

Joint Drumming in Brazilian and German Preschool Children: Cultural Differences in Rhythmic Entrainment, but No Prosocial Effects

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Abstract

As a core feature of musical rituals around the world, humans synchronize their movements to the pulse of a shared acoustic pattern—a behavior called rhythmic entrainment. The purpose of the present study was (a) to examine the development of rhythmic entrainment with a focus on the role of experience and (b) to follow one line of evidence concerning its adaptive function. We hypothesized (a) that children learn how to synchronize movements to sound during social interactions, where they experience this behavior as a convention of the surrounding culture's practice, and (b) that rhythmic entrainment has an adaptive value by allowing several people to coordinate their actions, thereby creating group cohesion and ultimately promoting cooperativeness. We compared the spontaneous synchronization behavior of Brazilian and German preschool children during joint drumming with an experimenter, either vis-à-vis or separated by a curtain, versus drumming along a playback beat. Afterward, we measured the children's prosocial tendencies toward the experimenter. We found that Brazilian children were more likely than German children to spontaneously synchronize their drumming in a social setting, even if the codrummer was hidden from view. According to hypothesis, the variation in individual synchronization accuracy between and within the two samples could be partly explained by differences in individual experience with active musical practice, as revealed by parental interviews. However, we found no differences in children's prosocial tendencies depending on whether they just had drummed alone or together with the experimenter.

Keywords

music, culture, children, synchronization, rhythmic entrainment, evolution, dance, drumming, development, social

Introduction

Collective music making and dancing, usually in ritual settings, are core elements of human cultural practices around the world. As a central feature of such musical rituals participants synchronize their body movements to the periodic pulse of a shared, repetitive

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acoustic or audiovisual pattern—a behavior that has been referred to as “rhythmic entrainment” (Merker, Madison, & Eckerdal, 2009), “sensorimotor synchronization” (Repp, 2005), “beat perception and synchronization” (Patel, Iversen, Chen, & Repp, 2005), or “coordinated rhythmic movement” (Phillips-Silver, Aktipis, & Bryant, 2010). While the general definition of entrainment as “the process in which the rhythms displayed by two or more phenomena become synchronized” (Clayton, Sager, & Will, 2004, p. 2) comprises physical phenomena (e.g., mode locking of coupled oscillators) and nonmusical behaviors (e.g., circadian rhythms), the present article focuses solely on the human behavior of pulse-based rhythmic entrainment during music making and dancing.

Tinbergen (1963) proposed four questions to guide the analysis of a behavior’s bases: What are its mechanistic causes, adaptive functions, evolutionary history, and developmental course? To eventually reach an integrative understanding of human rhythmic entrainment, all four questions are of equal importance. In line with Tinbergen’s reasoning, the aim of the present study was twofold. First, we wanted to better understand the developmental course of rhythmic entrainment, particularly the role of culture and experience during early childhood (Hannon & Trainor, 2007). Second, we intended to follow one line of evidence concerning a possible adaptive function of coordinated rhythmic movement in humans, namely, to create group cohesion and ultimately promoting prosocial behavior (Roederer, 1984). In the first part of the introduction, we argue that a cross-cultural comparison of young children’s performance during joint drumming can provide new insights into the early development of rhythmic entrainment. In the second part, we present our reasons for running two behavioral tests, one on spontaneous helping and one on sharing, following various kinds of drumming experiences, to add new data to the debate on possible adaptive functions of rhythmic entrainment.

The “Developmental Systems Approach” to Rhythmic Entrainment

Current theories in evolutionary developmental psychology advocate a multilevel gene–environment perspective (Blasi & Bjorklund, 2003), which is consistent with the “developmental systems approach” originally articulated by Gottlieb (1991). Central to this approach is the concept of epigenesis, which describes the emergence of novel structures during the course of development through a bidirectional relation between at least four levels of information transmission: genetic, neural, behavioral, and environmental; with the latter level encompassing physical, social, and cultural aspects (Gottlieb, 2007). From this viewpoint, there are no simple genetic *or* experiential origins of behavior, as development is the product of epigenesis, with complex interactions occurring among the above levels (Bjorklund & Pellegrini, 2000). This approach emphasizes that human children inherit not only a species-typical genome from their parents but also a species-typical environment, manifested in the surrounding culture (Mesoudi, Whiten, & Laland, 2006; Richerson & Boyd, 2005).

