Cognition 267 (2026) 106333

Contents lists available at ScienceDirect

Cognition

journal homepage: www.elsevier.com/locate/cognit

Brief article

Preferences for consonance are evident in Indigenous Amazonians with higher, but not lower, levels of global integration

Malinda J. McPherson-McNato [a,b,c,*], Eduardo A. Undurraga [d], Sophia E. Dolan [e], Alexander Durango [b,f], Bryan J. Medina [b,f], Ricardo A. Godoy [g], Josh H. McDermott [b,c,f,h,**]

[a] *Department of Speech, Language, and Hearing Sciences, Purdue University, West Lafayette, IN, USA*
[b] *Department of Brain and Cognitive Sciences, MIT, Cambridge, MA, USA*
[c] *Program in Speech and Hearing Bioscience and Technology, Harvard University, Cambridge, MA, USA*
[d] *Escuela de Gobierno, Pontificia Universidad Católica de Chile, Macul, Chile*
[e] *Wellesley College, Wellesley, MA, USA*
[f] *McGovern Institute for Brain Research, MIT, Cambridge, MA, USA*
[g] *Heller School for Social Policy and Management, Brandeis University, Waltham, MA, USA*
[h] *Center for Brains, Minds, and Machines, MIT, Cambridge, MA, USA*

ARTICLE INFO

Keywords:
Consonance
Cross-cultural
Music perception
Market integration
Globalization
Bolivia

ABSTRACT

It is unclear how elementary musical preferences are shaped by experience, in part due to the difficulty of measuring the presumptively relevant aspects of human experience. Previous work with an indigenous small-scale society in the Bolivian Amazon – Tsimane' – has failed to find evidence of the preference for canonically consonant to dissonant music intervals that is widespread in Western listeners. Leveraging changing conditions in the Amazon, we tested whether consonance preferences would be evident in Tsimane' who have more contact with global culture. We developed a survey to quantify integration with global and Bolivian markets and culture. Tsimane' participants with greater integration showed a small but significant preference for consonance, whereas those with less integration did not. We also tested Bolivians living in a small rural town and in a large city, and US non-musicians, observing increasing consonance preference across these groups (with group differences that exceeded those between the two groups of Tsimane'). Other preferences measured with the same task did not vary across groups. The results support the conclusion that consonance preferences change with exposure to globalized culture, and indicate that globalization is inducing measurable changes in music perception in small-scale societies.

1. Introduction

In Western music, some note combinations are considered pleasant, or 'consonant,' and others unpleasant, or 'dissonant.' Note combinations considered consonant by Western listeners tend to be related by low-integer frequency ratios (though see Parncutt and Hair (2018)). The underlying causes of the perceptual contrast between consonance and dissonance have been of longstanding interest (Stumpf, 1890; von Helmholtz, 1863). For example, developmental findings have been interpreted as evidence for consonance preferences at birth (Trainor, Tsang, and Cheung, 2002; Zentner and Kagan, 1996), but more recent studies indicate that observed effects in infants can be altered by exposure to music (Plantinga and Trehub, 2014). Moreover, consonance preferences increase in Western listeners from childhood to adulthood (Weiss, Cirelli, McDermott, and Trehub, 2019), and with musical experience (Arthurs, Beeston, and Timmers, 2018; Dellacherie, Roy, Hugueville, Peretz, and Samson, 2010; McDermott, Lehr, and Oxenham, 2010), and vary with familiarity with different Western musical styles (Lahdelma and Eerola, 2020; Popescu et al., 2019).

Previous results have also indicated that consonance preferences have strong cultural influences. For instance, Tsimane', an indigenous population in the Bolivian Amazon who historically have had limited exposure to Western culture and music, appear to lack a preference for consonant over dissonant note combinations (McDermott, Schultz, Undurraga, and Godoy, 2016; McPherson et al., 2020), consistent with the idea that the preference depends on exposure to particular types of

* Corresponding author at: Lyles-Porter Hall, 715 Clinic Drive, West Lafayette, IN 47907, USA.
** Corresponding author at: 43 Vassar St, Cambridge, MA 02139, USA.
E-mail addresses: mjmcp@purdue.edu (M.J. McPherson-McNato), jhm@mit.edu (J.H. McDermott).

https://doi.org/10.1016/j.cognition.2025.106333
Received 14 May 2025; Received in revised form 21 September 2025; Accepted 23 September 2025
Available online 14 October 2025

music. Tsimane' nonetheless showed an aversive response to "rough" tones formed by pairs of frequencies that produce audible beating, suggesting some cross-cultural consistency that could influence responses to chords (Eerola and Lahdelma, 2021). Analogous results have since been reported in other groups: the Kalash and Khow indigenous groups in Northwest Pakistan (Lahdelma, Athanasopoulos, and Eerola, 2021), and non-Western Arab listeners (Granot and Maimon, 2023).

Such cross-cultural differences are plausibly explained by the idea that preferences for consonance develop with experience with particular types of music. However, thus far, evidence for this idea has been circumstantial, based on intuitive notions of the degree of exposure to Western music for different groups of people who exhibit varying degrees of consonance preference (McDermott et al., 2016). More definitive evidence might be obtained by measuring the experiences of members of a small-scale society and assessing whether differences in experience predict consonance preferences.

In recent years, during our visits to Tsimane' communities, we observed rapid development due to efforts by the Bolivian government to expand public health services, schools, and roads among indigenous groups (Godoy, 2025; Huanca & Reyes-Garcia, 2015; Leonard et al., 2015). The villages close to the main town in the region are now on the electrical grid, some villages have a solar panel that can be used to charge electronic devices, and the cellular telephone network is gradually expanding to cover more villages. We sought to leverage the rapid changes happening in this part of the Bolivian Amazon to probe for effects of exposure to global culture on consonance preferences.

We quantified such exposure in Tsimane' participants using an index formed from variables chosen to quantify exposure of individual participants to global technology and culture, Christian music, and marketplace transactions. We then tested whether consonance preferences varied in Tsimane' as a function of this index. We hypothesized that Tsimane' participants with greater exposure to global culture would prefer consonance over dissonance, while those with less exposure would show the previously observed indifference to consonance vs. dissonance. We also tested three additional populations in Bolivian towns and cities to assess how any effects of globalization on Tsimane' would compare to differences between other groups within the country.

We conducted an initial version of these experiments in 2018, observing a consonance preference in more but not less globally integrated Tsimane'. We then adjusted the integration index based on our evolving understanding of the region, pre-registered the variables and the analysis, and conducted a second experiment that we report here in the main text. We describe the original experiments in Appendix B as they further support the general conclusions of this article.

2. Methods

2.1. Overview of study

We ran identical sets of experiments on five participant groups: US non-musicians in the Boston metropolitan area, Bolivian non-musicians in the city of Santa Cruz de la Sierra (hereafter Santa Cruz, the largest city in Bolivia), residents of a small Bolivian town (San Borja, Fig. 1a), Tsimane' residents of this town, and Tsimane' who live in traditional communities (in the region surrounding San Borja, Fig. 1a). San Borja residents had electricity in their homes and access to television and cellular telephone service. US and Santa Cruz participants were mainly college-educated, and all had smartphones.

Tsimane' have historically lived in small villages without electricity or running water, with contact with the rest of Bolivia largely limited to occasional trips to local towns to trade, visits from travelling traders, and occasional rural wage labor. Many only speak the Tsimane' language. Additionally, rain makes local roads unusable for much of the year, further isolating villages. However, villages near the town of San Borja have recently gained electricity and cellular telephone reception. Moreover, over the past two decades, some Tsimane' have relocated to San Borja for work and easier access to commercial goods. Most of these Tsimane' speak Spanish. These changes are recent. For example, one village (Mara) that we featured in previous publications (Jacoby et al., 2019; Jacoby et al., 2024; McPherson et al., 2020), and that was a data collection site for this study, obtained solar panels and cellular service between 2019 and 2021.

2.2. Global Integration index

We split Tsimane' participants into two groups based on a measure of their degree of integration with Bolivian and global culture and markets, which we will term a "Global Integration" index, inspired by the idea of "market integration" used in anthropology to refer to lifestyle influences on Indigenous People arising from outside their culture (Lu, 2007). The factors assessed for our index were determined from longitudinal surveys and ethnographic data on the Tsimane' (Godoy, 2025; Leonard

Table 1
List of questions used to Assess Global Integration. Re: question 2, San Borja and Yucumo are the largest towns in the region around the Tsimane' villages visited for this study; Trinidad is the capital of the Beni department that contains this region. Re: question 3, responses were based on whether the participant's household owned a motorized vehicle. Re: question 4, we used a standardized distance for each community derived from discussions with villagers. Question 7 was assessed by Spanish-speaking experimenters and translators.

