Does synchronised singing enhance social bonding more than speaking does? A global experimental Stage 1 Registered Report

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Authors

NB: all authors besides first author are currently listed in alphabetical order. For the Stage 2 Report, the order will be changed based on Stage 2 contributions, including listing authors in the order they submit their data (and approximately 20 additional students/research assistants who assist with data collection will be added; see Table S1). Authors that are unable to submit their data by the agreed time will be removed from the author list in the Stage 2 Report and thanked in the Acknowledgments section.

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Abstract: **The evolution of music, speech, and sociality have been debated since before Darwin. The social bonding hypothesis proposes that these phenomena may be interlinked: musicality may have facilitated the evolution of social bonding beyond the possibilities of spoken language. Although dozens of experimental studies have argued that synchronised rhythms can promote bonding, methodological issues including publication bias, sample bias, experimenter effects, and appropriateness of experimental controls make it unclear whether synchronous singing reliably and generally enhances bonding relative to speaking. Here, we propose a Registered Report to overcome these issues through a global experiment in diverse languages aiming to collect data from 1710 participants across 57 sites. The social bonding hypothesis predicts that bonding will increase more after synchronous singing than after spoken (sequential) conversation or (simultaneous) recitation, while alternative hypotheses predict that song will not increase bonding relative to speech. Regardless of outcome, these results will provide an unprecedented understanding of cross-cultural relationships between music, speech, and sociality.**

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Table 1 | Registered Report design planner (simplified overview adapted from https://osf.io/sbmx9; see main text for details)

Question	Hypothesis	Sampling plan (e.g., power analysis)	Analysis Plan	Rationale for deciding the sensitivity of the test for confirming or disconfirming the hypothesis	Interpretation given different outcomes [proposed Stage 2 title wording]	Theory that could be shown wrong by the outcomes
1. Does music **enhance** social bonding?	H1) Synchronous singing **enhances** social bonding relative to a pre-experiment baseline	Maximum feasible sample size: n= 1,710 participants across 57 sites (minimum: 450 participants [150 x 3 conditions] across 30 sites after all exclusions)	Single-blind* multi-site randomized controlled trial. GLMM of social bonding as a function of **time (pre- vs post-experiment; within-subjects)**, with experimental cohort as random effect.	Maximum feasible sample size determined by multi-site recruitment logistics; recommended[1,2] Bayes Factor threshold of 3	if $BF_{10} > 3$: *"Synchronised singing enhances social bonding"*	*"music does not directly cause social cohesion"*[3]
	H0a) Synchronous singing **does not enhance** social bonding relative to a pre-experiment baseline	(same as above)	(same as above)	(same as above)	If $BF_{10} < 1/3$: *"Synchronised singing does not enhance social bonding"*	*"musical behavior is not only associated with, but may causally support, social bonding"*[4]
2. Does music enhance social bonding **more than speech** does?	H2a) Relative to a pre-experiment baseline, synchronous singing enhances social bonding **more than conversation** does	(same as above)	(same as above, except as a function of **modality (singing vs. conversation; between-subjects)**	(same as above)	if $BF_{10} > 3$: *"Synchronised singing enhances social bonding more than conversation does"*	music is biologically *"useless…[c]ompared with language…"*[5]
	H2b) Relative to a pre-experiment baseline, synchronous singing enhances social bonding **more than synchronous recitation** does	(same as above)	(same as above, except as a function of singing vs. **recitation)**	(same as above)	if $BF_{10} > 3$: *"Synchronised singing enhances social bonding more than synchronous recitation does"*	(same as above, for different manifestation of "language")
	H0b) Relative to a pre-experiment baseline, synchronous singing **does not enhance** social bonding **more than conversation or synchronous recitation** does	(same as above)	(same as above, except as a function of singing vs. **conversation and recitation combined)**	(same as above)	if $BF_{10} < 1/3$: *"Synchronised singing does not enhance social bonding more than speaking does"*	music is *"more effective for collective bonding than language"*[4]

If multiple hypotheses are supported, we will combine different types of wording in the Stage 2 title. Possible examples include: *"Synchronised singing enhances social bonding more than conversation or synchronised recitation does"* or *"Synchronous singing enhances social bonding, but not more than speaking does"*. If all $1/3 \leq BF_{10} \leq 3$, we propose *"Inconclusive evidence for effects of synchronous singing on social bonding"*

*Following ref[6], we classify this experiment as "blinded" because the experimenters will be "not present during the manipulation and measurement of outcome variables"

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Introduction

All known human societies possess both music and language: separately in the forms of instrumental music and spoken language, and together in the form of songs with words[7–12]. Why have humans evolved capacities for both speech and music when most animals arguably have neither[12–14]? This puzzle led Darwin[15] to describe musicality as "among the most mysterious [faculties] with which [humans are] endowed", since "neither the enjoyment nor the capacity of producing musical notes are faculties of the least use to man in reference to his daily habits of life"[15]. Darwin speculated that musicality may have evolved via sexual selection, though this hypothesis remains controversial and difficult to test (for reviews, see [3,4,12,16–20]).

In contrast, many scholars both before and after Darwin have argued that musicality is an evolutionary byproduct or cultural invention based on biological adaptations for other capacities, particularly language[5,8,21–23]. This view is most famously associated with Pinker's dismissal of music as "auditory cheesecake" that is biologically "useless":

> *"As far as biological cause and effect are concerned,* ***music is useless……*** *It shows no signs of design for attaining a goal such as long life, grandchildren, or accurate perception and prediction of the world.* ***Compared with language****, vision, social reasoning, and physical know-how, music could vanish from our species and the rest of our lifestyle would be virtually unchanged."*[5] [emphasis added]

Recently, scholars have increasingly invoked a social bonding hypothesis[4,24,25] for the evolutionary value of music. Like the sexual selection hypothesis, the social bonding hypothesis is also controversial and difficult to test (for review, see refs.[3,4,12,16–19] and the 60 commentaries accompanying refs.[3,4]). However, it does make specific predictions that can be tested in contemporary human populations, such as:

> *"music (including dance) is better-suited to social bonding of large, complex groups than ABMs [Ancestral Bonding Mechanisms] (grooming and laughter), language, or other non acoustic bonding mechanisms such as shared decorations or non-musical ritual behaviors (e.g., praying together without music). Music should be more effective and/or efficient relative to other methods as group size and complexity increase, such that while making music in pairs might only produce a small increase in dyadic bonding relative to conversation, making music in larger, more complex groups of people (dozens or hundreds organized into differentiated sub-groups) should be* ***more effective for collective bonding than language****, laughter, grooming, and so on."*[4] [emphasis added]

Dozens of experimental studies have argued that synchronised movement (including singing or dancing) can enhance social bonding, as suggested by three independent meta-analyses of over 40 independent experimental studies combining data from over 4,000 participants[6,26,27]. This evidence led social bonding hypothesis proponents to argue that:

> *Behavioral experiments from social psychology support the MSB [music and social bonding] hypothesis, suggesting that* ***musical behavior is not only associated with, but may causally support, social bonding****.*[4] [emphasis added]

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Nevertheless, some remain skeptical that music specifically causes social bonding [3,6,28–31] (but cf. [32]). For example, Mehr et al. wrote:

> "***music does not directly cause social cohesion****; rather, it signals existing social cohesion that was obtained by other means*". [3] [emphasis added]

Some concerns are general ones about biases that are increasingly recognised as limiting the validity, replicability, and generalizability of experimental psychology in general [33–39]. For example, Rennung & Göritz's meta-analysis [6] found evidence that publication bias (i.e., the tendency for journals to only publish studies showing statistically significant results) has led to inflated effect size estimates of the relationship between synchrony and bonding. They also found that the potential for experimenter bias was controlled (through blinding or physical separation) in only 15% (9/60) of experiments, and that such "blinded" experiments also showed weaker effects relative to those that were not blind. And although it was not explicitly analysed by Rennung & Göritz, examination of the studies shows that the majority involved English-speaking university students as participants, who are not representative of most humans [33,34,38]. Reliance on English speakers is a particularly serious theoretical concern when comparing between music and speech because cross-linguistic differences in temporal patterning of speech (e.g., "stress-timed" British English, "syllable-timed" Yoruba, "mora-timed" Japanese) are argued to be related to musical rhythms [8,40–44].

An additional concern more unique to music is that it is difficult to experimentally manipulate music in a controlled but ecologically valid way. For example, previous high-profile claims of music's special powers such as the "Mozart Effect" have been found not to be robust when tested with appropriate controls [45–47]. In the case of relationships between music, speech, synchrony, and bonding, music throughout the world is overwhelmingly performed in synchronised groups [10,48] while speech is generally produced sequentially with speakers taking turns. Sequential turn-taking in speech and music also requires inter-personal rhythmic coordination, but of a different kind from simultaneous, synchronised production. While rhythmic synchronisation to an isochronous (equal-timed) beat is a defining feature of most of the world's music [10], languages around the world have their own sense of rhythmic structure that allows speakers to synchronise their speech to some extent even in the absence of an isochronous beat (e.g., group prayer, or group pledges like the USA's Pledge of Allegiance) [43]. Synchronised movement is also possible in the absence of musical sound (e.g., synchronised marching).