If we take the developmental systems approach to investigate the ontogeny of rhythmic entrainment, the ambitious goal is then to identify the specific ways in which the four levels of the developmental system interact over the course of ontogeny to generate the phenotypic behavior of synchronized movement to sound (Lickliter, 2008). For example, on the neural level, Patel (2006) suggested that during rhythmic entrainment, humans utilize the same brain circuits necessary for complex vocal learning, which provide the tight link between auditory processing and motor production. *Homo sapiens* is the only primate species able to voluntarily learn and imitate environmental sounds, notably the vocalizations of others—a capacity that evolved independently in our species since our divergence with chimpanzees, probably as an adaptation for song and/or speech (for review see Fitch, 2006). On the behavioral level, the “dynamic attending theory” (Jones & Boltz, 1989), for example, has been proposed to explain how individuals use regular accentuations in rhythmic music to predict the timing of future events and synchronize

their movements accordingly (Drake, Jones, & Baruch, 2000; Large & Jones, 1999; McAuley, Jones, Holub, Johnston, & Miller, 2006).

However, we were interested in the environmental level of the developmental system, particularly the role of socialization and enculturation during the development of rhythmic entrainment in humans. Socialization and enculturation processes are related and overlap in the course of development (Campbell, 2011). What distinguishes these two processes is their foci. Campbell (2011) defines musical *socialization* as the ways in which members of a social group interact musically with children so to transmit social beliefs and values. Musical *enculturation*, in turn, has been defined as “the process by which individuals acquire culture-specific knowledge about the structure of the music they are exposed to through everyday experiences, such as listening to the radio, singing and dancing” (Hannon & Trainor, 2007, p. 466). Thus, the social groups and cultures in which human are immersed are central to their musical development and musical abilities (e.g., Campbell & Wiggins, 2013). While some emphasis has been placed on early musical socialization in the past few years (e.g., Custodero, Rebello Britto, & Brooks-Gunn, 2003; Young, 2008), fewer studies have centered on cross-cultural comparisons (Morrison & Demorest, 2009). Yet, the small body of literature available to date provides compelling evidence concerning the role of culture in human musicality (e.g., Drake & Ben El Heni, 2003), including where children are concerned (Hannon & Trehub, 2005; Trehub, Schellenberg, & Nakata, 2008).

Therefore, for the current study, we asked what types of experience may lead to the transition from infants’ early responsiveness to musical sounds (for review see Hannon & Trainor, 2007), and proclivities for rhythmic movements (e.g., Zentner & Eerola, 2010) to the first really synchronized reactions to rhythmic patterns in late toddlerhood (Eerola, Luck, & Toivianen, 2006; Kirschner & Tomasello, 2009; Provasi & Bobin-Bègue, 2003)?

We hypothesized that for a human child to learn how to synchronize movements to the pulse of a piece of music, he or she first has to experience this behavior as an essential part—a convention—of the surrounding culture’s practice (Tomasello, 1999; Tomasello, Kruger, & Ratner, 1993; Vygotsky, 1978). During the preschool years, participation in group activities relies heavily on shared intentionality in the form of shared goals and plans, as well as purely social motives to share activities with others (Tomasello, Carpenter, Call, Behne, & Moll, 2005). In this regard, making music or dancing—as soon as there is more than one intentional agent involved—is in no way different from other forms of human collaborative interactions. We agree with Overy and Molnar-Szakacs (2009) that “imitation, synchronization, and shared experience may be key aspects of human musical behavior” (p. 490), and that in the context of live music making, “sound is perceived not only in terms of the auditory signal, but also in terms of the intentional, hierarchically organized sequences of expressive motor acts behind the signal” (p. 492). Imitation is generally defined as a behavior whereby an individual observes and replicates another’s behavior. It usually requires a full-fledged understanding of the model’s goals and intentions and allows for a nongenetic transmission of skills and information across human generations (Tomasello, 1999; Tomasello et al., 2005).

Thus, regarding the developmental origins of rhythmic entrainment, imitation of the synchronized actions of others (dancing, shaking, drumming, clapping) to the pulse of a shared musical stimulus—albeit for purely social reasons and not to accomplish any external goals—should be a key experience toward the acquisition of rhythmic synchronization skills in human children; see also Parncutt (2009), Patel (2006, 2008), Phillips-Silver & Keller (2012), and Trainor (2006, 2007).