	Question	Possible answers
1	Have you ever lived in any town outside your community for more than six months?	0 = no, 1 = yes
2	How often do you visit San Borja, Yucumo, Trinidad, or other larger cities?	0 = never, 1 = once a year, 2 = once a month, 3 = every week or more
3	Do you own a motorcycle, car, or motorized canoe?	0 = never, 0.5 = used to, 1 = yes
4	How far is your home community to the towns of San Borja or Yucumo (whichever is closest)?	0 = 2 days by canoe, 4+ hours by car, 1 = 1 day by canoe or 2+ hours by car, 2 = Less than 2 h by car, 3 = less than an hour by car
5	Have you worked for a company in the area in the last year (cattle, logging, trader)?	0 = never, 1 = occasionally, 2 = often
6	How often do you buy, sell, or trade goods?	0 = never, 1 = once a year, 2 = once a month, 3 = every week or more
7	Do you speak Spanish?	0 = no; 0.5 = little; 1 = fluent
8	What is the highest grade of schooling you have completed?	0–12 for none to 12th grade
9	Do you have electricity in your home *(i.e., is your home connected to the electrical grid)*, a solar panel, or a generator?	0 = never, 0.5 = used to, 1 = yes
10	Do you have a working television in your home?	0 = never, 0.5 = used to, 1 = yes
11	Do you own a working cell phone? What type?	0 = never, 1 = used to, 2 = yes, not a smartphone, 3 = yes, a smartphone
12	Do you have a working radio in your home?	0 = never, 0.5 = used to, 1 = yes
13	How often do you attend church?	0 = never, 1 = once a year, 2 = sometimes, 3 = every Sunday or more
14	How many Christian hymns do you know how to sing (either in Tsimane or Spanish)?	0 = None, 0.5 = Some, 1 = Many
15	Do you sing? If yes, where do you sing? (at home, at church, with friends) If yes, how often do you sing? *Note: for questions 15 and 16, we found that asking participants where they sang or played instruments helped to elicit accurate estimates of frequency.*	0 = never, 1 = once per year, 2 = between 1 and 3 times per month, 3 = once a week, 4 = more than once a week
16	Do you play a musical instrument? If yes, where do you play? (At home, at church, with friends). If yes, how often?	0 = never, 1 = once per year, 2 = between 1 and 3 times per month, 3 = once a week, 4 = more than once a week

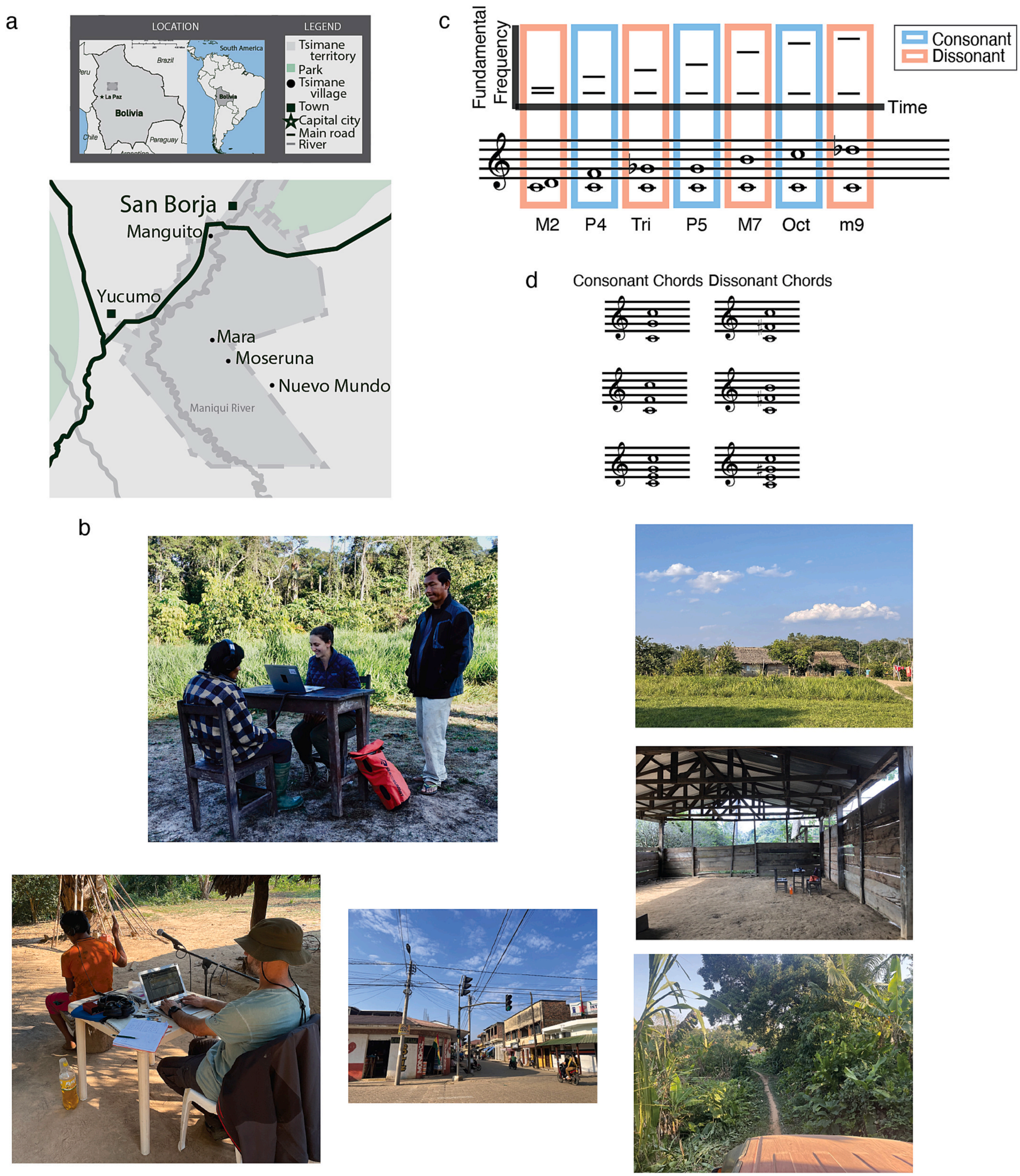


Fig. 1. Stimuli and experimental setup. a. Map of the region in Bolivia where most Tsimane' live, showing the villages where Tsimane' were tested (Manguito, Mara, Moseruna and Nuevo Mundo). b. Photos of experimental setup and testing locations, clockwise from top left: Experimental conditions in a Tsimane' village, showing a participant listening to sounds over closed headphones, and experimenter entering data on a laptop. The experimenter was blind to the stimulus condition. The village of Mara. An experimental testing site in the school in Moseruna. The road to Nuevo Mundo in the dry season; there was no vehicle access in the rainy season. Central San Borja. A hearing test being administered in a Tsimane' village. The participant raised their hand each time they heard a tone. c. Consonant and dissonant intervals used in interval preference experiment. d. Consonant and dissonant chords used in chord preference experiment.

et al., 2015), along with our first-hand knowledge of how the region has changed in the last decade.

We assembled as many variables as we could think of that might correlate with exposure to globalized culture, encompassing two main types of changes in Tsimane' lifestyle. The first set of variables captured efforts by the Bolivian government to bring electricity, commercial technology, and formal schooling to Indigenous populations, which has resulted in some Tsimane' having more interactions with the global economy and culture than in previous decades. The second set of variables captured exposure to Christian religious activities in the region, which has led to increased church attendance and related musical activities. We opted for a broader approach to assess exposure to globalized culture, rather than asking specifically about experience with Western music, because we were not confident that the extent and nature of musical exposure of Tsimane' could be accurately assessed with survey questions about exposure to Western music.

Our hypothesis was that Tsimane' participants with high levels of Global Integration would exhibit a preference for consonance over dissonance, while those with lower levels would show the previously observed indifference to consonance vs. dissonance. We pre-registered this Global Integration index and possible analyses (https://aspredicted.org/vwhf-xgqs.pdf). Each variable in our index was scaled to range from 0 to 1 (by dividing by the maximum possible value) and summed to yield a score from 0 to 16 for each participant. We split participants into two groups using a (pre-registered) median split of the index. The 16 variables were assessed with the questions in Table 1. These questions were part of a brief survey that all Tsimane' participants completed in conjunction with the experiments.