In fact, when Rennung & Göritz compared studies that used musical sounds (e.g., metronomes, singing, drumming) with studies that used silent synchrony, they found no evidence of a specific causal effect of music on prosociality. Instead, an overall conclusion from their meta-analysis was that synchrony "*does increase prosociality, but it is not generally superior to interventions that include some type of interaction among participants….such as solving a puzzle together or communicating*" - where "communicating" crucially could include speech. Strikingly, however, a different meta-analysis of the same studies came to the opposite conclusion that "*synchrony… increases social bonding…over and above general socially coordinated behavior*" [26].

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While Rennung & Göritz's meta-analysis did not find reliable support for the hypothesis that music enhances social bonding above and beyond speech, most of the studies they analysed did not directly compare music with speech. The one study that did directly compare music with speech reported a strong increase in self-reported trust after group singing (n=24 participants) when compared with group poetry recitation (n=24)[49]. The only other study we are aware of directly comparing social bonding effects of singing vs speech (published after Rennung & Göritz's meta-analysis) also reported a strong increase in self-reported social connection after group singing (n=37) compared with group recitation of song lyrics (n=31)[50]. However, group recitation might not represent a fair comparison of the full bonding potential of spoken language in its more ubiquitous conversational form (including as gossip[51]). To our knowledge, no previous studies directly compared the bonding effects of singing against conversation. (NB: A similar limitation of lacking a conversation condition applies to our 2020 draft Registered Report protocol that intended to address the same question[52]).

In sum, there is substantial but equivocal theoretical and experimental evidence both for and against the hypothesis that music enhances social bonding relative to speech, with no data directly comparing singing with conversation, which would finally allow for a direct test of the hypotheses. Formally, the competing hypotheses and predictions can be broken down into two separate but related questions, each with corresponding null and alternative hypotheses, as follows (cf. Table 1):

Question 1. Does music enhance social bonding?

Alternative hypothesis (H1): Synchronous singing enhances social bonding relative to a pre-experiment baseline

Null hypothesis (H0a): Synchronous singing does not enhance social bonding relative to a pre-experiment baseline

Question 2. Does music enhance social bonding more than speech does?

Alternative hypothesis a (H2a): Relative to a pre-experiment baseline, synchronous singing enhances social bonding more than conversation does

Alternative hypothesis b (H2b): Relative to a pre-experiment baseline, synchronous singing enhances social bonding more than synchronous recitation does

Null hypothesis (H0b): Relative to a pre-experiment baseline, synchronous singing does not enhance social bonding more than sequential conversation or synchronous recitation does

Our goal in this study is to harness the benefits of Registered Reports and multi-site global collaboration to collect such data in a way that will be equally informative regardless of whether the data support (H1, H2a, H2b) or contradict (H0a, H0b) some or all of the predictions of the social bonding hypothesis.

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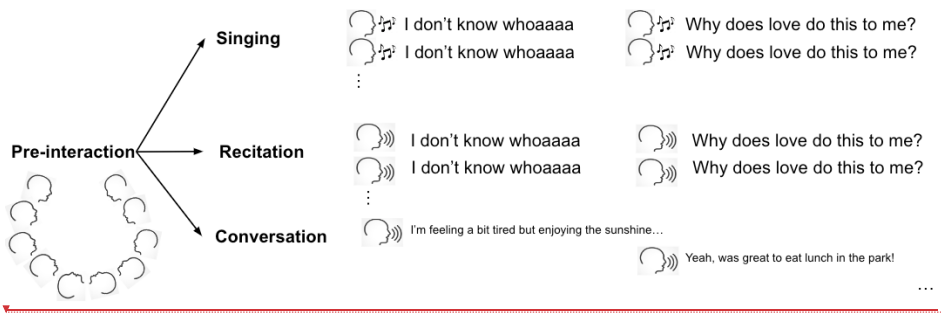


Figure 1. Schematic overview of the experimental design demonstrating an example of the experimental conditions. Here, only two participants are shown singing simultaneously, or speaking simultaneously (recitation) or sequentially (conversation), but the actual number of participants will be between 5-10 per experiment. Text columns #1 and #2 represent the first and second phrase of singing/speaking, such that when participant #1's text appears directly above participant #2's it indicates simultaneous singing/speaking, while when only one participant's text appears at a time this represents sequential conversation. This example shows lyrics for "Why Does Love Do This To Me?", the song chosen for participants using New Zealand English, and hypothetical conversation based on the ice-breaker prompt "How is your week going?", but note that the actual song and conversation prompt will be different (and generally in a different language) at each site. See Methods below for additional details regarding the experimental procedure.

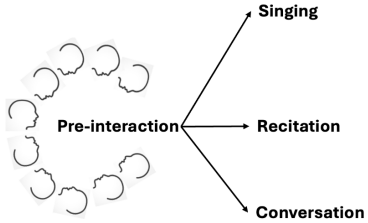
Methods

Ethics information

We have endeavoured to follow best practices in inclusive global collaborative research, including involving coauthors representing diverse communities from early stages of the research planning process[53–57]. The research will comply with all relevant ethical regulations and informed consent will be obtained from all human participants (see the first page of the Qualtrics survey for a detailed Participant Information Sheet). Participants will be compensated with course credit and/or payment at the standard rates for each participating institution (see Table S1). Permission to perform parts of this study were granted by the Keio University Shonan Fujisawa Campus Institutional Review Board (numbers 229 and 449), the University of Auckland Human Participants Ethics Committee (UAHPEC26969), and the Kenyan National Commision for Science, Technology & Innovation (NACOSTI/P/23/24284). Once the protocol has been finalised, the final version will be resubmitted to these committees and once these have been re-approved, coauthors will submit these to their local institutions for further ratification/approval as needed.

Design

Our design is classified as a single-blind, multi-site, randomised controlled trial with both within-subjects (H0a/H1) and between-subjects (H0b/H2a-b) components. The protocol has been refined via pilot testing at multiple sites in multiple languages (English, te reo Māori, and Japanese; see "Pilot data" section below for additional details). Note that we have consciously chosen to allow for variation across sites in the choice of both the song and the conservation prompt in order to maximise generalizability[37].



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Procedure to be repeated at each of the sites:

- 15-30 participants are recruited and randomly assigned into three groups of 5-10, each of which is asked to come to a specific room at a specific time for a ~45-minute experiment (see "Sampling plan" for justification of group sizes of 5-10 balancing theoretical and practical trade-offs).
- Each group of participants sit on chairs set up in a semicircle around a projector screen. The screen will display a pre-recorded video containing text instructions (in the local language) and a QR code by which they can access a Qualtrics survey using their own device or one provided by the experimenter if needed (see Fig. S1). Printed song lyrics are provided on paper. All participants will complete baseline measures of social bonding and other variables via the Qualtrics survey once before any experimental manipulation, and then repeat after the experimental condition to which they are randomly assigned (#1a-c). The task time in all conditions will take approximately 2.5 minutes. To achieve this, each site has pre-chosen a song that takes between 2-3 minutes to sing (in sites where an appropriate song could not be found, a shorter song will be repeated for 2-3 minutes), while the lyric recitation will be repeated twice as many times as for singing since lyric recitation is typically twice as fast as singing[42]. For the conversation condition, a timer will be visible counting down from 2 minutes and 30 seconds. In all conditions, participants will be given 5 minutes to complete both the task and the following survey. In each condition participants will remain seated throughout.
- **0) Pre-interaction (baseline):** Each participant will complete consent forms, measures of social bonding, and other variables (see Fig. 4) without speaking or otherwise interacting substantially with the other participants. Note that, unlike experimental conditions #1a-c, these measures will be done immediately, rather than after a task, as the goal is to measure baseline levels of social bonding prior to interaction.
    - Projector text: "*Welcome to our experiment! Without interacting with the other participants please sit in the provided chairs in a semi-circle facing this screen. Use your own device to access the link below, sign the consent form (Group ID: [S, C, or R, depending on whether they are in the singing, conversation, or recitation condition]), and answer Q1a-m. Please do not share your responses with the other participants.*"
    - To further minimise pre-experiment interaction, a sign with the following text is placed on the experiment room door: *"Welcome to our study. Please enter quietly and do not interact with the other participants until prompted to do so. Please close the door behind you & follow the instructions on the screen."*

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- **1a) Singing:** Participants sing a song in synchrony together in the local language that takes between 2-3 minutes to sing and that most people within that community would be expected to be able to sing together without needing to practise (pre-chosen by the lead experimenter for that language/community; see Table S1 for list of all songs/languages).
    - Projector text: "*Please sing along together with the accompanying music and lyrics.*"
- **1b) Conversation:** Participants take part in a conversation in their group. Like the song, the specific ice-breaker question will vary at different sites (see Appendix 3: "Conversation ice-breaker question criteria");
    - Projector text: "**How was your week so far? [example ice-breaker; to be replaced at each site with the question chosen for that site]** *Please discuss as a group. The person immediately to the right of the screen should begin and the others should join in when they are ready. Wait for the countdown, then begin. Please stop when the two and a half minute timer is up."*
- **1c) Recitation:** Participants recite the song lyrics (from the same song used in the singing condition) simultaneously but without singing. Because speech tends to be approximately 2x faster than singing on average[42], participants will be asked to repeat the lyric recitation twice as many times as the sung condition to ensure it takes a similar amount of time as the other conditions. We acknowledge that this introduces a different confound, but given the choice between controlling the time or the number of repetitions, we felt it more essential to control the overall interaction time to match both singing and conversation conditions (since in any case the content of the conversation condition is also different from both singing and recitation conditions and different songs also often have varying degrees of internal repetition).
    - Projector text: "*Please recite (without singing) the lyrics in the box on the right as a group. Wait for the countdown, then begin.*"
- **2) Post-interaction:** The same variables from the pre-interaction phase (0) will be collected again, plus a public goods game question.
    - Projector text: "*Please fill in the next page of the survey on your device now.*"
- **3) Demographic variables and debriefings:** Additional demographic variables will be collected for exploratory analysis, along with a brief debriefing text.
    - Projector text: "*Follow-Up Questionnaire: Please fill out the remaining page of the survey on your device. Thank you! Feel free to leave whenever you finish, even if the other participants are not done.*"
    - Debriefing text (from final page of Qualtrics survey): *"The goal of this experiment was to measure whether the average change in social bonding before and after the first singing/speaking/recitation condition from your group was greater than the change in other groups who experienced different singing/speaking/recitation conditions first. Please do not discuss the content of this experiment with other potential experiment participants. If you wish to be alerted when the audio recordings and results of our experiments are published, please provide the email address you would like us to use here (optional - you will not be emailed if you do not provide your address here): _____. We thank you for your time spent taking this survey. Your response has been recorded."*

Randomisation: For each site, 15-30 participants (depending on no-shows and recruitment limitations) will be recruited and randomly assigned to one of 3 groups each containing 5-10 participants. Note that the

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primary design is between-subjects, but there is also a within-subjects element in comparing the same participant before and after the different experimental interventions (see Fig. 4 for an example visualisation).

