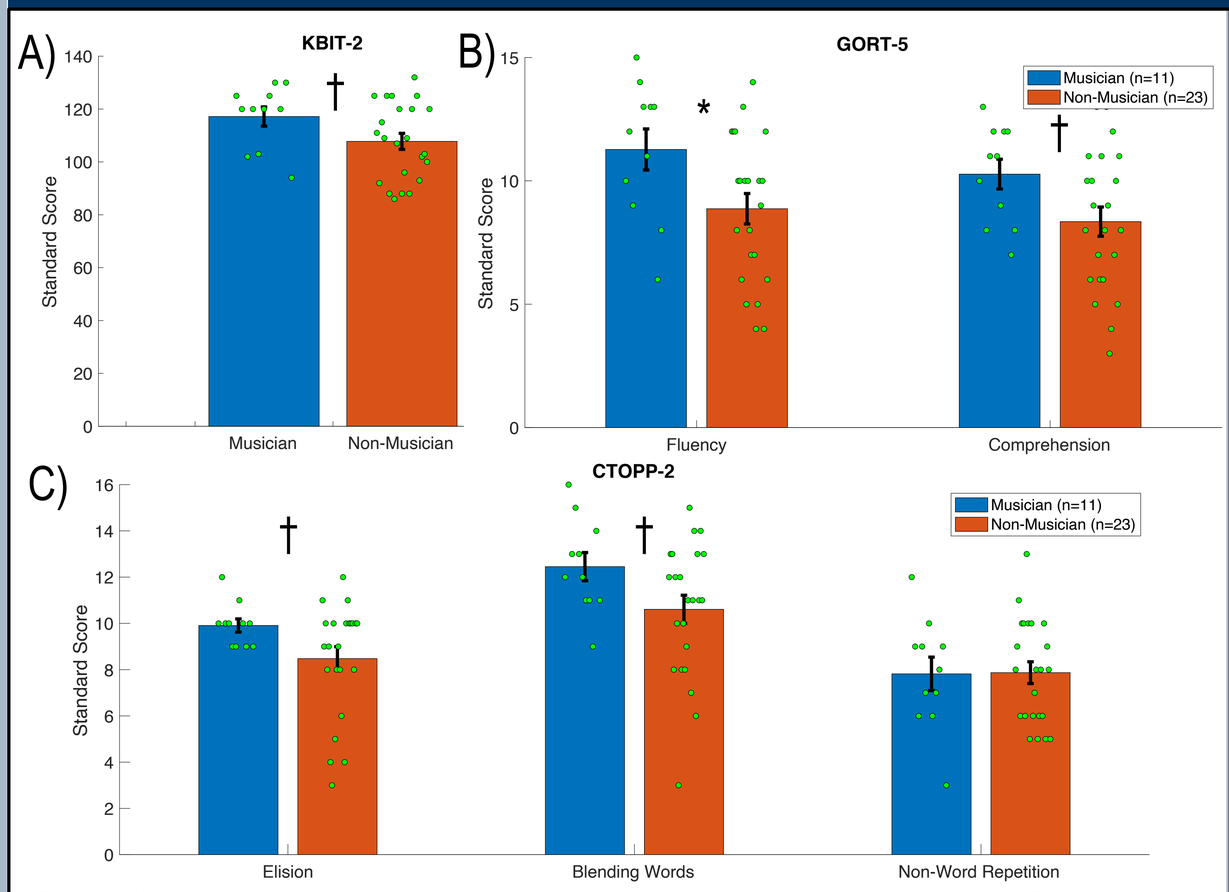

Figure 1: Comparisons of language and reading performance between musicians and non-musicians. A) The Kaufman Brief Intelligent Test measures non-verbal IQ, B) The Gray Oral Reading Tests measure how well subjects can read passages (fluency) and understand them (comprehension). C) The Comprehensive Test of Phonological Processing measures how well subjects can remove phonemes from spoken words to form new words (elision) and combine phonemes to form words (blending words). It also tests phonological working memory (non-word repetition). Green dots represent individual scores. † indicates $p < 0.1$ and * indicates $p < 0.05$ for musician > non-musician on a two-sampled *t*-test. Error bars represent standard error of the mean.

