Language and music: Singing voices and music talent

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Native speakers of tonal languages show enhanced musical melody perception but diminished rhythm abilities. This effect has now been rigorously demonstrated in a new study that tested the musical IQ of half a million human participants across the globe.

As humans, we all speak in a singing voice. Even when we are not singing, we generate a communicative speech stream that has pitch modulations. In English, we use these modulations to communicate affect or to distinguish assertions from questions. In tone or tonal languages, such as Mandarin or Cherokee, the pitch of words participates in its lexical or grammatical meaning[1]. As our early acoustic environment can have a strong effect on how we perceive sounds[2,3], it had been hypothesized that the intensive training in pitch perception needed for interpreting tonal languages would result in enhanced musical abilities, particularly in musical domains involving pitch. This *pitch generalization hypothesis* was first proposed by Diana Deutsch and her colleagues[4] in the context of absolute pitch abilities, which are higher in Mandarin and Vietnamese than in English speakers. As reported in this issue of *Current Biology*, Liu, Hilton *et al.*[5] leveraged the power of large-scale citizen science to show that speakers of 19 distinct tonal languages exhibited improved musical pitch perception. Even more surprising, the researchers discovered that the improvement in musical pitch abilities was accompanied by a decline in the ability to perceive musical rhythm.

Variations in the pitch of our voice as we speak, or intonation, help us distinguish an affirmation (''The door is open'') from a question (''The door is open?'') and allows us to communicate affect[6]. Furthermore, in tonal languages, specific pitch rules are applied to syllables and/or words to change their meaning. For example, Mandarin uses four tones plus a neutral tone that can on its own determine the meaning of words which have otherwise identical phonemes. The pitch can be rapidly descending from high to low, as in *mà* meaning scold, relatively high and steady as in *mā* for mom, relatively low with a fall followed by a rapid rise as in *mǎ* for horse or a mid-level with a raise as in *má* for hemp (Figure 1).

The mastering of tonal languages thus requires expertise both in production and perception of voice pitch. It might therefore not be too surprising to find that speakers of tonal languages may have enhanced not only absolute but also relative musical pitch perception abilities. Moreover, this gain in musical ability can be observed in children as young as four years old[7]. However, the previously reported effect sizes varied significantly, with some studies even failing to find a statistically significant difference (see Table 1 of Liu, Hilton *et al.*[5]). These discrepancies, coupled with the relatively small sample sizes, raised the possibility that the previously reported enhanced pitch perception abilities in tonal language speakers could have been the result of confounding variables, such as music training, cultural, or socio-economic factors. Furthermore, most prior studies compared Cantonese or Mandarin with English speakers leaving scant evidence that the enhanced pitch abilities