Blinding: Following ref.[6], we classify this experiment as "blinded" because the experimenters will be "not present during the manipulation and measurement of outcome variables", by having participants enter a room where they receive instructions by text on a projector. Participants cannot be blind to condition (i.e., they know whether they are singing or speaking), but our hypothesis tests are designed to be results-blind (since support for either hypothesis will be theoretically informative). Importantly, while participants may guess that the experiment is designed to measure an increase of bonding between people before and after the experimental intervention, they are unlikely to be aware that the ultimate goal is to compare the size of any increase in their own singing/speaking condition with the size of the increase from participants in other singing/speaking conditions. Participants' intuitions about experiment goals will be checked post-experiment for exploratory analysis.

Positive controls/outcome-neutral criteria: Our design includes the following measures to ensure interpretable data:

-Our bonding measures must not show ceiling or floor effects, otherwise support for the null hypothesis would be inconclusive (pilot data from Fig. S1 suggest that ceiling/floor effects should not be a concern).

-Including a within-participant pre-interaction condition allows us to confirm whether group singing and group conversation increase bonding relative to the baseline in addition to whether one increases bonding more than the other.

-The use of both conversation (sequential speaking) as well as recitation (simultaneous speaking) will allow us to control for possible confounds between manipulating domain (speech vs song) and synchrony (simultaneous vs sequential) and allow us to make the novel comparison between singing and conversation while also comparing our results with previous studies that showed increases in bonding for singing compared to recitation[49,50]

Inclusion criteria:

Each site will recruit participants who meet the following inclusion criteria:

-Age 18 or over

-Able to sing the song chosen for that site (with lyrics provided)

-Able to discuss the song in the same language its lyrics are written in

-Willing to have their singing/speaking voice recorded and shared publicly (without being identified by name).

Note that, while we welcome and do not intentionally exclude individuals with limited musical/linguistic abilities or experience, our requirements for participants to be willing and able to sing a specific song and have their voices shared publicly is likely to inevitably result in selection bias in recruitment, as better singers, more extroverted people, etc. may be more likely to volunteer to participate. Our participants will therefore not represent a random subset of the broader target population(s). We will interpret our results in light of this and other limitations.

Exclusion criteria:

The following participants/sites will not be included in confirmatory analyses:

-Participants who fail to show up on time at the agreed location

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-Participants who fail to complete the experiment and submit the Qualtrics survey
-Participants who are unable to complete the singing/speaking task in the specified language
-Participants who fail the attention check (see "Moderating variables and attention check" section)
-Participants with any confirmatory dependent variable's data missing or corrupted due to technical glitches
-Duplicate submissions by the same participant: During pilot experiments some participants failed to stop as instructed and accidentally completed the entire survey before the experimental condition began, and then re-did the survey. Such cases can be identified if the participant notifies the experimenter after the experiment and/or if the number of Qualtrics responses for a cohort is greater than the number of participants provided by the experimenter. It is impossible to precisely match a response to a participant due to the anonymous nature of the survey, but duplication can be inferred if the number of responses is greater than the number of participants and two responses from a group have identical answers for demographic variables. In such cases, the first set of responses should be excluded (cf. line 52 of https://github.com/comp-music-lab/sync-coop-song-speech/blob/main/SongSpeechCooperation.R for an example).
-All participants from groups where "Instruction compliance" is judged unacceptable by the experimenter (<25 out of 100). This will be rated after the experiment but before observing the Qualtrics survey, so is outcome-independent. In such cases, experimenters will re-recruit a replacement group of participants.
-Sites where useable data are only collected from fewer than 15 participants across all 3 groups (as this might suggest other data quality/recruitment issues)

Note that if fewer than 5 participants show up and complete the experimental singing/speaking tasks, none of the data from any participants in that group will be included in confirmatory analyses. However, if 5 or more participants successfully complete the tasks but some participants' data has to be excluded (e.g., because they failed to successfully submit the Qualtrics survey), data from the other participants will still be included in confirmatory analyses.

If following these exclusion criteria leads to the number of participants with usable data dropping below the specified minimums of n=150 participants each for the singing, conversation, and recitation conditions, we will re-recruit participants/collaborators until we meet minimum sample size requirements.

Sampling plan

Sample size estimation:

Our multi-site design means that our sample size estimation is primarily constrained by the maximum feasible sample size. Through initial consultation with potential collaborators, we determined the optimal sample size that would allow us to maximise diversity across many sites while allowing experimenters to feasibly recruit relatively large groups of participants was up to 30 participants per site (max 10 per condition across three conditions) for each of each of the sites shown in Fig. 3. Pilot experiments suggested that getting all participants to show up at the agreed location on time was a major unavoidable logistical issue, and that groups of 4 or fewer may not be large enough to test the predictions of the social bonding hypothesis (since singing in small groups "*might only produce a small increase… relative to conversation*"[4]). We thus decided to allow for experiments to run if at least 5 participants assembled on

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time for a given group). Note that while the social bonding hypothesis also predicts that the bonding advantages of singing should increase with even larger sample sizes (*"while making music in pairs might only produce a small increase in dyadic bonding relative to conversation, making music in larger, more complex groups of people [dozens or hundreds organized into differentiated sub-groups] should be more effective for collective bonding than language"*[4]), and we would have ideally preferred to recruit larger samples per group, the current experiment is not designed to test this specific prediction of the hypothesis, since such large samples are not feasible to recruit across many sites.

If all sites can collect the required data, this would give us a sample size of 855-1,710 participants, with a minimum sample of 285 participants per condition. However, it is likely that some sites (perhaps 10-20%) will ultimately not be able to meet these recruitment goals. We propose that even if as few as 30 of the 57 sites (53%) are able to meet the recruitment targets, the resulting sample of 450-900 participants across 30 sites (minimum 150 participants per condition) would still constitute "an important message for the field"[58] - both in terms of sample size and sample diversity - even if our resulting Bayes Factor falls in the inconclusive range ($1/3 < BF_{10} < 3$). If fewer than 30 sites succeed in meeting recruitment targets, we will re-recruit new collaborators until we can meet these minimum sample sizes (minimum 150 participants per condition across a minimum of 30 sites).

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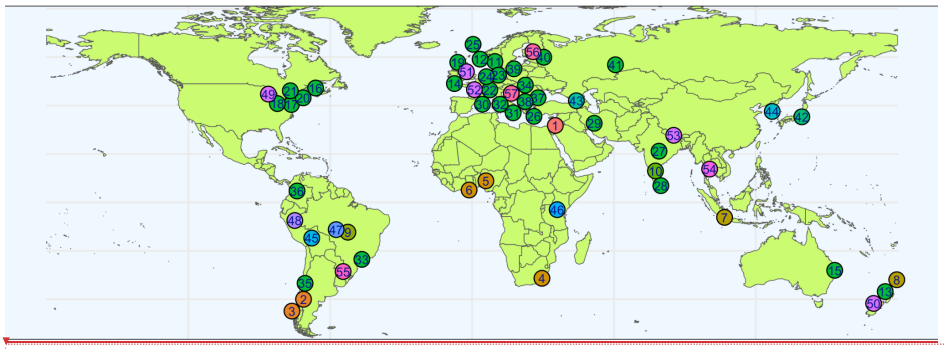

Afro-Asiatic		20 English [people who stutter]	**Kartvelian**
1 Modern Hebrew		21 English [Toronto]	43 Georgian
Araucanian		22 German [Leipzig]	**Koreanic**
2 Mapudungun		23 German [Frankfurt]	44 Korean
3 Tsesungún (Huilliche)		24 German [Mannheim]	**Mosetén-Chimané**
Atlantic-Congo		25 Norweigan	45 Tsimane' (Mosetén-Chimané)
4 IsiZulu (Zulu)		26 Greek *Greek*	**Nilotic**
5 Yoruba		27 Hindi *Indic*	46 Maasai
6 Fante (Akan)		28 Sinhala	**Nuclear-Macro-Jê**
Austronesian		29 Western Farsi *Iranian*	47 Rikbaktsa
7 Bahasa Indonesian		30 French *Romance*	**Pano-Tacanan**
8 Te Reo Māori (Māori)		31 Italian (Rome)	48 Shipibo-Konibo
Cariban		32 Italian (Padua)	**Sino-Tibetan**
9 Língua Kuikuro (Kuikúro-Kalapálo)		33 Portuguese [São Paulo]	49 Mandarin Chinese [Michigan]
Dravidian		34 Romanian	50 Mandarin Chinese [Auckland]
10 Kannada		35 Spanish [Santiago]	51 Mandarin Chinese [London]
Indo-European		36 Spanish [Bogotá]	52 Mandarin Chinese [Reading]
11 Danish *Germanic*		37 Bulgarian *Slavic*	53 Newari (Kathmandu Valley Newari)
12 Dutch		38 Macedonian	**Tai-Kadai**
13 English [Auckland]		39 Polish	54 Thai
14 English [London]		40 Russian (Moscow)	**Tupian**
15 English [Gold Coast]		41 Russian (Ekaterinburg)	55 Mbyá-Guaraní
16 English [Boston]		**Japonic**	**Uralic**
17 English [NY]		42 Japanese	56 Finnish
18 English [Hamilton]			57 Hungarian
19 English [Nottingham]			

Figure 3. Map of the 57 proposed participant recruitment sites/languages. See Table S1 for more details (e.g., song titles, coauthors responsible for data collection, participant compensation).