Questions 1–4 assessed access to and time spent in local towns, questions 5–8 assessed activity in and ability to communicate with the broader Bolivian economy, questions 9–12 assessed access to modern communication technology, and questions 13–16 assessed contact with local missionaries and Christian music specifically. Sub-indices formed from each of these four subsets were modestly correlated: r ranged from 0.11 to 0.45, depending on the pair of subsets; these correlations were individually statistically significant for all but one pair. Although the main analysis used the index described here that pooled all 16 variables, we also pre-registered an analysis in which participants were instead divided based on indices using either only the economic variables (questions 1–11) or the music-related variables (questions 12–16).

The survey was only conducted with Tsimane' participants as the variables were not relevant to the other participant groups.

2.3. Participants

Participant information and study timeline are summarized in Appendix A.

2.3.1. Tsimane' in villages

145 Tsimane' participants living in traditional villages were enrolled. 19 were removed by experimenters for non-compliance (not answering questions with the allowable responses), had childcare or other obligations arise during testing, or were otherwise unable to complete the experiment. An additional 19 participants were removed because their hearing thresholds (see below) were, on average, within 25 dB of the presentation level in the critical frequency range for the experiments (approximately 250–3500 Hz). This left 107 Participants, two of whom did not complete hearing tests. These two participants were not excluded.

Tsimane' participants were recruited in four villages, chosen to vary in access to electricity, proximity to roads and towns, and cellular telephone service, to sample Tsimane' participants who were likely to vary in exposure to globalized culture (Fig. 1a, b). Participants were recruited by word of mouth following a village meeting in which compensation and consent were explained to study participants. One village (Manguito) was accessible by a one-hour car ride along a paved road from San Borja. Two villages (Mara and Moseruna) were a two-day walk or a three-hour drive from the town of San Borja along a dirt road only accessible to high-clearance vehicles and motorcycles if recent weather had been dry. The final village, Nuevo Mundo, was located an additional 15 km past Moseruna, on an unfinished dirt road accessible only to high-clearance vehicles and motorcycles when weather had been dry. The entire trip from San Borja to Nuevo Mundo took approximately five hours in such a vehicle. Within each village, exposure to technology and Bolivian towns varied, with some participants spending several months of each year in a local town, and others never having been to a town. 46 of the 107 participants reported owning or having owned a phone, 24 of which reported that they owned or had owned a smartphone.

A median split based on Tsimane' Global Integration indices (median = 6.08) yielded 52 participants in the less integrated group (33 females; mean age = 31.9, S.D. = 12.5), and 55 participants in the more integrated group (30 females; mean age = 28.4, S.D. = 10.2 years). The average Global Integration Index for the Less Integrated group was 4.21, S.D. = 0.99, and the average Global Integration Index for the More Integrated group was 8.06, S.D. = 1.38.

2.3.2. Tsimane' living in San Borja

Most Tsimane' living in the town of San Borja are either on the Tsimane' Council (the governing body of Tsimane' in the study region), work in construction, are involved in teaching (they moved to town for training and stayed), or are the spouses or children of teachers, construction workers, or Tsimane' Council members. 27 participants were recruited through word of mouth. One participant was removed because of poor hearing. All 26 remaining participants (12 female; mean age = 28.7, S.D. = 13.2) spoke Tsimane' and Spanish. All but two participants reported owning a smartphone; one did not have a phone, and one owned a phone that was not a smartphone. We did not ask about computer ownership. Tsimane' living in San Borja completed the same demographic survey as Tsimane' living in villages, and we could therefore compute a Global Integration index for this population as well. The average Global Integration index for Tsimane' living in San Borja was 10.70, S.D. = 1.39.

2.3.3. San Borja

43 participants were recruited. One was removed because of poor hearing. Of the remaining 42 participants, 20 were female (mean age = 29.2; S.D. = 10.0 years). Participants were recruited by word of mouth. 11 reported playing musical instruments (mean number of years for those 11 participants = 5.8, S.D. = 7.5, range = 0.5–23 years). Participants had an average of 10.2 years of schooling (S.D. = 2.1). Six participants reported owning or having owned a computer, and all owned smartphones.

2.3.4. Santa Cruz

Participants were recruited by online advertisement and word of mouth. 35 participants (11 female) were initially recruited. Seven of these participants reported over five years of formal musical training and were removed from the analysis. No other participants were removed. The final group analyzed contained 28 participants (10 female), mean age = 26.9, S.D. = 6.2 years). Participants had an average of 15.1 years of schooling (S.D. = 2.9). 31 participants reported owning or having owned a computer, and all reported owning smartphones.

2.3.5. Boston

32 non-musician participants were recruited (19 female; mean age = 33.1 years, S.D. = 9.3 years). 25 reported no formal musical training, seven reported three or fewer years of formal musical training (mean = 2.2, S.D. = 1.0 for those seven participants). On average, participants had 15.8 years of schooling (S.D. = 1.9). None were excluded from analysis. All participants reported owning a computer and smartphone.

2.3.6. Sample sizes

The sample size for Boston was chosen based on power analyses of pilot data, which suggested that 18 participants were necessary to see split-half reliabilities above $r = 0.9$, 80 % of the time on the interval preference task. Sample sizes for Bolivia were as large as possible given practical constraints, but were always larger than 18.

2.4. Study timeline

Experiments were conducted in July 2018 (San Borja, on the premises of CBIDSI, a non-profit organization in San Borja), August 2019 (Santa Cruz, at Fundación Natura Bolivia, a non-profit organization in Santa Cruz), August–November 2019 (Boston, on MIT's campus), July–August 2023 (Tsimane' in San Borja), and July–August 2023 and 2024 (Tsimane', in villages); the break was due to the COVID-19 pandemic. Pilot experiments with Tsimane' participants (Appendix B) were conducted in 2018.

2.5. Ethics

The study was approved by the Tsimane' Council, and the Committee on the Use of Humans as Experimental Subjects at MIT. Experiments were conducted with the informed consent of participants, who were compensated with money in the US, Santa Cruz, and San Borja, and with a package of goods for Tsimane' participants in villages.

2.6. Stimulus presentation

Stimuli were played by MacBook Air laptop computers using over-ear closed headphones (Sennheiser HD 280Pro), at a presentation level of 70 dB SPL. Audio presentation was calibrated beforehand with a GRAS 43AG Ear & Cheek Simulator connected to a Svantek SVAN 977 audiometer, enabling tone presentation at the desired sound pressure level.

Because Tsimane' villages lack fully enclosed or soundproof spaces, we optimized listening conditions by selecting testing locations that were as distant as possible from village activities, and typically assigned a team member to keep children and animals out of earshot from the experimental stations (Fig. 1B). To further minimize the audibility of the background noise, we used closed circumaural headphones that attenuated external sounds (Sennheiser HD-280 Pro). To help minimize differences in testing conditions between groups, we conducted experimental sessions for Boston participants in public areas of the MIT campus. We chose locations where there would be consistent low background noise from students and staff walking by or studying at nearby tables (e.g., a public atrium). Experimental sessions in Santa Cruz were conducted in office spaces and a coffee shop. Experimental sessions in San Borja were conducted in open air conditions with ambient background noise from the surrounding town activities. The same headphones and computers were used with all groups.

2.7. Experimental protocol

All experiments were completed in a single session for each participant, ranging from 30 to 60 min. The order of experiments was randomized within each session.

After the participant heard each stimulus, responses were given verbally ('like it a lot', 'like it a little', 'dislike it a little' or 'dislike it a lot', Fig. 2a). Instructions and responses were in English in Boston, in Spanish for Tsimane' in San Borja, San Borja participants and Santa Cruz participants, and in Tsimane' for all Tsimane' villager participants. For Tsimane' participants, translators (who spoke Tsimane' and Spanish) delivered the instructions and interpreted the participants' responses. The experimenter entered the spoken response into a MATLAB interface.