To test this specific hypothesis, we adapted the joint drumming experiment from Kirschner and Tomasello (2009) and collected comparable data from Leipzig, Germany, and from Salvador da Bahia, Brazil, assuming that preschool children from these two cities gain qualitatively different experiences with music. Specifically, we expected experience with intentionally shared and

rhythmically entrained behavior to music in social contexts to be more chronically accessible to young children from Salvador da Bahia, Brazil (Reiter, 2009), than from Leipzig, Germany (Wingerter, 2005). If such experiences are indeed essential for children to learn rhythmic entrainment, we predict that children from Salvador da Bahia, Brazil, should be more likely than those from Leipzig, Germany, to spontaneously synchronize their rhythmic movements when drumming together with a social partner, compared with drumming solo to a playback beat.

Adaptive Functions of Rhythmic Entrainment

Within the last decade, some serious speculation has been made concerning the adaptive function of rhythmic entrainment in humans. Theorists asked whether coordinated rhythmic movement to sound evolved to solve a reproductive or survival problem in our ancestral environment, for example, as a means to maximize the amplitude of a group signal (Merker, 2000); as a way of signaling coalition strength between groups (Hagen & Bryant, 2003); or as a practice of establishing expectation and turn-taking in mother–infant interactions (Dissanayake, 2000). Several other authors argued that rhythmic entrainment to music may have been adaptive during cultural evolution for its role in coordinating the actions of large groups of people, thereby creating a feeling of “boundary-loss” or “we-ness” among the participants of a musical ritual. Such social cohesion may have ultimately promoted cooperation and mutual assistance among the group members (e.g., Bispham, 2006; Cross, 2007; McNeill, 1995; Roederer, 1984).

Indeed, recent empirical research has supported a causal link between synchronous activity and prosocial tendencies. Wiltermuth and Heath (2009) found that synchronized marching significantly enhanced cooperation among participants compared with nonsynchronous walking. Hove and Risen (2009) demonstrated that tapping synchrony between participant and experimenter had a positive effect on subsequent affiliation ratings. Finally, Kirschner and Tomasello (2010) showed that prosocial effects of group music making are already evident in preschoolers. In their study, pairs of 4-year-old children helped and cooperated with each other more likely after 3 min of joint singing and dancing, compared with peers that had interacted in a comparable, but nonmusical exercise. However, the latter experiment’s design did not allow the authors to disambiguate the mechanism behind music’s prosocial effects on preschool children, for example, whether the synchronization of movements during the musical game was relevant for the observed effects or not.

Following these three lines of recent empirical evidence, we found it interesting to test in our study whether simple joint drumming with another person would already provoke prosocial tendencies in young children, namely, the proclivity for helping and sharing (Eisenberg, Fabes, & Spinrad, 2006). To be able to compare the prosocial effects of joint versus solo drumming, we implemented two behavioral tasks right after drumming. In the first task, the experimenter had a sudden accident that offered the child the choice of either helping him or continuing his or her own play activity (after Kirschner & Tomasello, 2010). In the second task, the child was offered the choice of either sharing some of his or her private resources with the experimenter or continuing to spend them all alone in a fun game (after Warneken & Tomasello, 2009). We hypothesized that children who were invited to drum with the experimenter should, on average, be more likely to help and share resources with him later on than children who drummed along with a playback beat, without any involvement from the experimenter.

Method

Participants

Seventy-seven children composed the final sample of the present investigation, including 36 three-year-old children from Leipzig, Germany (18 males and 18 females, $M = 3.5$, range:

3.02-3.98 years), and 41 two- to four-year-old children from Salvador da Bahia, Brazil (18 males and 23 females, $M = 3.5$, range: 2.84-4.32 years). German participants were recruited from a database of parents who had previously agreed to participate in child studies. They came from mixed socioeconomic backgrounds, however with a majority from middle and lower-middle classes. Brazilian children were initially recruited from a local university outreach program, through posters, flyers distributed in classes, and phone invitations. Once testing began, parents offered to distribute flyers in alternative places including community centers, churches, day care centers, and schools in the city and suburbs of Salvador. This guaranteed the participation of children from diverse social strata, although the vast majority came—like in Germany—from middle and lower-middle classes. Three additional German children were tested but excluded from the analyses because they refused to drum during the pretest ($n = 1$) or decided to stop playing while the experiment was still running ($n = 2$). Likewise, nine additional Brazilian children were tested but excluded from the analyses either because they oversaw the experimenter's accident in the helping test ($n = 1$), decided to stop playing while the experiment was still running ($n = 2$), their age turned out to be far outside the target window ($n = 5$), or due to experimenter error ($n = 1$).