Analysis Plan

Independent variable: Vocal modality (synchronous singing, synchronous lyric recitation, or sequential conversation)

Dependent variable: Social bonding (average of six self-reported attitudinal prosociality variables).

The social bonding hypothesis defines social bonding broadly as:

> *"the formation, strengthening, and maintenance of affiliative connections ("bonds") with certain conspecifics (i.e., the set of social processes that engender the bonded relationships that underpin prosocial behavior)... we use "social bonding" as an umbrella term to encompass both bonding processes (over short and longer time scales) and their effects. Consequently, we take "social bonding" to encompass a variety of social phenomena including social preferences, coalition*

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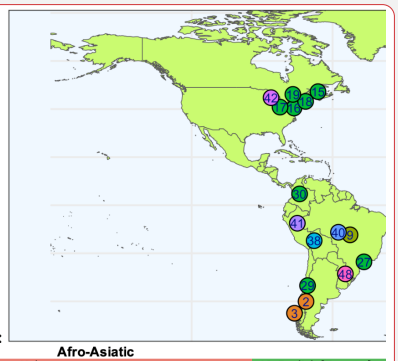

Afro-Asiatic		19 English [Toronto]
1 Modern Hebrew		20 German [Leipzig]
Araucanian		21 German [Frankfurt]
2 Mapudungun		22 Norwegian
3 Tsesungún (Huilliche)		23 Hindi
Atlantic-Congo		24 Western Farsi
4 IsiZulu (Zulu)		25 French
5 Yoruba		26 Italian
6 Fante (Akan)		27 Portuguese [São Pa
Austronesian		28 Romanian
7 Bahasa Indonesian		29 Spanish [Santiago]
8 Te Reo Māori (Māori)		30 Spanish [Bogotá]
Cariban		31 Bulgarian
9 Língua Kuikuro (Kuikúro-Kalapálo)		32 Macedonian
Dravidian		33 Polish
10 Kannada		34 Russian
Indo-European		J
11 Danish *Germanic*		35 Japanese
12 Dutch		Ka
13 English [Auckland]		36 Georgian
14 English [London]		(Ko
15 English [Boston]		37 Korean
16 English [NY]		
17 English [Hamilton]		
18 English [people who stutter]		

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Cooperation will be measured using the following

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formation, identity fusion, situational prosociality, and other phenomena that bring individuals together."[4]

For our confirmatory analyses, we will follow Rennung & Göritz, who previously collated different 17 different self-report measures of bonding/prosociality (perceived similarity, closeness, and liking) used in previous studies and condensed them into 9 variables after removing items with "inadequate discriminatory power, difficulty, and homogeneity"[59]. From Rennung & Göritz's 9 variables, we excluded the following three variables to minimise redundancy and ensure that the questions could be interspersed with non-bonding-related questions in the questionnaire without making it overly obvious that we intended to measure social bonding:

"I have a lot in common with the other participants"
"In general, I'm glad to be a member of this group of participants"
"I feel affection towards the other participants"

The final set of 6 variables we used to create our social bonding score are:

1) "I feel I am on the same team with the other participants"
2) "I am similar to the other participants''
3) ''I trust the other participants"
4) Inclusion of other in the self (IOS): ''How close do you currently feel to all the other participants?"
5) "I feel strong ties to the other participants"
6) "I identify with the other participants"

All variables will be collected using a 0-100 continuous slider via Qualtrics. With the exception of the "Inclusion of other in the self" (IOS) set of increasingly overlapping circles (Fig. 4), all sliders will ask for levels of agreement with a statement ranging from 0 ("strongly disagree") to 100 ("strongly agree"; numerical values will not be shown to participants; see Fig. 4)

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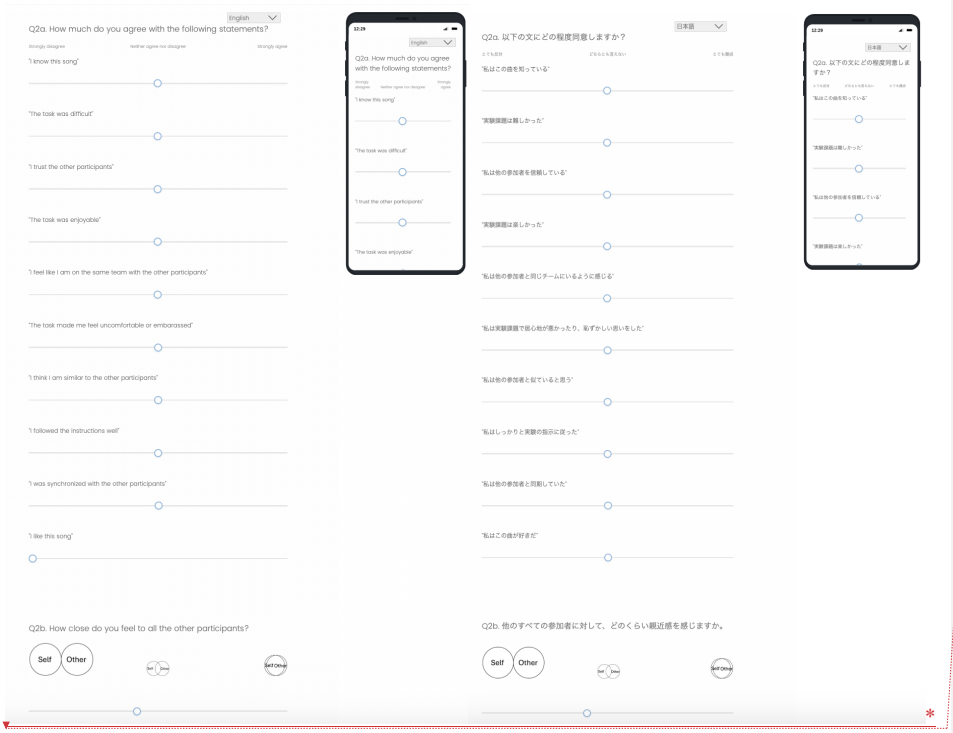
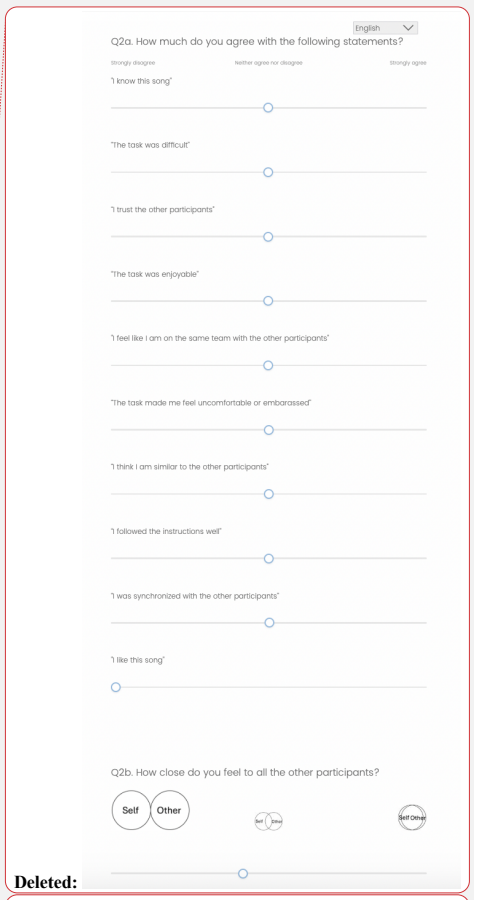


Figure 4. Screenshot of the setup of key variables using 0-100 sliding scales via Qualtrics, showing the English version (left) and an example translated version in Japanese (right). Note that our 6 dependent variables listed above are interspersed with 6 other variables to limit potential demand effects by making the experimental goal less obvious. [NB: Due to a Qualtrics bug, the "Inclusion of self in other" circle sizes are currently uneven - prior to In Principle Acceptance this will be unified and/or changed to circles that dynamically overlap depending on the degree to which the slider is moved to the right. It will also be updated to reflect additional variables added during the review process.]