We note that consonance is a multifaceted phenomenon (Parncutt and Hair, 2011; Parncutt, Reisinger, Fuchs, and Kaiser, 2018; Tenney, 1988) that may not be fully captured by pleasantness (Arthurs et al., 2018). Pleasantness judgments are nonetheless correlated with the various other traits one might in principle measure (Lahdelma and Eerola, 2020), and have the advantage of being straightforward to explain to untrained listeners. They were also a natural choice for these

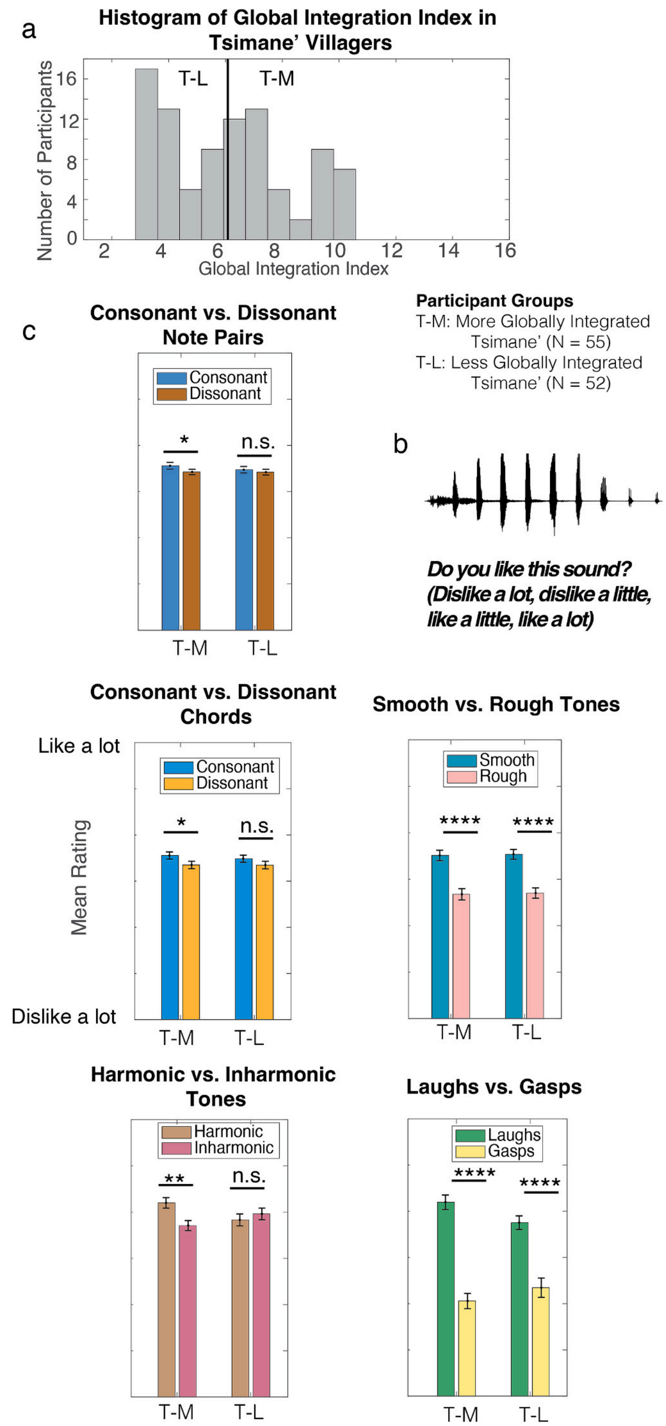


Fig. 2. Results for Tsimane' with differing extents of global integration a. Histogram of Global Integration index for Tsimane' villager participants, with a vertical line showing the median. b. Schematic of trial structure showing a sound waveform of laughter from the Laughs vs. Gasps experiment. c. Results of all preference experiments in more and less Globally Integrated Tsimane'. Error bars show standard error of the mean. Significance of differences between conditions denoted by asterisks: **** $= p < .0001$, *** $= p < .001$, ** $= p < .01$, * $= p < .05$.

experiments because we were confident in their translation from English to both Tsimane' and Spanish based on our prior work (McDermott et al., 2016; McPherson et al., 2020).

We originally pre-registered a screen for participant compliance in the groups tested in 2023 and 2024. This screen involved a second experiment measuring responses to recorded vocalizations. We subsequently decided it was preferable to preserve the same inclusion criteria across all tested groups, and thus did not use this screen.

2.8. Stimuli

2.8.1. Musical intervals

Stimuli were composed of synthetic tones that were 2000 ms in duration and contained harmonics 1–12 (in sine phase). To mimic the acoustics of many musical instruments (Fletcher and Rossing, 2010), harmonic amplitudes were attenuated by −14 dB/octave, and tones had temporal envelopes that were the product of a half-Hanning window (10 ms) at either end of the tone and a decaying exponential (decay constant of 4 s^{-1}).

Interval stimuli consisted of concurrently presented pairs of these tones (Fig. 1c). The pitch interval between the two tones was either a unison, major second, perfect fourth, tritone, perfect fifth, major seventh, octave, or minor ninth. These intervals were chosen to include the three canonically consonant intervals with the closest similarity to the harmonic series (the octave, fifth, and fourth), along with a selection of canonically dissonant intervals, chosen to alternate with the consonant intervals when ordered according to the interval size in semitones. Interval size was thus dissociated from similarity to the harmonic series (i.e., Western consonance, associated with simple integer ratios).

Two different tuning systems were used (Appendix A) in separate blocks to test whether the small deviations from harmonicity present in modern instrument tuning might affect aesthetic determinations. Depending on the interval, the intervals tested differed by 0–12 cents between the two tuning systems. Interval stimuli were presented in three different pitch ranges, with root note fundamental frequencies either zero or two semitones above 110, 220, and 440 Hz. This resulted in 48 trials for each block, presented in random order.

2.8.2. Musical chords

Chords were composed of three or four synthetic notes (Fig. 1d). Each note was a complex tone generated as in the interval experiment. The chord set was selected to contain three chords that would sound highly consonant to Western listeners and three chords that would sound highly dissonant despite having similar interval sizes to the consonant chords. We sought to avoid extreme differences in roughness, as these would be expected to yield a difference in pleasantness for all groups, given the evidence for an aversion to roughness in Tsimane' and other non-Western groups (Lahdelma et al., 2021; McDermott et al., 2016; McPherson et al., 2020), and might impair the ability to detect differences between the subsets of Tsimane' listeners who were the focus of the paper. In practice, this was achieved by avoiding small intervals that produce prominent beating between the note F0s. The avoidance of small intervals also served to make the comparison of consonant and dissonant chords more controlled with respect to interval size and spectral centroid. The consonant chords consisted of: 1) a perfect fifth with the root doubled one octave above, 2) a perfect fourth with the root doubled, and 3) the major triad with the root doubled. The dissonant chords consisted of 1) a tritone with the root doubled, 2) a tritone and a major seventh, and 3) the augmented triad with the root doubled (Fig. 1d). Chords were generated using just intonation and were presented twice in three different pitch registers (with root f0s either zero or two semitones above 110 Hz, 220 Hz, or 440 Hz). This resulted in 36 trials, presented in random order.

2.8.3. Harmonic and inharmonic tones

Harmonic tones contained 10 harmonics of the f0. Tones were made inharmonic by jittering the component frequencies by pre-set amounts (in semitones): [−0.75 0.75 0.5 –0.5 1 –1 0.75 –0.75 0.5 –0.5], or [0.75 –0.75 –0.5 0.5 –0.1 0.1 –0.75 0.75 –0.5 0.5], used equally often. These jitter patterns were chosen to produce low periodicity (and thus to sound unpleasant to Western listeners) while not substantially altering beating. The tones were otherwise identical to those in the interval and chord experiments. Each tone was presented four times in each of two different registers, each time generated from a different f0 (1 and 3 semitones above and below 262 and 524 Hz). For the inharmonic tones, the first jitter pattern listed above was used when the generating f0 was 3 semitones below or 1 semitone above the reference values (262 and 524 Hz), and the second pattern was used otherwise. This resulted in 16 trials, which were randomly intermixed in a single block with the smooth and rough tone trials described below.