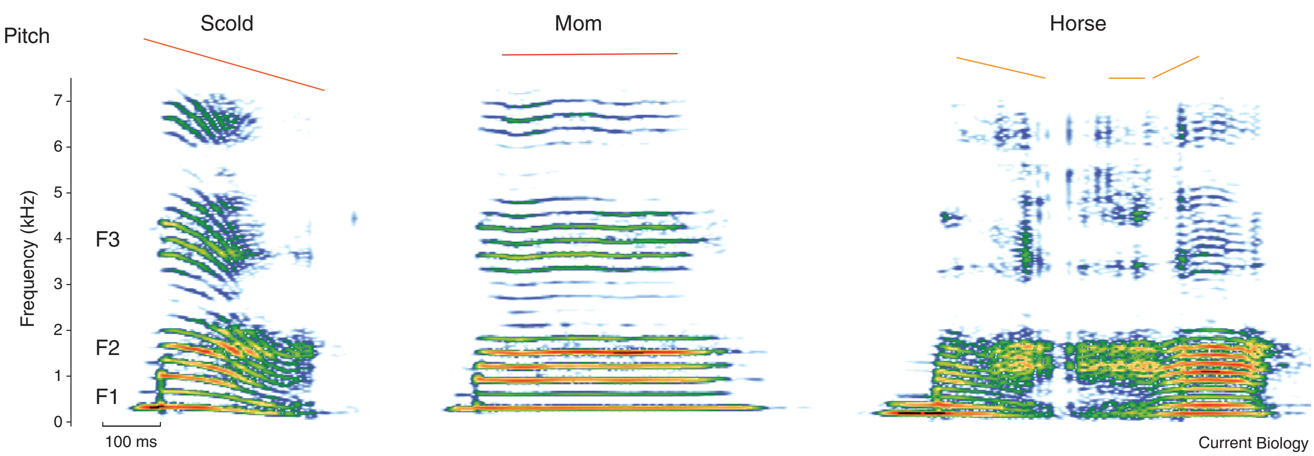

Figure 1. Spectrographic representations of a native Mandarin speaker pronouncing *mà* (Scold), *mā* (Mom), and *mǎ* (Horse).
Note the changes both in pitch height and pitch modulations, also diagrammed at the top of the spectrograms. The formants for the /a/ sound (F1, F2, F3), on the other hand, are constant. The sound file can be found in the online version.

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generalize to other tonal languages. Therefore, it was difficult to rigorously infer whether it was the use of pitch in tonal languages, or other specific Chinese language or cultural characteristics, that were the principal driver of the effect.

Liu, Hilton *et al.*[5] harnessed the power of large-scale citizen science to overcome the lack of generalization that has plagued many smaller-scale experiments in psychology[8], providing the strongest evidence to date for the pitch generalization hypothesis. They found that speakers of not only Mandarin or Cantonese, but also of 17 other tonal languages, exhibited improved musical pitch perception. Specifically, their ability to recognize melodies from their relative pitch contour was enhanced. The effect size was noteworthy, corresponding to about half of what is observed in participants with musical training. This improvement in melodic pitch did not transfer to other musical abilities, such as the detection of a miss-tuned voice against an instrumental background. On the contrary, the tonal language speakers' enhancement in melodic pitch came at a cost of decreased performance in musical rhythm discrimination, a pattern also observed across all 19 tonal languages examined! This decline in rhythm performance might also be attributed to language experience; native speakers of tonal languages may attend less to parameters related to rhythm in the speech stream, such as syllable duration, because pitch variations are more informative in their native tongue[9]. Therefore, the decrease in rhythm performance could reflect a tradeoff for limited cognitive resources, or alternatively, an adaptive strategy for optimizing the perception of informative features in speech signals. Further investigation is needed to clarify the relative roles of rhythm and pitch in bearing information in tonal languages.

The work of Liu, Hilton *et al.*[5] is a *tour-de-force* and will serve as an example on how to perform rigorous and efficient crowd-science studies through a virtual platform. The results are based on the responses of almost half a million participants from all over the world, including 34 thousand native speakers of the 19 tonal languages! To achieve this level of participation, the on-line music test needed to be engaging and sufficiently short to ensure that participants would both start and finish the