Ethical Considerations

Permission to conduct the study in Leipzig and Salvador was obtained from the ethics review boards of each individual research institution, prior to the commencement of the study. A detailed explanation of the study was presented to each family upon their arrival. Parents were also informed about their rights as research participants. Once all questions concerning the study were answered in full, parents were asked to sign consent forms in either German or Portuguese.

Experimenters

Testing was done by two experimenters. Experimenter 1 (E1; female) guided the child through the entire study and demonstrated all tasks. In Leipzig, a German native speaker played the role of E1, whereas in Salvador, a Portuguese native speaker took over the task. However, Experimenter 2 (E2; male, first author) remained in his role in both research sites, to keep the experimental protocol as similar as possible for both groups. E2 pretended to be unaware of the entire task sequence, followed the instructions of E1, and solved all provided tasks just like and along with the tested child. Consequently, all verbal instructions were given by E1, meaning that E2's utterances could be restricted to a few predetermined sentences during the response measures.

Study Design

In the original joint drumming experiment by Kirschner & Tomasello (2009), German Kindergarten children in three different age groups (2.5, 3.5, and 4.5 years) were invited to drum together with a human partner, along with a drum machine or a playback beat. The authors found that, on average, children at all three tested ages spontaneously entrained their movements to the isochronous beat with higher accuracy if it was presented in a social context. They also found remarkable interindividual differences in synchronization accuracy, which remained unexplained: For example, some participants synchronized their drumming equally well to all three stimulus types, whereas other children did never drum in synchrony. Therefore, for the current study, we wanted to evaluate interindividual differences in synchronization accuracy. Therefore, we interviewed all parents, asking detailed questions about the participants' musical and social backgrounds. This data would allow us to better describe the observed drumming behaviors and

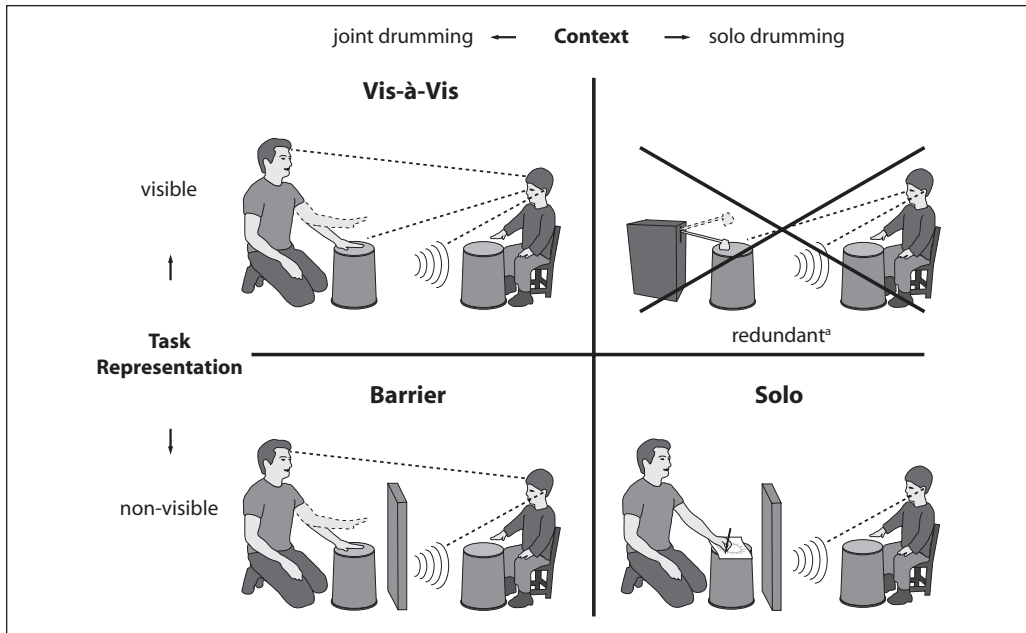


Figure 1. Drumming conditions.

Note. Barrier was the novel experimental condition, Vis-à-Vis and Solo were two control conditions adopted from Kirschner and Tomasello (2009). The dashed lines illustrate the perceptual differences between the conditions: In condition Vis-à-Vis, the child heard and saw the experimenter drumming and both shared the intention to drum together. Condition Barrier was similar except for the fact that the child could not see the experimenter's movements anymore. In condition Solo, the child drummed along with a playback beat, while the experimenter drew a picture.