Connectivity Results

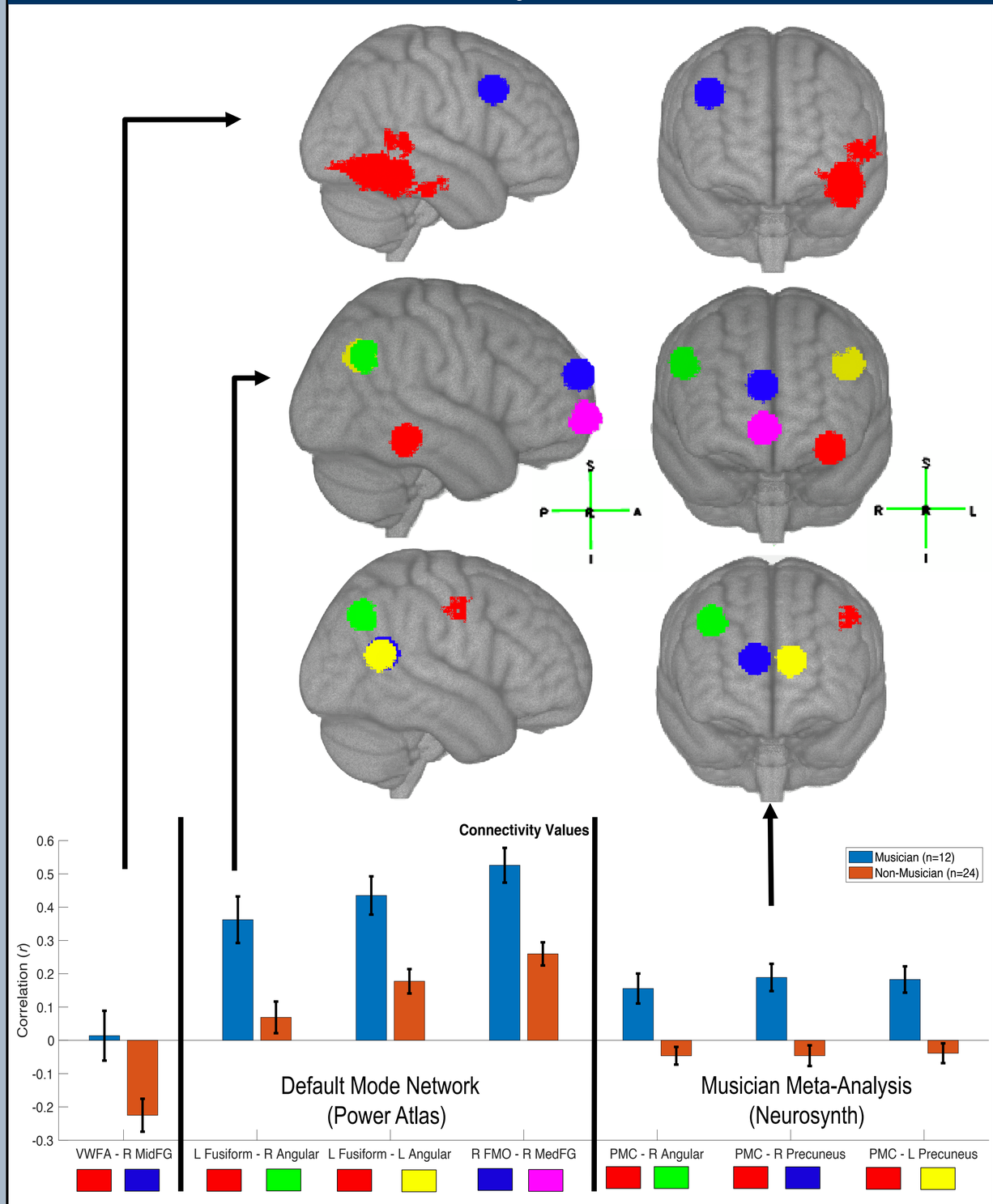

Figure 2: Resting state ROI-to-ROI connectivity values for selected regions. All comparisons displayed are significant for musicians > non-musicians (two-sided t-test, $p < 0.05$ FDR corrected, controlled for age and sex), The y-axis measures the correlation between the hemodynamic BOLD responses of given regions over the course of the resting state fMRI scan. Regions are color-coded to be identified in the accompanying pictures. Error bars represent standard error of the mean.