Previous research has not consistently found that one of these variables is a superior measure of social bonding. To avoid issues involving multiple comparisons, we will therefore combine these variables into a single joint measurement of social bonding. Our pilot experiment (see "Pilot data" #4 below) collecting the first four variables (i.e., "same team", "similar", "trust", and IOS) found an acceptable level of internal consistency (MacDonald's total omega = .82, hierarchical omega = .60; Cronbach's alpha = .72). Therefore, we will use the mean of all 0-100 scales as our dependent variable for social bonding.

The final (In Principle Accepted) version of the Qualtrics survey and instruction video texts will be translated/adapted to the language, song lyrics, and conversation question of each site by the authors responsible for data collection at that site (see Table S1).



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Statistical models

Model for confirmatory analysis:

Although the (synchronised) singing condition, the (synchronised) recitation, and the (sequential) conversation conditions differ in both modality and synchrony, evaluating these effects individually brings complexity to designing decision rules for determining which features should be significant in rejecting the null hypotheses H0a and H0b. Therefore, we choose to model the combination of these effects as a single effect, resulting in the use of indicator variables for the three conditions.

We model each cohort of 5-10 participants using a random effect to account for a number of variables that may (co)vary between groups, including (but not limited to):

-differences in group size due to no-shows
-language spoken
-song chosen (e.g., musical/lyrical/symbolic content, amount of repetition)
-content of conversation prompt and spontaneous discussion in a group
-cultural values (e.g., individuality/collectivity, norms about group singing/speaking)
-experimenter effects (e.g., physical set-up of the experiment room, method of participant recruitment)
-time of day
-geographical location
-etc.

We use a linear mixed model, and our linear predictor function is modelled as follows:

$$\mathbf{y}_{(jn)} = \mathbf{X}_{(jn)}\boldsymbol{\beta} + u_{(j)} + u_{(n)} + \boldsymbol{\varepsilon}_{(jn)}$$

This linear predictor denotes a response by n_{th} participant of j_{th} cohort. $\mathbf{y}_{(jn)}$ is a two-dimensional vector comprising scores of social bonding before and after intervention. $\boldsymbol{\varepsilon}_{(jn)}$ is an error term of a two-dimensional vector. $\mathbf{X}_{(jn)}$ is a 2x4 design matrix whose first row is predictors, including intercept, of pre-intervention, and the second row is that of post-intervention. The predictor variables except for intercept are as follows: indicator of singing condition, indicator of conversation condition, and indicator of lyrics recitation condition. The indicator variables take either 1 or 0 depending on the condition assigned to participants, and they are all 0 in the case of pre-intervention. Therefore, the pre-intervention score only takes into account intercept, random effects, and error terms. $u_{(j)}$ is a random effect of j_{th} cohort, and $u_{(n)}$ is a random effect of n_{th} participant. The same linear predictor function is used to test both H1 and H2.

We pool the various potential effects described above into a single random effect rather than explicitly modelling each factor to avoid incorporating too many parameters into the model. Our primary analysis goal is to estimate the fixed effects in three experimental conditions (i.e., singing, recitation, and conversation) under varying factors, including locations, languages, sites, and chosen songs, rather than inferring the magnitude of those factors. Therefore, we consider the decomposition of random effects into multiple factors unnecessary for this confirmatory analysis.

The probability distributions corresponding to the above linear predictor function are defined as follows.

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$$\mathbf{y} \sim \text{MVN}(\mathbf{X\beta} + \mathbf{Zu}, \mathbf{R})$$

$$\mathbf{u} \sim \text{MVN}(\mathbf{0}, \mathbf{D})$$

$$\mathbf{R} = \sigma^2 \mathbf{I}_{2N}$$

MVN denotes the multivariate normal distribution, and $\boldsymbol{\beta}$ and $\mathbf{u}$ represent fixed and random effects, respectively. $\mathbf{I}_{2N}$ is an identity matrix whose size is equal to double the total number of data points N. Like standard linear mixed models, we assume random effects $u_{(j)}$ and $u_{(n)}$ are normally distributed around 0 with unknown covariance $\mathbf{D}$, and elements of error term vectors $\boldsymbol{\varepsilon}_{(jn)}$ are also normally distributed with unknown variance σ^2. We classify effects into fixed effects and random effects based on whether we model them as constant across all subjects or as varying between subsets of subjects.

Regarding the prior distributions of our model, firstly, we define priors on the variance parameter and the covariance matrix of random effects. The prior on the variance parameter σ^2 is:

$$\sigma \sim \text{Half-t}(\nu_\sigma, A_\sigma)$$

This is known as a noninformative prior on standard deviation parameters[60,61], allowing the model to include a wide range of values for σ as necessary. The prior on the covariance $\mathbf{D}$ is;

$$\mathbf{D} = \mathbf{D}_C \oplus \mathbf{D}_N$$

$$\mathbf{D}_C = \text{diag}(s^2, \ldots, s^2), \mathbf{D} \in \mathbb{R}_+^C$$

$$\mathbf{D}_N = \text{diag}(r^2, \ldots, r^2), \mathbf{D} \in \mathbb{R}_+^N$$

$$s \sim \text{Half-t}(\nu_s, A_s)$$

$$r \sim \text{Half-t}(\nu_r, A_r)$$

$\oplus$ is the direct sum operator, and C is the total number of cohorts. $\mathbf{D}$ is a block diagonal matrix consisting of the covariance matrices of cohort-level random effect and individual-level random effect. The priors on variance components are again modeled with Half-t distribution. This prior is the multivariate version of the above noninformative prior on variance. For clarification, this multivariate formulation is equivalent to C independent draws of u from a normal distribution $N(0, s^2)$ and N independent draws from $N(0, r^2)$.

Secondly, two different prior configurations are specified for $\boldsymbol{\beta}$ to test H1 and H2. The first alternative hypothesis (H1) is tested against the point null-type hypothesis, so the non-local alternative prior[62,63] is employed for the alternative hypothesis (H1) to balance the convergence rates between Bayes factors in favour of the null hypothesis (H0a) and H1. The common modelling approach is to set a point null distribution for model H0a (e.g., Dirac delta function) and an unrestricted distribution for H1 (e.g., normal distribution). However, this situation indicates that H1 assigns non-zero probabilities to both the null hypothesis (parameter value of null) and the alternative hypothesis (parameter value other than null), making the two models not mutually exclusive, as opposed to the classical frequentist test. The non-local alternative prior is designed to avoid overlapping between the null hypothesis parameter space and the alternative hypothesis by removing probability density from the null point. Otherwise, Bayes factors converge with fewer samples when H1 is true compared to when H0a is true, leading to overconfidence in

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evaluating the alternative hypothesis[62]. In particular, we use the product moment density. Note this density is modified from the original formula to test the single element of the fixed effects vector. The prior on $\boldsymbol{\beta}$ for the null hypothesis against H1 is:

H0a: $\beta_1 = 0, \boldsymbol{\beta}^{(H0)} \sim \text{MVN}(\boldsymbol{\beta}^{(H0)} \mid \mathbf{m}^{(H0)}, g\boldsymbol{\Sigma}^{(H0)})$

(H0) denotes the $p-1$ dimensional parameter model that p is the dimension of $\boldsymbol{\beta}$, and $\beta_1 = 0$ corresponds to setting the point null hypothesis on the synchronous singing effect. The prior on $\boldsymbol{\beta}$ for the alternative hypothesis with the non-local alternative prior is:

H1: $\boldsymbol{\beta} \sim \frac{\beta_1^2}{d_p}\text{MVN}(\boldsymbol{\beta} \mid \mathbf{m}, g\boldsymbol{\Sigma})$

d_p is a normalising constant.

Regarding testing H2a and H2b, we use the same prior distribution for $\boldsymbol{\beta}$ but impose different linear inequality constraints, which are based on Bayesian linear inequality constrained models[64,65]:

H2a: $\boldsymbol{\beta} \sim \text{MVN}(\boldsymbol{\beta} \mid \mathbf{m}, g\boldsymbol{\Sigma})$ with $\beta_1 > \beta_2$
H2b: $\boldsymbol{\beta} \sim \text{MVN}(\boldsymbol{\beta} \mid \mathbf{m}, g\boldsymbol{\Sigma})$ with $\beta_1 > \beta_3$
H0b: $\boldsymbol{\beta} \sim \text{MVN}(\boldsymbol{\beta} \mid \mathbf{m}, g\boldsymbol{\Sigma})$ with $\beta_1 < \beta_2$ when testing against H2a
H0b: $\boldsymbol{\beta} \sim \text{MVN}(\boldsymbol{\beta} \mid \mathbf{m}, g\boldsymbol{\Sigma})$ with $\beta_1 < \beta_3$ when testing against H2b
Note that we will report two Bayes factors in this regard: one comparing H0b and H2a, and the other comparing H0b and H2b.