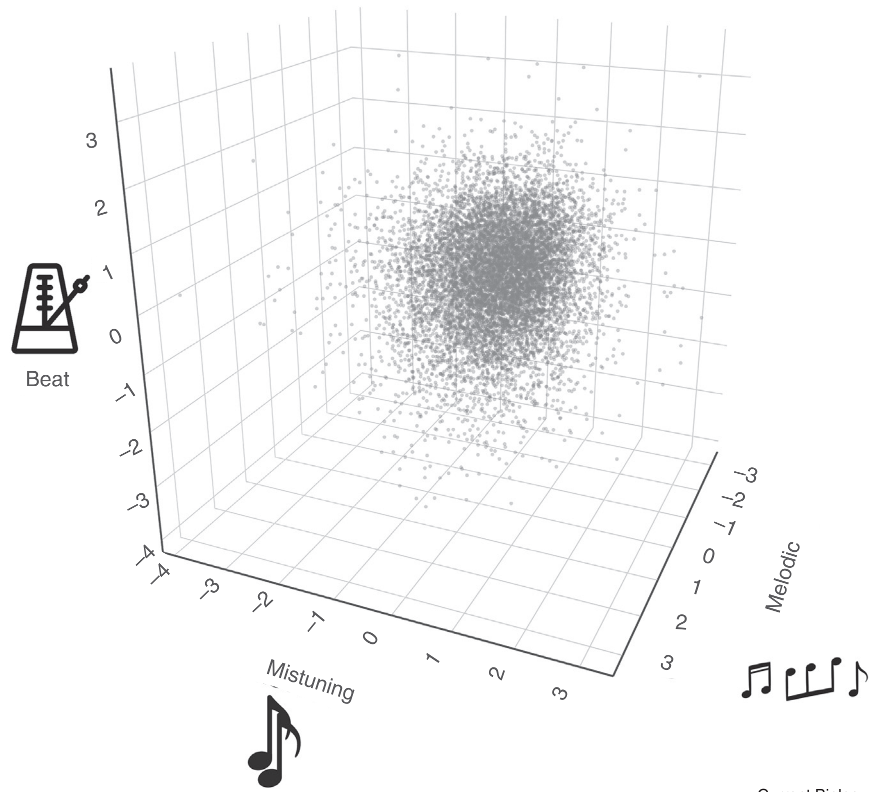

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Figure 2. Scatter plot of the scores on the music IQ test from a random sample of participants.
In the Liu, Hilton *et al.*[5] study, participants were tested on three separate music abilities: rhythm perception (Beat), mistuning of voice and instrumental pitch (Mistuning) and melody recognition (Melodic). The participant scores on these adaptive tests have a near-normal multivariate distribution with weak correlations across dimensions.

testing session. The musical IQ test designed for this on-line investigation is particularly effective in this respect. It is sufficiently easy for everyone to understand and at the same time challenging enough to motivate performance. The musical IQ test assesses *only* three dimensions of music performance, specifically melody recognition, mistuning and rhythm matching, but these three musical perceptual dimensions are greatly independent from each other with small cross-correlation coefficients around 0.25 (Figure 2). I highly recommend those interested in these results to test their own musical IQ at https://themusiclab.org/quizzes/miq.

In testing the effect of tonal language exposure, it is remarkable that one of the dimensions (melody) yielded a clear positive effect, a second dimension (miss-tuning) a null result that doubles as a control and the third dimension (rhythm) a similarly strong negative effect (whereas the small positive correlation would predict that all three dimensions would vary together). In this respect, this well-designed music test played an important role in justifying the validity of the results. In addition, in lieu of a typical introduction, the authors performed a meta-analysis of previous literature which, in quantifiable terms, set the stage for their work. Finally, the methodology was pre-registered, and the statistical analyses included random effect modeling and validation by cross-validation. The work of Liu, Hilton *et al.*[5] will serve as an example on how to perform crowd science investigations.

Liu, Hilton *et al.*[5] demonstrate that music and language perception are intertwined. Experiences with a native tonal language yield domain general abilities in pitch perception that are reflected in the music domain. The traditional view that music and language are distinct psychological faculties with corresponding distinct supporting brain systems (for example, right *versus* left cerebral cortex) has further been challenged[10–12] by this work. How pitch and rhythm for music and speech are processed similarly and/or distinctively in the human cortex and how this processing is affected by learning remain an active area of research[13,14]. Leveraging the differences that humans across our planet experienced in the analysis of the acoustic features of their native tongue provides a unique opportunity for comparative studies in psycho- and neurolinguistics.

DECLARATION OF INTERESTS

The author declares no competing interests.