^aThe control condition belonging to the fourth cell in the 2×2 design (drumming along with a machine that provides an audiovisual, but nonsocial stimulus) was omitted because it had already been tested by Kirschner and Tomasello (2009).

check for existing correlations between individual synchronization accuracy and personal experience in active music making.

Second, we wanted to exclude one remaining alternative explanation for Kirschner and Tomasello's (2009) major finding—namely, that the average increase in synchronization accuracy during joint drumming was caused by an enhanced visual perception (Sebanz, Bekkering, & Knoblich, 2006) while drumming with a human model compared with a mechanical apparatus and did not require any form of shared intention of drumming together in synchrony, as hypothesized by the authors. Specifically, the child's predictive simulation of the experimenter's periodic action might have caused spontaneous, but rather unintentional coupling of visually perceived and self-produced movements (Hove, 2008). Therefore, the current study included a new condition, in which the child still drummed together with the experimenter in a social context, but this time without perceiving any additional visual rhythmic cues (condition "Barrier," Figure 1). This was done by closing a curtain between child and experimenter as soon as the joint drumming began. Although the curtain covered the experimenter's body movements, his head still reached over the curtain, allowing for mutual gaze and smiling during joint drumming. We predicted children in the Barrier condition, who were familiar with the concept of synchrony during joint rhythmic activity, would entrain their movements with those of the experimenter even if they could not see, but just hear him drumming.

As baseline conditions, we adopted the two relevant conditions from the original study: joint drumming with the drum partner's movements fully visible (condition "Vis-à-Vis," Figure 1), and letting the child drum alone together with prerecorded drumbeats while the experimenter was doing something else (condition "Solo"). Whereas Kirschner and Tomasello (2009) used a simple isochronous beat of either 100 or 150 beats per minute (bpm) as stimulus, we decided to include a stepwise tempo shift in the stimulus beat to test whether children follow it differently depending on condition and culture.

In addition to the cultural background and drumming manipulation, we included gender as a predictor variable, resulting in a $2 \times 3 \times 2$ between-participants design, with three predictor variables (Culture, Condition, Gender), and three response measures (synchronization accuracy during drumming, spontaneous helping, and sharing after drumming). Within both cultural samples, participants were randomly assigned to one of the three drumming conditions. With regard to synchronization accuracy, the study had one additional within-subjects predictor variable (Tempo Change), included to measure any differences in the children's synchronization accuracy before the tempo change in the stimulus beat, compared with synchronization accuracy after the tempo change. Finally, we considered each child's "active music experience" as a correlational measure in the analysis, a factor we extracted *ex post* from the parental interviews.

General Procedure

Children and their parents were welcomed in a special warm-up area of the local research facility. Upon arrival, E1 interviewed the parents according to the structured questionnaire while E2 started playing together with the child. After the child's mother or father had finished the interview, E1 explained the actual purpose of the study. A few minutes later, children were guided to a separate study room without their parents. The entire testing session lasted about 15 min and consisted of a short warm-up followed by three repetitive play rounds, which were all embedded in a continuous cover story, developed to keep the child motivated throughout the session, and to cover each task as experimenter-guided pretend play. During the warm-up, E1 introduced a henhouse ($55 \times 45 \times 40$ cm cardboard box), occupied by 4 hidden puppet hens who, according to E1, were still asleep. To later distinguish the four hens from each other, they were fixed to 4 cardboard disks, each with a different color (red, blue, green, and yellow). To wake up the hens and get them out of the box, the child was asked to play on a small frame drum that was attached to the top of the box. This pretest was designed to check whether the child knew how to play a drum at various slow and fast tempi and did it unhesitatingly. Subsequently, the child and the two experimenters woke up all four hens one by one via drumming and then carried them across the room to a cardboard roost with four seats, in which each seat corresponding to the color code of one hen.

After the warm-up, the first round of the main game served to familiarize the child with the overarching cover story and the entire task sequence, consisting of seven steps: (a) choosing 2 hens from the roost and put them on two cardboard nests, (b) drumming for the hens to get them laying their eggs (papier-mâché marbles), (c) sorting the eggs by color into big transparent plastic tubes, (d) transporting the eggs to a magic oven and pour them into the chimney, (e) removing two trays from the oven that contain a number of fresh cookies (wood chips), (f) feeding the cookies to two hungry cardboard cows, and (g) bringing the two hens back to the roost.