Finally, hyperparameters of the prior on $\boldsymbol{\beta}$ are set to be noninformative based on the techniques proposed in Overstall & Forster[66]. We set $\mathbf{m}$ as a vector of zeros as in Overstall & Forster[66], which indicates $\boldsymbol{\beta}$ can be neutrally either positive or negative. $\boldsymbol{\Sigma}$ is a covariance matrix based on the Fisher information matrix for $\boldsymbol{\beta}$ that is $\boldsymbol{\Sigma} = NI(\boldsymbol{\beta})^{-1}$ as also suggested by Overstall & Forster[66]. Setting the variance parameter using the inverse of the Fisher information matrix, which is equal to standard errors of the parameters of interest, being multiplied by the sample size is known as the unit-information prior in the objective Bayes analysis literature[67,68]. The derivation of Fisher information matrix of linear mixed models is[66]:

$$\boldsymbol{I}(\boldsymbol{\beta}) = \nabla^2_{\boldsymbol{\beta}}\mathcal{L}(\boldsymbol{\beta}) = \mathbf{X}^\top\mathbf{V}^{-1}\mathbf{X}$$

$$\mathbf{V} = \mathbf{Z}\mathbf{D}\mathbf{Z}^\top + \mathbf{R}$$

$\mathcal{L}(\boldsymbol{\beta})$ is the log likelihood function, which is the logarithm of the marginalized density of linear mixed models (i.e., logarithm of $\text{MVN}(\mathbf{y} \mid \mathbf{X}\boldsymbol{\beta}, \mathbf{Z}\mathbf{D}\mathbf{Z}^\top + \mathbf{R})$). Lastly, it is known that when the mean parameter of the unit-information prior is largely misspecified (i.e., when $\mathbf{m} = \mathbf{0}$ is far from the true $\boldsymbol{\beta}$ in this case), it markedly impacts the posterior estimate of the variance parameter for linear models[69]. We empirically observed that this is also the case for the variance of random effects. Paciorek recommends multiplying the variance of the unit-information prior by a large factor g to avoid this issue[69], which we include in our model described above. Instead of manually specifying the factor g, we empirically found that setting a prior on this factor and treating it like Zellner's g-prior[70] with a hyper-prior, which is also a frequently used objective Bayes method[67,68], effectively works. Specifically, we set the benchmark prior to g[71–73]

$$g = 1/r - 1$$
$$r \sim \text{Beta}(0.01, 0.01N)$$

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The posterior distributions of our model are inferred using Markov Chain Monte Carlo sampling, primarily with Hamiltonian Monte Carlo employing the No-U-Turn sampler algorithm[74]. Additionally, we use the stepping-stone sampling algorithm[75,76] to compute marginal likelihood, which is necessary for calculating Bayes factors.

Pilot data

We have performed multiple rounds of experiment piloting:

1) Pilot experiments for 56 Japanese participants in 2019 singing/reciting キラキラひかる（Twinkle Twinkle Little Star) in various ways using earlier protocols (reported in[52])
2) Online pilot experiments in March 2024 singing "Auld Lang Syne" with 30 coauthors across 5 conditions (including alternating singing and non-verbal greeting conditions as well as singing, conversation, and recitation conditions)
3) Pilot experiments in Auckland (NZ) in May 2024 singing "Don't Forget Your Roots" in English and "Tūtira Mai Ngā Iwi" in te reo Māori with 16 participants (combination of coauthors and naive participants) across singing and conversation conditions.
4) Pilot experiments in Auckland (NZ, English) in June/July 2024 singing "Why Does Love Do This To Me?" with 14 naive participants (Fig. 4).

Results from pilot experiment #4 are visualised in Fig. 4 (pilot figures from #1 can be viewed at ref.[52] and from #2-3 at https://osf.io/download/66734e162026e9019a23e268/?version=5&displayName=Many%20Voices%202%20preprint%202024-06-27-2024-06-26T21%3A38%3A42.950Z.pdf). Fig. 4 shows that our design is capable of inducing and measuring an increase of bonding from before to after a group singing/speaking task without concerns about floor/ceiling effects. It also tentatively suggests possible support for the social bonding hypothesis, since bonding appears to increase more in the singing condition than in the conversation or recitation conditions. However, this should not be over-interpreted as the sample size for this pilot experiment is very small and restricted to English speakers in Auckland, NZ. Note that the three preliminary rounds (1-3 above) used protocols substantially different from the one proposed here, while the 4th round was almost identical to the current protocol except that the speech condition asked participants to discuss the song's lyrics rather than answer an ice-breaker question, and the dependent variable only averaged the first 4 of what are now 6 items.

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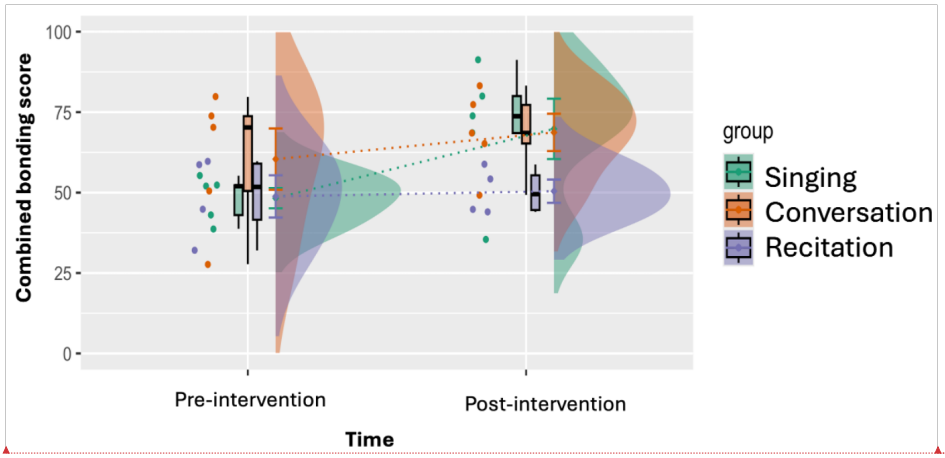

Figure 4. Pilot data (n=14, in 3 groups of 4-5 individuals) from participants in Auckland, New Zealand before and after singing, conversation, and recitation conditions using the song "Why Does Love Do This To Me?". The mean combined bonding score appears to increase more after the singing condition than after either spoken conversation or recitation conditions. No conditions appear to suffer from ceiling/floor effects.

Data to be collected for exploratory analysis:

In order to aid post-hoc interpretation of results and future follow-up studies, we will also collect the following types of data (which will not be used for our primary confirmatory hypothesis testing shown in Table 1):

Public goods game: Previous studies exploring links between synchrony and social bonding/prosociality have used a variety of proxies, including self-reported attitudinal prosociality and behavioral measures via behavioral economic games (e.g., stag hunt, public goods game)[6,26,27]. We have chosen to focus our confirmatory analyses on self-reported variables rather than behavioral economics games, for the following reasons:

1) Meta-analyses suggest equivocal results with behavioral economics game measures.[6,26]
2) Compared to behavioral measures, self-report measures are often more reliable, practical, flexible, and inclusive (especially important for our multi-site cross-cultural design), without being necessarily worse regarding expectancy effects[77].
3) Our pilot experiments suggested concerns with possible ceiling effects (a majority of participants in pilot experiments chose to contribute the maximum possible amount).
4) Behavioral economics game measures can require careful calibration of the monetary incentives via iterated pilot experiments to capture the intended effects. This is challenging even for one or a few sites, and unfeasible for our set of 57 sites spanning diverse languages and economies.

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We will collect a behavioral economic measure, but will limit it to exploratory analyses (see "Public goods game" section for details), since any discrepancies between self-report and behavioral results will be difficult to interpret conclusively.

For all sites, we will also collect a measure of a monetary contribution in a cooperative public goods game in addition to subjective self-report ratings, using the following scenario:

> "Imagine that all participants can anonymously contribute some of their payment to a pool of money that will be multiplied by 1.5 and divided equally among the participants. The more you contribute, the more all participants will receive on average, but the less you contribute the more you personally will receive in the end. So, if everyone in a group of 5 contributes 50% of their payment (i.e., $5), each person in the group would get $12.50 instead of $10 [amount/currency to be adapted based on each site's payment schedule]. If, however, the others all contribute 50% but you contribute 0%, the others would receive $11 total but you would receive $16. No one will know how much any other individual chose to contribute, only the total amount.
>
> How much would you realistically want to contribute to the shared pool (from 0%-100%)?"

Note that we have chosen to open this question with "Imagine that…" in order to maximise comparability across sites given that not all countries/institutions/labs allow paying real money to participants in varying amounts or deceiving participants into falsely believing they will be paid real money.

Participant expectancy: Immediately following collecting measures after the primary experimental condition, the following free response questions will be asked to explore possible participant expectancy effects:

1) Inferred study goals: "What do you think was the goal of the experiment, and what do you think the results will be?
2) General comments: "Do you have any comments regarding the study?"

Moderating variables/attention check: Following previous studies, we will collect the following variables in tandem with (and interspersed with) our primary dependent variables of bonding. This is partly to enable exploratory analyses, partly to reducing the likelihood of expectancy effects by making the goal of the experiment less obvious, and partly to include an attention check question to ensure data quality:

1) Prior familiarity with other participants: "How many of the other participants in the group have you seen or met before?" (0-7)
   - If participants answer that they know one or more participants, they will then rate each known participant for the following statement: "I knew this participant well before the study?"
2) Difficulty: "The task was difficult''
3) Enjoyment: ''The task was enjoyable"
4) Embarrassment: "The task made me feel uncomfortable or embarrassed"
5) Attention check: "I am currently participating in an experiment". (0="strongly disagree", 100 = "strongly agree"; participants who respond to this question with less than 75 will be excluded from confirmatory analyses.
6) Instruction following: "I followed the instructions well"

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7) Synchronisation (perceived): "I was synchronised with the other participants"
8) Familiarity: "I know the song on the printed paper"
9) Liking: "I like the song on the printed paper"
10) Leadership: "One of our group acted as a leader in the task"

Note that while ideally we would like to recruit participants who don't already know each other, it will not be feasible to completely ensure that all participants don't know each other at all (e.g., in some communities the number of native speakers of local languages is limited and most already know each other). We will therefore collect data on participant familiarity and use this to explore the potential role of familiarity in mediating synchrony-bonding relationships.