2.8.4. Smooth and rough tones

The smooth and rough tone stimuli were generated as in previous studies (McDermott et al., 2010; McDermott et al., 2016), by presenting pairs of single frequencies to either the same or different ears (diotic and dichotic presentation, respectively). Diotic presentation of two similar but non-identical frequencies produces the 'rough' sensation of beats, typically considered unpleasant by Western listeners. In contrast, dichotic presentation of two such frequencies greatly attenuates perceived beats but leaves the spectrum unchanged relative to the diotic version. Stimuli were generated in three different frequency ranges. The frequencies composing each stimulus were separated by either 0.75 or 1.5 semitones (1.5 for the low- and mid-frequency ranges, and 0.75 for the high-frequency range, to produce beat frequencies with prominent roughness), such that considerable beating was heard when presented diotically. The lower of the two frequencies was one or three semitones above or below 262, 524, or 1048 Hz. This resulted in 2x3x4 = 24 trials, randomly intermixed in a single block with the harmonic/inharmonic tones trials described above. The block also included 4 trials with pure tone stimuli, the results of which are not analyzed here.

2.8.5. Vocalization stimuli

Vocalizations were the same fifteen recordings (five each of laughter, gasps, and crying) previously used as control stimuli in two previous papers (McDermott et al., 2016; McPherson et al., 2020). The stimuli were presented in random order in a single block of 15 trials. The crying sounds gave similar results to the gasps (low ratings by all groups) and their ratings were omitted from the analysis to simplify the data presentation to two stimulus conditions per experiment.

2.8.6. Hearing test

To ensure participants could hear the stimuli, we conducted a hearing test designed for the field (Jacoby et al., 2019). We presented pure tones diotically at frequencies of 60, 127, 285, 605, 1358, 2155, 3229, 5126, 8137, and 11,500 Hz. Participants faced away from the experimenter and raised their hands when they heard a tone (Fig. 1B). Tones were initially presented at a comfortable level. The experimenter iteratively adjusted the level to determine the faintest tone at each frequency that the participant could reliably detect. The experimenter was blind to the frequency. We removed any participant whose average hearing threshold was below 45 dB SPL in the 285–3229 frequency range (all sounds were presented at 70 dB SPL). This frequency range was the most relevant for our experiments.

2.9. Analysis

Results were averaged across stimulus exemplars within conditions, and statistical tests were performed on these mean ratings for each participant.

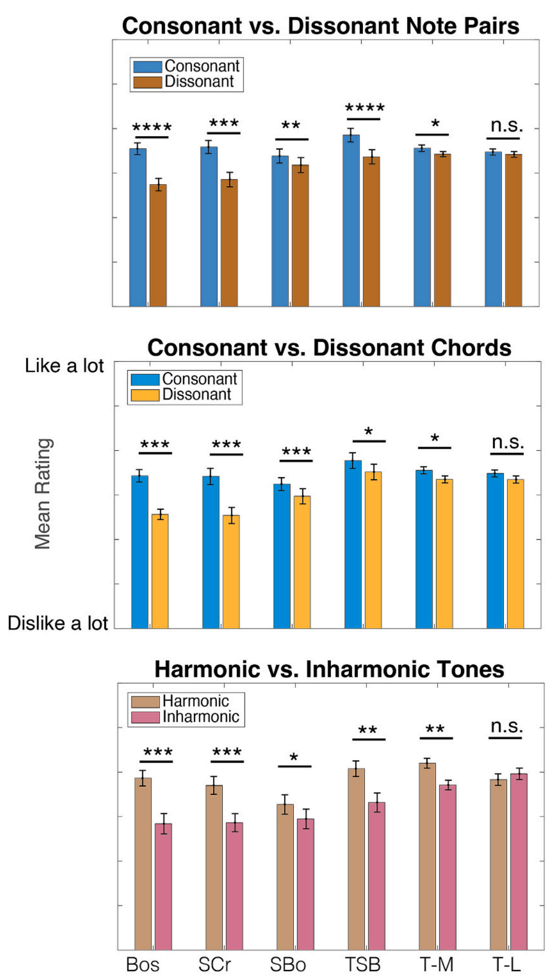
2.9.1. Statistics

Paired *t*-tests were used to test for differences between conditions within groups, and mixed-design ANOVAs were used to test for main effects and interactions between the effects of stimulus condition and participant group. Though it is not standard to run t-tests on individual participant groups if an ANOVA on all groups does not indicate a significant interaction, we report all individual-group t-tests that were pre-registered, regardless of ANOVA significance. We note that finding a significant effect in one group while not finding one in another does not on its own provide good evidence for an interaction (Nieuwenhuis, Forstmann, and Wagenmakers, 2011).

Data distributions of mean ratings were assumed to be normal and were evaluated as such by eye using histograms. To be conservative, we double-checked each ANOVA using non-parametric multi-condition tests in which we computed F statistics and evaluated their significance with approximate permutation tests (randomizing the assignment of the data points across the conditions being tested 10,000 times to obtain a null distribution, to which the F statistic value could be compared to obtain statistical significance). In each case, these non-parametric tests yielded the same result (significant vs. non-significant) as the corresponding parametric test.

3. Results

We first analyzed the Tsimane' living in villages as a function of their Global Integration index, splitting the participants into two groups above and below the median index (Fig. 2). An ANOVA suggested that any differences between the two groups were subtle: there was not a significant interaction between integration index and the effect of consonance when comparing the Less and More integrated Tsimane' ($F(1,105) = 1.05$, $p = .31$, $\eta p^2 = 0.009$). As per our pre-registration, we also separately tested for preferences in each group individually. We found that a preference for consonant over dissonant intervals was undetectable in Tsimane' with lower values of Global Integration (Fig. 2b; $p = .32$, $BF_{10} = 0.24$, indicating moderate evidence for the null hypothesis that there was no preference (Rouder, Speckman, Sun, Morey, and Iverson, 2009)). This finding replicates previous studies of Tsimane' participants (McDermott et al., 2016; McPherson et al., 2020). However, Tsimane' with higher Global Integration showed a significant preference for consonance over dissonance ($p = .03$). The difference between groups was independent of the tuning system: we found no interaction between tuning and consonance vs. dissonance ($F(1,105) = 0.02$, $p =$



Participant Groups
Bos: Boston Non-musicians (N=32)
SCr: Santa Cruz Residents (N=28)
SBo: San Borja Residents (N =42)
TSB: Tsimane' who live in San Borja (N=26)
T-M: More Globally Integrated Tsimane' (N = 55)
T-L: Less Globally Integrated Tsimane' (N = 52)

Effect Sizes (Cohen's d)

	Bos	SCr	SBo	TSB	T-M	T-L
Intervals	1.50	1.49	0.27	0.89	0.39	0.16
Chords	1.71	1.53	0.37	0.51	0.49	0.34
Harmonic vs. Inharmonic	1.28	1.31	0.32	1.30	0.84	0.20
Smooth vs. Rough	0.84	1.10	0.82	1.13	1.27	1.50
Laughs/Gasps	3.60	3.47	2.81	4.62	2.55	1.52

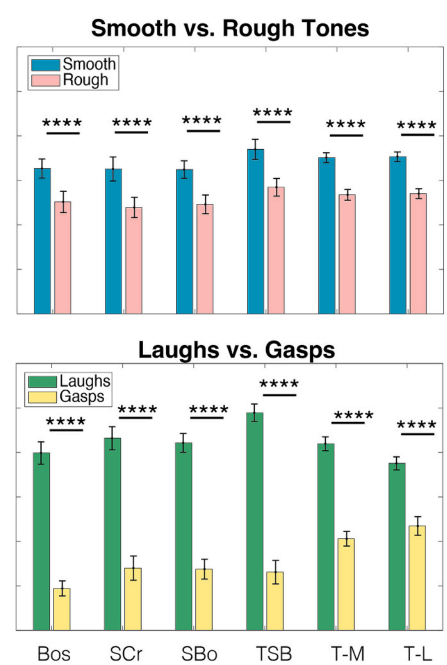


Fig. 3. Summary of results of all preference experiments in all participant groups. Error bars show standard error of the mean. Table shows effect sizes (Cohen's d) for all experiments and participant groups. Significance denoted by asterisks: **** = $p < .0001$, *** = $p < .001$, ** = $p < .01$, * = $p < .05$.

.91, $\eta p^2 = 0.0001$; data are thus pooled across tuning systems in the results figures); this null result for tuning system replicates a previous study (McPherson et al., 2020).

Preferences for consonance varied across the other participant groups (Fig. 3) as in previous work (McDermott et al., 2016). The preference was robust in US and Santa Cruz listeners ($p < .0001$ and $p < .001$, respectively), and weaker but statistically significant in residents of the small Bolivian town ($p < .01$). We also found that the Tsimane' who lived in the small Bolivian town had a significant preference for consonance ($p < .0001$); this finding has not been previously published. As expected, this group of Tsimane had an average Global Integration index that was higher than those of both Less and More integrated Tsimane' villagers (10.70, 8.06, and 4.21, respectively).