Abbreviations: **L/R** – Left/Right; **VWFA** – Visual word form area; **MidFG** – Middle frontal gyrus, **Fusiform** – Fusiform gyrus; **Angular** – Angular gyrus; **FMO** – Frontal medial orbital gyrus; **MedFG** – Medial Frontal Gyrus; **PMC** – Premotor cortex

Discussion and Conclusions

- We found significantly better reading performance in musicians as compared to non-musicians. The differences in phonological or cognitive skills, however, did not reach significance.
- The increase in behavioral performance was coupled with higher correlations in reading and language networks as well the default mode network (DMN).
- R MidFG is more highly recruited in subjects with reading disorders [12]. This may represent a reliance on top-down cues and may underly the anti-correlation between R MidFG and VWFA in non-musicians.
- We reaffirmed increased resting-state default mode network connectivity in musicians [5]. However, our results contradict prior evidence suggesting that Fusiform – DMN functional segregation is positively correlated to adult reading competency [13]. This calls for further investigation of these connections.
- The L PMC has been implicated in beat perception [14]. Reading and beat perception may rely on similar neural processes [15].
- Future intervention studies measuring differences in skill and intrinsic connectivity are needed to delineate the causal nature of this relationship.
- In the future, we plan on recruiting more subjects to study the neural correlates of differences in reading and language skills in dyslexic musicians.

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Works Cited

[1]: Jäncke, Lutz. "Music drives brain plasticity." *F1000 biology reports* 1 (2009).
[2]: Grube, Manon, et al. "Auditory sequence analysis and phonological skill." *Proceedings of the Royal Society B: Biological Sciences* 279.1746 (2012): 4496-4504.
[3]: Loui, Psyche, et al. "Relating pitch awareness to phonemic awareness in children: implications for tone-deafness and dyslexia." *Frontiers in psychology* 2 (2011): 111.
[4]: Anvari, Sima H., et al. "Relations among musical skills, phonological processing, and early reading ability in preschool children." *Journal of experimental child psychology* 83.2 (2002): 111-130.
[5]: Fauvel, Baptiste, et al. "Morphological brain plasticity induced by musical expertise is accompanied by modulation of functional connectivity at rest." *Neuroimage* 90 (2014): 179-188.
[6]: Luo, Cheng, et al. "Musical training induces functional plasticity in perceptual and motor networks: insights from resting-state FMRI." *PLoS one* 7.5 (2012).
[7]: Wiederholt, J. Lee, and Brian R. Bryant. *Gray oral reading tests: GORT-3*. Austin, TX: Pro-ed, 1992.
[8]: Wagner, R., et al. *CTOPP-2: Comprehensive Test of Phonological Processing–Second Edition*. Austin, TX: Pro-ed, 1999.
[9]: Kaufman, Alan S. *Kaufman brief intelligence test: KBIT*. Circle Pines, MN: AGS, American Guidance Service, 1990.
[10]: Whitfield-Gabrieli, Susan, and Alfonso Nieto-Castanon. "Conn: a functional connectivity toolbox for correlated and anticorrelated brain networks." *Brain connectivity* 2.3 (2012): 125-141.
[11]: Power, Jonathan D., et al. "Functional network organization of the human brain." *Neuron* 72.4 (2011): 665-678.
[12]: Morken, Frøydis, et al. "Children with dyslexia show cortical hyperactivation in response to increasing literacy processing demands." *Frontiers in psychology* 5 (2014): 1491.
[13]: Koyama, Maki S., et al. "Resting-state functional connectivity indexes reading competence in children and adults." *Journal of Neuroscience* 31.23 (2011): 8617-8624.
[14]: Grahn, Jessica A., and James B. Rowe. "Feeling the beat: premotor and striatal interactions in musicians and nonmusicians during beat perception." *Journal of Neuroscience* 29.23 (2009): 7540-7548.
[15]: Ozernov-Palchik, Ola, and Aniruddh D. Patel. "Musical rhythm and reading development: does beat processing matter." *Ann. NY Acad. Sci* 1423 (2018): 166-175.

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