REFERENCES

1. Lee, O.J. (2023). Tones of Asian languages: A comparative overview of tonology. In The Routledge Handbook of Asian Linguistics, C. Shei, and S. Li, eds. (London: Taylor & Francis), pp. 261–278.
2. Kuhl, P.K. (1995). Learning and representation in speech and language. Curr. Opin. Neurobiol. *4*, 812–822.
3. Kuhl, P.K. (2004). Early language acquisition: Cracking the speech code. Nat. Rev. Neurosci. *5*, 831–843.
4. Deutsch, D., Henthorn, T., and Dolson, M. (2004). Absolute pitch, speech, and tone language: Some experiments and a proposed framework. Music Percept. *21*, 339–356.
5. Liu, J., Hilton, C.B., Bergelson, E., and Mehr, S.A. (2023). Language experience predicts music processing in a half-million speakers of fifty-four languages. Curr. Biol. *33*, 1916–1925.
6. Gussenhoven, C. (2004). The Phonology of Tone and Intonation: Research Surveys in Linguistics (Cambridge: Cambridge University Press). https://doi.org/10.1017/CBO9780511616983.
7. Creel, S.C., Weng, M., Fu, G., Heyman, G.D., and Lee, K. (2018). Speaking a tone language enhances musical pitch perception in 3-5-year-olds. Dev. Sci. *21*, e12503. https://doi.org/10.1111/desc.12503.
8. Yarkoni, T. (2022). The generalizability crisis. Behav. Brain Sci. *45*, e25. https://doi.org/10.1017/S0140525X20001685.
9. Jasmin, K., Sun, H., and Tierney, A.T. (2021). Effects of language experience on domain-general perceptual strategies. Cognition *206*, 104481. https://doi.org/10.1016/j.cognition.2020.104481.
10. Jäncke, L. (2012). The relationship between music and language. Front. Psychol. *3*, 123. https://doi.org/10.3389/fpsyg.2012.00123.
11. Jantzen, M.G., Large, E.W., and Magne, C. (2016). Editorial: Overlap of neural systems for processing language and Music. Front. Psychol. *7*, 876. https://doi.org/10.3389/fpsyg.2016.00876.
12. Rebuschat, P., Rohrmeier, M., Hawkins, J.A., and Cross, I. (2011). Language and Music as Cognitive Systems (Oxford: Oxford University Press).
13. Peretz, I., Vuvan, D., Lagrois, M.-É., and Armony, J.L. (2015). Neural overlap in processing music and speech. Philos. Trans. R. Soc. Lond. B Biol. Sci. *370*, 20140090.
14. Norman-Haignere, S.V., Feather, J., Boebinger, D., Brunner, P., Ritaccio, A., McDermott, J.H., Schalk, G., and Kanwisher, N. (2022). A neural population selective for song in human auditory cortex. Curr. Biol. *32*, 1470–1484.e12.

Sleep regulation: The gut sets the threshold

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Sleep is regulated by many environmental factors including food availability and exposure to sensory stimuli. A recent study identifies a gut–brain axis that is activated by dietary proteins and inhibits sensory responsiveness, allowing animals to enter and maintain deep sleep.

Sleep is critical for healthy physiology and normal brain function, and loss of sleep is widely associated with neurological and metabolic disease. Mammals undergo different states of sleep, each with unique properties that are thought to be critical for maintenance of brain function. There is growing evidence that deep sleep is an ancient process that is present throughout much of the animal kingdom[1,2]. A new study by Titos *et al.* reported in *Cell* now shows that specialized cells in the gut of fruit flies are activated by dietary proteins and communicate with the brain to promote deep sleep[3].

Sleeping animals become less responsive to sensory stimuli including light, noise, and touch. The responsiveness is decreased further during periods of deep sleep, which is thought to have particularly rejuvenating properties[4]. This reduction in sensory responsiveness during sleep is shared in animals ranging from jellyfish through humans, suggesting ancient evolutionary origins and a fundamental role in sleep function[1]. Nevertheless, the biological basis for changes in arousability during sleep remain poorly understood.

The fruit fly, *Drosophila melanogaster*, is a powerful system for the study of sleep. Large scale genetic screens have been widely applied to uncover genes and neural circuitry that regulate sleep[4]. Most of these studies use prolonged periods of inactivity as a readout of sleep duration, a measure that cannot distinguish different sleep states. For this reason, surprisingly little is known about how deeply flies sleep, and how sleep depth changes across different environmental contexts.

Previous systems have been developed to quantify arousal threshold, an indicator of sleep depth[5]. However, these systems tend to be more laborious than those used to measure inactivity, precluding their use in large-scale genetic