Demographic variables: We will collect the following variables to explore possible mediating effects and individual differences (including but not limited to individual differences in musical abilities[78]). Note that all demographic variables will be collected after collecting all data used for confirmatory analyses, in order to minimise potential expectancy effects[28] and any other potential unintended effects on participants during the main experiment phase.

1) Gender: "What is your gender?" ("woman", "man", "non-binary", "prefer not to answer")
2) Age: "How old are you?"
3) 1st language: "What is (are) your 1st/native language(s)?"
4) Ethnicity/race: "What ethnic/racial group(s) do you identify as?"
5) Religion: "What (if any) religious group(s) are you affiliated with?
6) Location: "Where are you performing this experiment?"
7) Birthplace: "Where were you born?"
8) Musicianship (self-perceived): "I consider myself a musician"
9) Musicianship (compliments): ""I have been complimented for my talents as a musical performer"
10) Singing training: "How many years of formal musical training have you had in singing?" (numeric)
11) Singing enjoyment: "I enjoy singing"
12) Singing frequency: "I sing regularly"
13) Musical instrument training: "How many years of formal musical training have you had in musical instruments?"
14) Music instruments played: "I have had training on the following musical instrument(s)"
15) Extraversion: "I am someone is outgoing or sociable"

Cohort-level variables: Each experiment will be monitored in real time by the local experimenters via Zoom video, where the instruction video will also be shown using screen share (the experimenters' video and audio will be muted). These videos will not be published, but will be used by the experimenters to monitor compliance and allow them to intervene if subjects misunderstand instructions, in case of an emergency, etc. After each experiment, experimenters will rate the following variables. Note that these ratings can only be done at the cohort-level and cannot be linked directly to individual participants because individual participant surveys are done anonymously via Qualtrics.

1) Experiment date
2) Experiment start time

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Additional data types: For a subset of sites, we will also collect a measure of cooperation in the form of a monetary contribution in a cooperative task in ac... [263]

3) Experiment location
4) Experimenter name
5) Number of participants (NB: This may vary from the number of Qualtrics responses - for example, if one participant from a group of 10 fails to complete the Qualtrics survey, only 9 responses will appear but the "Number of participants" for that cohort is 10.)
6) Instruction compliance (0-100). NB: This will be rated after the experiment but before observing the Qualtrics survey. All participants from groups where "Instruction compliance" is judged unacceptable by the experimenter (<25 out of 100) will be excluded and experimenters will re-recruit a replacement group of participants.

Site-level variables: The following additional exploratory variables may be investigated to explore potential factors affecting all participants at a site:

1) Singing/speaking language
2) Participant compensation (e.g., raw amount [in USD equivalent], relative Purchasing Power Parity, etc.)
3) Musical/acoustic features of chosen songs (e.g., tempo [bpm], pitch height [Hz], emotional valence [0-100 negative-positive subjective rating by researcher team who chose the song], etc.)

Audio recordings: We will record audio of the experiments in order to allow us to perform acoustic analyses. The microphone(s) should be placed in order to maximise recording quality while minimising effects on participants, with more emphasis on the former than the latter. For example, while wiring participants with individual microphones would give best audio quality, it is also likely to cause them the most anxiety, so it is preferable to use an unobtrusive microphone even though audio quality may not be optimal.

Acoustic analyses may include variables such as synchrony (including both "self-synchrony" to an isochronous beat and synchrony to other vocalizers[79]), differences in rhythmic/metric/tonal properties of different languages and of different song lyrics within languages. Such analyses will be complex and are intended to be explored primarily in future publications, so we will not specify detailed analysis plans here. The purpose of highlighting them here is simply to explain the need to record audio for future analysis purposes.

Post-experiment conditions: For the purpose of exploratory analysis, after completing the primary experimental intervention (singing, conversation, or recitation) and survey, participants will be asked to do the other experimental conditions, plus an alternating singing condition (taking turns singing one line at a time). The primary goal of these conditions is to enable future acoustic analyses replicating within-participant comparison of the same participant solo singing vs. solo speaking[42]. Following all these conditions, we will ask them to repeat the social bonding measures again to explore whether bonding continues to increase after doing multiple conditions in order. Data from these post-experiment exploratory conditions will be collected from all sites. However, if for any reason we fail to collect usable data from these post-experiment exploratory conditions but do collect usable data for the primary confirmatory analyses, we will still include these data in confirmatory analyses.

Acknowledgments: The current study can be considered a greatly revised and expanded version of a

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previous Stage 1 Registered Report (Savage, Yamauchi, Hamaguchi, Tarr, Kitayama, & Fujii, 2020). This was submitted to a journal in February 2020 and received helpful peer reviews from Martin Lang, Chris Chambers, and an anonymous reviewer but not pursued further due in part to Covid restrictions on in-person experiments. This new manuscript incorporates some text and ideas from that manuscript, and we thank Momoka Yamauchi and Miri Hamaguchi for their work on the previous manuscript. We also thank Damián Blasi, Andrei Miu, Simina Pitur, Larissa Renfrew, Marin Naruse, Camila Bruder, Violeta Magalhães, and Olcay Muslu for discussing ideas and pilot experiments.

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Data availability: The pre-recorded video protocol used for the New Zealand English pilot experiment #4 and audio recordings of the pilot experiment are available at https://osf.io/e4pqv/, where all raw data will also be uploaded after Stage 2 data collection. (This video was used for the recitation-first condition - other conditions will be identical except for the order in which recitation, singing, and conversation conditions are presented.) The Qualtrics survey is available at https://auckland.au1.qualtrics.com/jfe/form/SV_1Y791QuPaKbwJAa

Code availability: Pilot data (from pilot experiment #4; see Fig. 4) and analysis code are available at https://github.com/comp-music-lab/sync-coop-song-speech.

Author contributions:
Conceptualisation: Savage, Purdy, Opondo, Jacoby, Benetos, Fitch, Fujii, Ozaki, Pfordresher, Hegde, Liu
Investigation [participated in pilot experiments]: Savage, Pavlovich, Parkinson, Purdy, Chiba, Nweke, Nguqu, Opondo, Bamford, Ozaki, Pfordresher, McBride, Calhoun, Vanden Bosch der Nederlanden, Raviv, Liu, Dabaghi, Varnosfaderani, Sadaphal, Hegde, Csaba, Jacoby, Belyk, Youngblood, Krzyżanowski, Færøvik, Hansen, Tierney, Benetos, Popescu, Lomsadze, Pisanski.
Analysis: Ozaki, Savage, Pavlovich, McBride, Sadaphal, Youngblood, Leongómez, Bulbulia, Ravignani, Jadoul, Chiba
Data collection: [See Table S1 for details of which coauthors will collect data from which sites during Stage 2]
Writing – original draft: Savage, Ozaki
Writing – editing: Pisanski, Belyk
Writing – translation of protocols into local languages: [Will be done after In Principle Acceptance by the authors responsible for data collection in that language; see Table S1]
Project administration: Savage
Funding acquisition: Savage, Purdy, Opondo, Jacoby, Benetos, Fitch, Fujii

Conflicts of interest. The authors declare no financial conflicts of interest. Savage and Leongómez are Recommenders at *Peer Community In Registered Reports*.

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Supplementary Materials

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Figure S1. An example of the experimental set-up from the baseline condition (#0) of a pilot experiment [NB: Following this pilot experiment, we decided to increase group sizes to range from a minimum of 5 to a maximum of 10].

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Appendix 1. Logistics

Recruitment text:

The following short text will be translated/adapted to the local context as needed (e.g., language/venue/compensation/date/time) and distributed via social media (e.g., X, Facebook, Bluesky) and participant recruitment email lists along with the full Participant Information Sheet:

English (New Zealand):

Project title: *Relationships between music and speech in Aotearoa New Zealand and around the world*

-Are you age 18 or over?

-Can you sing the song "Why Does Love Do This To Me?" by The Exponents *(with lyrics provided)?*

-Are you willing and able to sing and speak in English?

-Are you willing to share your singing/speaking voice with the world?

We are recruiting participants for a study on cross-cultural relationships between speaking and singing. Participants will be paid $30 and the study will take less than one hour.

Time: 10-11am, Thursday 16 May 2024

Place: University of Auckland Building 201 Room 726

RSVP: manyvoicesproject@gmail.com

For more details, please see the attached Participation Information Sheet and contact our research team at the Waipapa Taumata Rau / University of Auckland School of Psychology:

-Danya Pavlovich (Ngāpuhi, Ngāti Hine; dpav474@aucklanduni.ac.nz)

-Hineatua Parkinson (Ngāti Hine, Ngāti Patuwai, Whakatōhea; atua.parkinson@auckland.ac.nz)

-Prof. Suzanne Purdy (Te Rarawa, Ngāi Takoto; sc.purdy@auckland.ac.nz)

-Dr Patrick Savage (patrick.savage@auckland.ac.nz)

Approved by the University of Auckland Human Participants Ethics Committee on 11 Dec 2023 for three years, Reference Number UAHPEC26969. Funded by the Royal Society Te Apārangi (22-UOA-052 & 22-UOA-040).

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Example of translated text

[will wait to translate into all languages when English version is finalised and receives In Principle Acceptance]

te reo Māori:

Te taitara kaupapa: *Te hononga i waenga i te puoro me te whaikorero i Aotearoa me te ao katoa*

-He 18 tau neke atu ranei?
-Ka taea e koe te waiata i nga waiata ***"Tūtira Mai Ngā Iwi"*** *(i te titiro ki nga kupu)?*
-Kei te pai koe ki te ***waiata/whakawhitiwhiti korero (i te reo Māori)*** *mo te waiata takitahi me te roopu roopu?*
-Kei te pai koe ki te whakapuaki i to reo waiata/korero ki te ao?