We found similar results in the experiment with chords (see Fig. 1d for chord composition). There was not a significant interaction between integration index and consonance between More and Less integrated Tsimane' villagers ($F(1,105) = 0.28$, $p = .60$, $\eta p^2 = 0.003$). However, we observed a small but significant difference for more integrated Tsimane' ($p = .04$), along with no significant difference for less integrated Tsimane' ($p = .09$, $BF_{10} = 0.61$, indicating anecdotal evidence for the null hypothesis, again replicating previous studies with Tsimane' participants).

Preferences for harmonic vs. inharmonic tones, which isolate an acoustic property related to consonance (Bidelman and Heinz, 2011; Bones et al., 2014; Cousineau, McDermott, and Peretz, 2012; McDermott et al., 2010), also varied across groups. Here there was a significant interaction between integration index and harmonicity ($F(1,105) = 13.7$, $p = .0003$, $\eta p^2 = 0.12$) for More and Less Integrated Tsimane'. We again observed a significant preference in Tsimane' with higher Global Integration ($p < .001$) but not in Tsimane' with less Global Integration ($p = .19$, $BF_{10} = 0.35$, indicating anecdotal evidence for the null hypothesis).

We also pre-registered analogous analyses using sub-indices composed of only the economic variables from the index (questions 1–11 from Table 1) or only the music-related variables (questions 12–16) (https://aspredicted.org/vwhf-xgqs.pdf). The resulting sub-indices based on these subsets of variables were correlated ($r = 0.39$, $p = .0001$), and splitting Tsimane' participants using either sub-index gave qualitatively similar results as the main Index (significant preferences in participants with indices above the median, and non-significant preferences in participants below the median). These results are consistent with the idea that the observed differences in preferences between groups of Tsimane' are driven by musical exposure induced by integration with global and Bolivian markets and culture.

We did not pre-register analyses based on individual variables, and so do not report them here. However, given the number of variables and modest effects, no such analysis would survive correction for multiple comparisons; larger data sets would be needed to relate effects to specific variables. The data are available at the project repository for such exploratory analysis.

Control experiments verified that the cross-cultural variation in consonance preferences was not due to an inability to perform the task or a misunderstanding of the instructions. Preferences were present in all participant groups for smooth over rough synthetic tones (t-tests, $p < .0001$ for all groups), and with similar magnitude (no interaction between the Global Integration index and roughness preference, $F(1,105) = 0.0002$, $p = .99$, $\eta p^2 < 0.0001$). Preferences were also present across groups for laughter over gasps (t-tests, $p < .0001$ for all groups). There was a significant interaction of integration index and laugh/gasps $F(1,105) = 4.08$, $p = .02$, $\eta p^2 = 0.04$), potentially driven by modest cultural differences in vocal emotion expression (Sauter, Eisner, Ekman, and Scott, 2010).

Although the key new effect described here (consonance preferences in more globally integrated Tsimane') was small (see Fig. 3 for all effect sizes), we note that it was consistently present across all three of the experiments that were related to consonance, and that the analysis was pre-registered. Moreover, pilot versions of the same experiments (with a slightly different, non-pre-registered analysis) showed a similar pattern of results (Appendix B). This consistency is very unlikely to have occurred by chance and increases our confidence in the conclusions despite the small effects. We also note that larger consonance preferences were evident in Tsimane' who had relocated to the small Bolivian town of San Borja, providing further evidence for the idea that experience with global culture induces such preferences.

4. Discussion

We measured lifestyle variables related to integration with globalized culture among Tsimane', and found them to identify a subset of Tsimane' who showed statistically significant preferences for consonance. Less integrated Tsimane' exhibited robust preferences for some stimulus variables, but not for consonance. The results are consistent with the idea that recent development in the region is increasing exposure to globalized culture among some Tsimane', and that variation in this experience correlates with aesthetic associations with musical sounds. Our experiments cannot speak to the specific life experiences that underlie the observed associations, but they are plausibly driven by increased experience with Western-influenced music.

We view the present work as making two main contributions relative to previous work, one methodological and one substantive. The first contribution is to introduce a method for quantifying life experiences of members of small-scale societies that might influence music perception. The specific demographic and socioeconomic variables that are used for this purpose will need to be customized for use in other small-scale societies, but the general approach should be widely applicable. The second contribution is to provide evidence that globalization is introducing changes in life experiences that, in turn, induce changes in music-related perception within small-scale societies. These findings indicate that results obtained in such societies are likely to vary over time, and that the effects of globalization could potentially cause cross-cultural studies to overestimate the extent of universality.

The variation in Tsimane' preferences with global integration was nonetheless modest. Pronounced differences in preferences remained evident between Tsimane' with higher Global Integration and city residents both in Bolivia (Santa Cruz) and Boston (who showed similar results). Moreover, residents of the rural Bolivian town (including Tsimane' who had relocated to live in the town) showed a more modest preference than city residents, as in previous work (McDermott et al., 2016; McPherson et al., 2020), indicating that substantial variation exists even among individuals who have grown up with access to electricity, cellular telephones, and television.

CRediT authorship contribution statement

Malinda J. McPherson-McNato: Writing – review & editing, Writing – original draft, Visualization, Supervision, Software, Project administration, Methodology, Investigation, Funding acquisition, Formal analysis, Conceptualization. **Eduardo A. Undurraga:** Writing – review & editing, Methodology, Investigation, Conceptualization. **Sophia E. Dolan:** Writing – review & editing, Investigation. **Alexander Durango:** Writing – review & editing, Investigation. **Bryan J. Medina:** Writing – review & editing, Investigation. **Ricardo A. Godoy:** Writing – review & editing, Project administration, Methodology, Investigation, Conceptualization. **Josh H. McDermott:** Writing – review & editing, Writing – original draft, Supervision, Software, Resources, Project administration, Methodology, Investigation, Funding acquisition, Conceptualization.

Declaration of competing interest

We have no known conflict of interest to disclose.

The experiments in Indigenous participants, and their analysis, were pre-registered. Pre-registrations are available to view at https://aspredicted.org/vwhf-xgqs.pdf

Acknowledgments

The authors thank Tomás Huanca and Esther Conde of the Centro Boliviano de Investigación Socio-integral (CBIDSI) for operational support in Bolivia; Spanish-Tsimane' translators Elias Hiza, Salomón Hiza, Manuel Roca, and Dino Nate; drivers Pastor and Hardy Roca; Fundación Natura Bolivia for testing space and logistical support in the city of Santa Cruz de la Sierra; River Grace for assistance running experiments on US participants. This work was supported by a McDonnell Scholar Award to J.H.M. an NIH grant F31DC018433-01 to M.J.M, and a Harvard University Mind Brain Behavior Interfaculty Initiative Graduate Student Award to M.J.M.

Appendix A. Participant, timeline, and stimuli information

Table A1
Summary of participants and study timeline.

Participant group	Year tested	Total number tested	Excluded	Final participant number	Age	Sex (F/M)
Tsimane in villages	2023–2024	145	38	107		
More Integrated Tsimane				55	mean = 31.9, S.D. = 12.5	30/25
Less integrated Tsimane				52	mean = 28.4, S.D. = 10.2	33/19
Tsimane' in San Borja	2023	27	1	26	mean = 28.7, S.D. = 13.2	12/14
San Borja	2018	43	1	42	mean = 29.2; S.D. = 10.0	20/22
Santa Cruz	2019	35	7	28	mean = 26.9, S.D. = 6.2	10/18
Boston	2019	32	0	32	mean = 33.1, S.D. = 9.3	19/13

Table A2
Interval stimuli. Table of intervals used in preference experiments, with interval ratios and interval in cents for both Just and Equal temperament to aid comparison. These stimuli were used in the experiment described in the main text as well as in the 2018 pilot study described in Appendix B.

Interval name	Just intonation		Equal temperament	
	Ratio	Interval in cents	Semitones	Interval in cents
Unison	1:1	0	0	0
Major second	9:8	203	2	200
Perfect fourth	4:3	498	5	500
Tritone (Aug. 4th/Dim 5th)	43:32	590	6	600
Perfect fifth	3:2	702	7	700
Major seventh	15:8	1088	11	1100
Octave	2:1	1200	12	1200
Minor ninth	32:15	1312	13	1300

Appendix B. Summary of 2018 pilot study

In 2018, we conducted a pilot version of the experiments reported in the main text in a partially overlapping set of villages. None of these data have been previously published. In this pilot study, we used a set of 11 demographic and socioeconomic variables (based on our understanding of the region at that time) to characterize integration with global culture. We found a consonance preference in more but not less integrated Tsimane', but the survey variables and analysis were not pre-registered. Based on our evolving understanding of the region and how to assess the rapidly evolving relevant lifestyle factors with survey questions, we subsequently adjusted the variables contributing to the Global Integration index, pre-registered the variables and the analysis, and conducted the experiment described in the main text. We describe the original experiments here to provide further support and context for the general conclusions of this paper.

B.1. Methods

B.1.1. Market Integration Index used for 2018 pilot study

The 11 variables were assessed with the following questions. Asterisks indicate questions that were identical in the Global Integration index used in the main experiment (in 2023–2024).

1. *Have you ever lived in any town outside your community for more than six months? (0 = no, 1 = yes)
2. *How often do you visit San Borja, Yucumo, Trinidad, or other larger cities? (0 = never, 1 = once a year, 2 = once a month, 3 = every week or more. Note: San Borja and Yucumo are the largest towns in the immediate region where the Tsimane' in our sample live; Trinidad is the capital of the Department of Beni)
3. Do you own a motorcycle or motorized canoe? (0 = never, 0.5 = used to, 1 = yes)
4. *Do you speak Spanish? (This was assessed with the aid of translators, 0 = no; 0.5 = little; 1 = fluent)
5. *What is the highest grade of schooling you have completed? (0–12 for none to 12th grade)
6. Do you have electricity in your home *(i.e., is your home connected to the electrical grid, or to a generator*)? (0 = never, 0.5 = used to, 1 = yes)
7. *Do you have a working television in your home? (0 = never, 0.5 = used to, 1 = yes)
8. Do you own a working cell phone? (0 = never, 1 = used to, 2 = yes)
9. *Do you have a working radio in your home? (0 = never, 0.5 = used to, 1 = yes)
10. How many Christian hymns do you know how to sing (either in Tsimane or Spanish)? (0 = None, 0.5 = Some, 1 = Many)
11. Do you sing in church? If so, how often? (0 = never, 1 = once per year, 2 = between 1 and 3 times per month, 3 = once a week, 4 = more than once a week)

We note that because the variables we surveyed are not the same as those in the main experiment, and because the phrasing of some questions changed, we cannot analyze our new data using the old index or vice versa.

B.1.2. Participants

Only Tsimane' participants residing in villages were run in this experiment. 99 participants (50 female) completed the experiments (mean age = 26.55, max = 47 years, S.D. = 9.10 years). An additional 13 participants began the experiments but did not complete them for various reasons (e.g., restless or sick children who needed attention, or noncompliance), and their data were not analyzed.

Tsimane' participants lived and were tested in six villages, chosen to vary in access to electricity, proximity to roads and towns, and cellular telephone service to sample a wide range of Tsimane' participants. Participants were recruited by word of mouth within each village, following a community meeting in which the study and participant compensation were explained. We recruited participants in Manguito, Mara, and Moseruna (as in the experiment described in the main text), as well as three additional villages along the river Maniqui. These three villages (Anachere, Emeya, and Iñañare) were only accessible by a 2–3 day trip on a motorized canoe (and are among the more distant villages from San Borja).

B.1.3. Stimulus presentation, experimental protocol, and stimuli generation

The stimulus presentation, experimental protocol, and stimuli were identical to the experiment in the main text (except that we did not include the experiment to assess compliance).

B.1.4. Analysis

Each socio-economic variable was scaled to range from 0 to 1 (by dividing by the maximum possible value, i.e., 3 for the visiting towns variable, and 12 for the education variable), and summed to yield a summary Global Integration index for each participant (the score could thus range from 0 to 11). We examined the bottom two-thirds and the upper third of participants (a cutoff of 3.5/11 in that scale) when ranked according to this score. This split was chosen to prioritize power in the less integrated group, in whom we expected to see weak or undetectable consonance preferences, while keeping the more integrated group sufficiently powered. The more integrated Tsimane' group contained 34 participants (9 female), mean age = 24.62, S.D. = 7.02 years. The less integrated Tsimane' group contained 65 participants (41 female), mean age = 27.55, S.D. = 9.91 years.

In all other respects, the analysis of the data was identical to that for the main experiment.

B.2. Results

The results are generally consistent with the results of the main experiment (Fig. B1). Replicating previous results, a consonance preference was undetectable in less integrated Tsimane' ($p = .72$), but the more integrated Tsimane' showed a significant preference for consonance over dissonance ($p = .017$). However, the interaction between group and consonance preference was not significant ($F(1,97) = 2.36$, $p = .13$, $\eta p^2 = 0.02$). The variations in preference replicated in the experiment featuring consonant and dissonant chords with three and four notes. As with two-note chords, we observed a small but significant difference for more Globally Integrated Tsimane' ($p = .026$), but again, replicating previous results, no significant difference for less Globally Integrated Tsimane' ($p = .79$). In the experiment measuring preferences for harmonic and inharmonic tones, there was no significant difference for either Tsimane' group ($p > .60$ in both cases). Both participant groups showed preferences for smooth over rough synthetic tones, and for laughs over gasps (roughness: $p < .0001$ for both participant groups; vocalizations: $p < .0001$, for both participant groups).

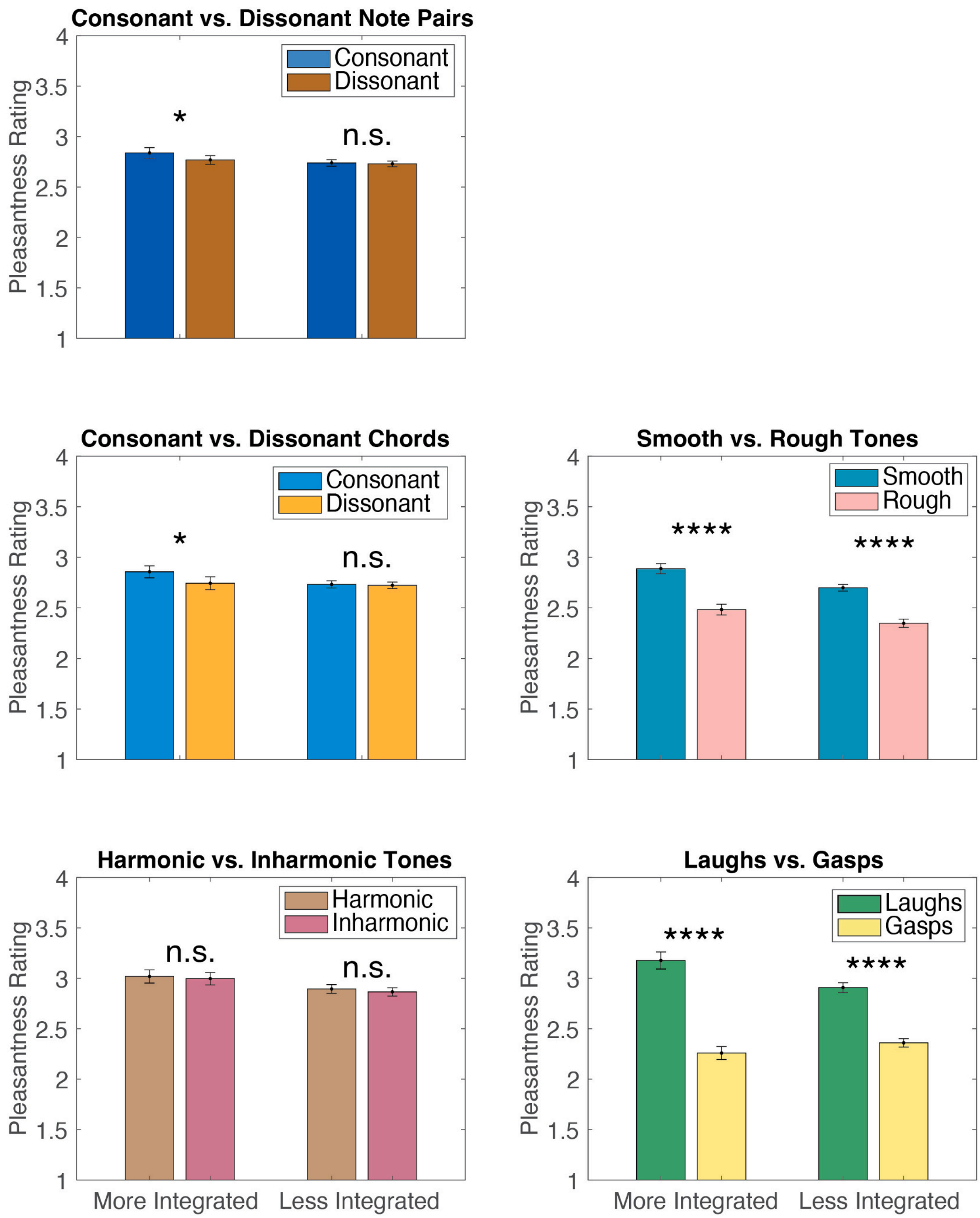


Fig. B1. Results of pilot experiment conducted in 2018 with Tsimane' participants. The analysis used an earlier version of the Global Integration index, described in Appendix B. Tasks were identical to those in the main experiments.