Kei te kimi kaiuru matou mo te rangahau mo nga hononga-a-iwi i waenga i te korero me te waiata. Ka utua nga kaiuru $30 ka iti iho i te kotahi haora te roa o te ako.

Wā: 11am-12pm, Rāpare 16 Haratua 2024
Wahi: Waipapa Taumata Rau Whare 201 Room 726
RSVP: manyvoicesproject@gmail.com

Mo te roanga atu o nga korero, tirohia te Pepa korero mo te whai waahi ka whakapiri atu ki ta matou roopu rangahau i te Waipapa Taumata Rau / Te Kura Kaupapa Hinengaro o Te Whare Wananga o Tamaki Makaurau.

-Danya Pavlovich (Ngāpuhi, Ngāti Hine; dpav474@aucklanduni.ac.nz)
-Hineatua Parkinson (Ngāti Hine, Ngāti Patuwai, Whakatōhea; atua.parkinson@auckland.ac.nz)
-Prof. Suzanne Purdy (Te Rarawa, Ngāi Takoto; sc.purdy@auckland.ac.nz)
-Dr Patrick Savage (patrick.savage@auckland.ac.nz)

I whakamanahia e Waipapa Taumata Rau te Komiti Matatika Tangata Kaiuru i te 11 o Tihema 2023 mo nga tau e toru, Tau Tohutoro UAHPEC26969. Na te Royal Society Te Apārangi i putea (22-UOA-052 & 22-UOA-040)

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Table S1. Planned songs, languages/communities, collaborators, and participant reimbursement at each site. (Many songs are tentative pending further piloting.)

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	Language (/community)	Song title	Named coauthors responsible for data collection [+ number of research assistants/ supervisees anticipated to be added as coauthors in Stage 2]	Approximate participant reimbursement
English (Auckland)		Why Does Love Do This To Me?	Jia, Purdy	NZD$30 / course credit
	English (NY)	Jingle Bells	Ampiah-Bonney, Gabriel, Pfordresher	USD$15 / course credit
	English (Boston)	Livin' on a Prayer	Loui [+1]	Course credit
	English (London)	Rudolph the Red-Nosed Reindeer	Tierney [+ 1]	GBP£6
	English (people who stutter, NYC)	Hey Jude	Youngblood, Belyk	USD$18
	English (Toronto)	O Canada	Cabildo, Vanden Bosch der Nederlanden	CAD$15 / course credit
	English (Hamilton)	O Canada	Trainor [+1]	CAD$25
	French	Au Clair de la Lune	Pisanski [+1]	EUR€10
	German (Frankfurt)	Die Gedanken sind frei	Larrouy-Maestri [+ 1-2]	EUR€14
	German (Vienna)	Alle Vögel sind schon da	Haiduk	EUR€7
	Portuguese (São Paulo)	Oração Ao Tempo (Caetano Veloso)	Varella [+2]	BRL100
	Spanish (Bogotá)	Colombia tierra querida	Ariza, Leongómez	COP15,000
	Spanish (Santiago)	Canción Nacional de Chile	Soto-Silva, Silva-Zurita [+1]	CLP7,000
	Chezungun	Mari mari kumelekaimi	Silva-Zurita, Soto-Silva [+1]	CLP7,000

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Mapudungun	Wesha Kona	Moya [+1]	Course credit
Mandarin (Reading)	难忘今宵	Liu [+ 1]	GBP£5
Mandarin (London)	茉莉花	Huang, Benetos	GBP£22
Mandarin (Michigan)	茉莉花	Ma [+1]	USD$10
Mandarin (Auckland)	茉莉花	Jia	NZD$30
Korean	걱정말아요 그대	Jung, Kim, McBride	KRW5000
Hindi	सारे जहाँ से अच्छा	Sadaphal, Fitch	INR500
Kannada	Jaya bharata Jananiya tanujaate jaya he karnataka maate	Hegde [+1]	INR500
Hebrew	TBD	Shilton, Jacoby	ILS50
Tsimane’	TBD	Jacoby	TBD
Norwegian	Forelska i Læreren	Færøvik	Course credit
Guarani	Nhãnderu Tenonde Guiae	Barbosa	BRL100
Rikbaktsa	Jakara Watá	Natsitsabui, Barbosa	BRL100
Kuikuro	Mitote	Kuikuro, Barbosa	BRL100
Japanese	東京音頭	Chiba, Kitayama, Fujii	JPY¥1100
isiZulu	Umvumo/ Amahubo	Nguqu, Opondo	ZAR150
Maasai	Oh Yeleiyo	Parselelo	KES2,000
te reo Māori	Tūtira Mai Ngā Iwi	Pavlovich, Parkinson, Purdy	NZD$30
Finnish	Viidestoista yö	Bamford, Tarr	EUR€15
Hungarian	Micimackó	Honbolygó, Kertész	Course credit
Yoruba	Jse Oluwa	Nweke [+1-2]	NGN30,000
Fante	Yɛyɛ Enuanom	Arhine	GHS150
Italian (Rome)	“La canzone del sole” (first half: 0.00-2.20)	Novembre, Coissac [+1?]	EUR€8

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Italian (Padua)		“Hanno ucciso l’uomo ragno” (first half 0:00-3:00)	Grassi, Guiotto Nai Fovino [+1]	EUR€8
	Danish	Jeg ved en lærkerede	Hansen	DKK150
	Georgian	Chemo tsitsinatela	Lomsadze	GEL50
	Bulgarian	Зарад тебе, моме мори	Kurdova	BGN20
	Farsi	Morgh-e-Sahar	Dabaghi Varnosfaderani, Beck	EUR€15
	Russian (London)	"Пусть бегут неуклюже" (песенка крокодила Гены)	Proutskova	GBP£
	Thai	สามัคคีชุมนุม	Tirantani, Calhoun	THB400
	Bahasa Indonesian	Mengheningkan Cipta	Khasanah, Calhoun	IDR200,000
	Dutch	TBD	Raviv [+1]	EUR€13
	Polish	Sto Lat	Krzyzanowski, Podlipniak	PLN30
	Romanian	Ploaie in luna lui marte (Nicu Alifantis)	Popescu [+1-2]	Course credit / standard rate (TBD)
	Shipibo-Konibo	TBD	Zariquiey	TBD
Nepali		Resham Firiri	Duran, Shakya	NPR2500
English (Australian)		Waltzing Matilda	Thompson, Ross +1]	Course credit
English (Nottingham)		Let It Be	Tunçgenç, Ong [+1]	GBP£10/Course credit
Bislama		Yumi, yumi, yumi[?]	Forsythe, Atkinson [+1]	TBD
Macedonian		Makedonsko devojce	Arabadjiev	TBD
Russian (Ekaterinburg)		"Пусть бегут неуклюже" (песенка крокодила Гены)	Pavlov, Kosachenko	Course credit
Sinhala		සුලඟ සුලඟ	Dias [+1]	LKR3,000
Greek		Milo mou kokkino	Sotirios	EUR€10
German (Mannheim)		Grün, grün, grün sind alle meine Kleider	Reindl	Course credit

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Appendix 2: Song selection criteria

Each site has chosen a song that would be appropriate for their language/culture. The criteria for choosing a song were:

-**lyrics** are mostly in the **same language** that participants will use for their group conversation (some lyrics in other languages or meaningless vocables like "la la" are acceptable, but should not make up the majority of the song)

-should be **easy for most potential participants from that society to sing together in synchrony** (e.g., unison, homophony) with karaoke-style pre-recorded instrumental accompaniment without needing to practise ahead of time (though they can read the lyrics while singing). If pre-recorded instrumental accompaniment would not be appropriate for a given site/society, an a cappella (unaccompanied) song may be chosen instead.

-should be the kind of song that would be appropriate to sing by young adults who don't already know each other as a short "ice-breaker" exercise. As such, **songs that might easily become awkward, embarrassing, or offensive should be avoided** (e.g., children's songs, songs with polarising content or associations such as national anthems or religious songs). However, these factors may vary from site to site (e.g., for some communities a national anthem or religious song might be the best choice, while in others it might be the worst). The experimenters from each site should interpret this on the basis of their own local knowledge.

-the song should take **between 2-3 minutes** to sing (you are welcome to modify the number of verses/choruses (including repeating the song) to make this happen

-if the song has **instrumental interludes/introductions/outros,** these should **not be longer than 1 minute** total and there **should still be 2-3 minutes of singing time** not including these instrumental sections.

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Appendix 3: Conversation ice-breaker question criteria:

Each team will choose their own unique ice-breaker question for the conversation condition (this can be taken directly from one of the following lists, adapted from them, or newly created themselves, but teams should all choose different questions):
https://www.mural.co/blog/icebreaker-questions
https://museumhack.com/list-icebreakers-questions/
https://www.parabol.co/resources/icebreaker-questions/

Criteria for questions:
-Should not be about music/singing
-Should not use words/concepts that will be rated to create our dependent variable (i.e., "team", "similar", "trust", "close", "ties", "identify").
-Should not ask sensitive/personally identifiable information (e.g., name, address, birthday, religion, sexuality, etc.)
-Should be capable of short answers (5-15 seconds per person)

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