Data availability

All data are available at https://osf.io/4tnvm/?view_only=57dae1d3501b40c99ac6b6d71f8a326b,

References

Arthurs, Y., Beeston, A. V., & Timmers, R. (2018). Perception of isolated chords: Examining frequency of occurrence, instrumental timbre, acoustic descriptors and musical training. *Psychology of Music, 46*(5), 662–681.

Bidelman, G. M., & Heinz, M. G. (2011). Auditory-nerve responses predict pitch attributes related to musical consonance-dissonance for normal and impaired hearing. *Journal of the Acoustical Society of America, 130*(3), 1488–1502.

Bones, O., Hopkins, K., Krishnan, A., & Plack, C. J. (2014). Phase locked neural activity in the human brainstem predicts preference for musical consonance. *Neuropsychologia, 58*, 23–32.

Cousineau, M., McDermott, J. H., & Peretz, I. (2012). The basis of musical consonance as revealed by congenital amusia. *Proceedings of the National Academy of Sciences, 109*, 19858–19863.

Dellacherie, D., Roy, M., Hugueville, L., Peretz, I., & Samson, S. (2010). The effect of musical experience on emotional self-reports and psychophysiological responses to dissonance. *Psychophysiology, 48*, 337–349.

Eerola, T., & Lahdelma, I. (2021). The anatomy of consonance/dissonance: Evaluating acoustic and cultural predictors across multiple datasets with chords. *Music & Science, 4*, 20592043211030471.

Fletcher, N. H., & Rossing, T. D. (2010). *The Physics of Musical Instruments*. Springer.

Godoy, R. (2025). *Researching Well-Being in an Indigenous Amazon Community: A Detailed Survey of the Tsimane'Over Time*. Taylor & Francis.

Granot, R., & Maimon, N. B. (2023). Consonance dissonance and cadences: The case of Israeli Arabs. *Music Perception: An Interdisciplinary Journal, 40*(4), 293–315.

von Helmholtz, H. (1863). *Die Lehre von den Tonempfindungen als physiologische Grundlage fur die Theorie der Musik*. Braunschweig: F. Vieweg und Sohn.

Huanca, T., & Reyes-Garcia, V. (eds.) (2015). *Cambio global, cambio local: La sociedad tsimane' ante la globalización*. Barcelona, Spain: Icaria.

Jacoby, N., Polak, R., Grahn, J. A., Cameron, D. J., Lee, K. M., Godoy, R., Undurraga, E. A., Huanca, T., Thalwitzer, T., Doumbia, N., Daniel, G., Margulis, E. H., Wong, P. C. M., Jure, L., Rocamora, M., Fujii, S., Savage, P. E., Ajimi, J., Konno, R., … McDermott, J. H. (2024). Commonality and variation in mental representations of music revealed by a cross-cultural comparison of rhythm priors in 15 countries. *Nature Human Behaviour, 8*(5), 846–877.

Jacoby, N., Undurraga, E. A., McPherson, M. J., Valdes, J., Ossandon, T., & McDermott, J. H. (2019). Universal and non-universal features of musical pitch perception revealed by singing. *Current Biology, 29*, 3229–3243.

Lahdelma, I., Athanasopoulos, G., & Eerola, T. (2021). Sweetness is in the ear of the beholder: Chord preference across United Kingdom and Pakistani listeners. *Annals of the New York Academy of Sciences, 1502*(1), 72–84.

Lahdelma, I., & Eerola, T. (2020). Cultural familiarity and musical expertise impact the pleasantness of consonance/dissonance but not its perceived tension. *Scientific Reports, 10*(1), 8693.

Leonard, W., Reyes-García, V., Tanner, S., Rosinger, A., Schultz, A., Vadez, V., & Godoy, R. (2015). The Tsimane' Amazonian Panel Study (TAPS): Nine years (2002−2010) of annual data available to the public. *Economics and Human Biology, 19*, 51–61.

Lu, F. (2007). Integration into the market among indigenous peoples: A cross-cultural perspective from the Ecuadorian Amazon. *Current Anthropology, 48*(4), 593–602.

McDermott, J. H., Lehr, A. J., & Oxenham, A. J. (2010). Individual differences reveal the basis of consonance. *Current Biology, 20*, 1035–1041.

McDermott, J. H., Schultz, A. F., Undurraga, E. A., & Godoy, R. A. (2016). Indifference to dissonance in native Amazonians reveals cultural variation in music perception. *Nature, 535*, 547–550.

McPherson, M. J., Dolan, S. E., Durango, A., Ossandon, T., Valdés, J., Undurraga, E. A., Jacoby, N., Godoy, R. A., & McDermott, J. H. (2020). Perceptual fusion of musical notes by native Amazonians suggests universal representations of musical intervals. *Nature Communications, 11*, 2786.

Nieuwenhuis, S., Forstmann, B. U., & Wagenmakers, E.-J. (2011). Erroneous analyses of interactions in neuroscience: A problem of significance. *Nature Neuroscience, 14*(9), 1105–1107.

Parncutt, R., & Hair, G. (2011). Consonance and dissonance in theory and psychology: Disentangling dissonant dichotomies. *Journal of Interdisciplinary Music Studies, 5*(2), 119–166.

Parncutt, R., & Hair, G. (2018). A psychocultural theory of musical interval: Bye bye Pythagoras. *Music Perception: An Interdisciplinary Journal, 35*(4), 475–501.

Parncutt, R., Reisinger, D., Fuchs, A., & Kaiser, F. (2018). Consonance and prevalence of sonorities in Western polyphony: Roughness, harmonicity, familiarity, evenness, diatonicity. *Journal of New Music Research, 48*(1), 1–20.

Plantinga, J., & Trehub, S. (2014). Revisiting the innate preference for consonance. *Journal of Experimental Psychology: Human Perception and Performance, 40*(1), 40–49.

Popescu, T., Neuser, M. P., Neuwirth, M., Bravo, F., Mende, W., Boneh, O., … Rohrmeier, M. (2019). The pleasantness of sensory dissonance is mediated by musical style and expertise. *Scientific Reports, 9*(1), 1070.

Rouder, J. N., Speckman, P. L., Sun, D., Morey, R. D., & Iverson, G. (2009). Bayesian t tests for accepting and rejecting the null hypothesis. *Psychonomic Bulletin & Review, 16*(2), 225–237.

Sauter, D. A., Eisner, F., Ekman, P., & Scott, S. K. (2010). Cross-cultural recognition of basic emotions through nonverbal emotional vocalizations. *Proceedings of the National Academy of Sciences, 107*(6), 2408–2412.

Stumpf, C. (1890). *Tonpsychologie*. Leipzig: Verlag S. Hirzel.

Tenney, J. (1988). *A History of 'Consonance' and 'Dissonance'*. New York: Excelsior Music Publishing Company.

Trainor, L. J., Tsang, C. D., & Cheung, V. H. W. (2002). Preference for sensory consonance in 2- and 4-month-old infants. *Music Perception, 20*(2), 187–194.

Weiss, M. W., Cirelli, L. K., McDermott, J. H., & Trehub, S. E. (2019). Development of consonance preferences in Western listeners. *Journal of Experimental Psychology. General., 149*(4), 634–649.

Zentner, M. R., & Kagan, J. (1996). Perception of music by infants. *Nature, 383*(6595), 29.