Rounds 2 and 3 were exact repetitions of Round 1, only that one round included a test of the child's spontaneous helpfulness toward E2 after drumming (marble transport at Step 4, as described below), and the other round included a test for the child's spontaneous willingness to share his or her private resources with E2 after drumming (cow feeding at Step 6, as described below). During data acquisition, we alternated the drumming condition from session to session,

and counterbalanced the order of response measures two and three within sessions (either helping task first or sharing task first). Our reason for running the manipulation phase again before the second transfer-task was to reinforce any prosocial effects of drumming in case they were transient and faded while the child was concerned with the tasks to follow.

Dependent Measure: Prosocial Tests

For the helping task, we modified the test developed by Kirschner and Tomasello (2010) such that the E2 pretended to have an unlucky accident (the bottom of his tube fell off and all of his red marbles rolled over the floor), presenting the child with the choice of waiting and/or helping E2 to gather up the marbles or ignoring his problem and proceeding with her own play activity (pouring her own yellow marbles into the distracter). We coded the child's reaction to the accident according to the effort he or she made to help E2 solve his problem and categorized three ranks of helpfulness. The highest rank was ascribed to children who actively contributed to the solution of E2's problem and also waited until it was finally solved. The lowest rank of helpfulness was ascribed to those children who observed E2's accident, but instantly turned away without any verbal excuse or leave-taking.

To measure children's willingness to voluntarily share their own limited resources with E2, we developed a task that required child and E2 to each feed cookies (wood chips) one after the other to a separate cardboard cow (after Warneken & Tomasello, 2009). During the actual test, E2 ran out of cookies far before the child, leaving her with the choice of either sharing some of her cookies with E2 or feeding them all to her own cow. Importantly, E2 never explicitly asked for cookies, instead communicated his dilemma with three distinct sentences that only indirectly expressed his desire for the limited resource with stepwise increasing perspicuity. After each sentence, E2 made a defined pause to give the child the opportunity to share some of her cookies. We coded the child's reaction to E2's behavior according to the effort he or she made to compensate for E2's problem, that is, whether the child gave away some cookies at the first instance, only after E2's increased complaints or even never. Consequently, we categorized five ranks of prosociality. More details on both prosocial tasks, including materials, procedure, coding, and analysis, are given in the appendix.

Dependent Measure: Synchronization Accuracy

Materials. The setup of the drumming scene consisted of two small chairs, two floor-drums (40-cm high, ca. 20 cm in diameter), a frame (80 × 80 cm) with a movable curtain, and a table (50 × 30 × 55 cm) with a cardboard box (67 × 13 × 8 cm) on top with the hens' nests (2 holes of 9 cm in diameter), and four transparent plastic tubes (45-cm high, 25 cm in diameter) standing in front of the table. The chairs, drums, and frame were all placed in a straight line such that child and E2, when seated, would face each other with the two drums aligned between them and—depending on condition—the closing of the opaque curtain would hide E2's body from the child's view except for E2's head. The table was placed alongside this arrangement with the four tubes facing away from the drums. Importantly, before any tube could be carried away, a wooden clamp attached to the table had to be lifted up by the experimenters (see Figure 8). This clamp enabled them to control the exact timing when the child could lift certain tubes.

To record the child's drumbeats directly and exclude background noise, we used a piezoelectric sensor that was glued to the skin inside the child's drum. The skin of E2's drum was mantled with a soft cotton tissue, such that playing this drum created virtually no sound. In fact, across all conditions, the stimulus sounds came from two loudspeakers, one hidden inside E2's drum and one hidden under E2's chair. A laptop and an external sound card were used to simultaneously

playback the drumming stimuli and record the child's response beats, using a software tool programmed in Labview 8.5 (National Instruments Corporation, Austin, Texas, USA). The laptop was placed next to E2's chair, hidden from the child's view, and operated by E2 during the experiment such that the child did not notice it.

To secretly plant eggs in the nests, we constructed the following mechanism: Inside the nest box, a hidden slide board carried four cups (A-D) with the same diameter (9 cm) as the two holes on top of the box. Before every new round started, Cups B and D were filled with 6 eggs each (marbles painted in the equivalent colors of the hens and tubes). At the slide's starting position, the empty Cups A and C stood right under the two holes, such that from an outside view, the nests were empty. Pulling a string at the experimenter's side of the box caused the slide to move to its ending position and reveal the content of Cups B and D at the holes. However, because the cardboard disks fixed to the hens' body fitted right onto these holes during testing, the child did not notice the replacement of cups inside the nest box.

Drumming stimuli. During all three drumming conditions, we used the same prerecorded drum-beat sequences as stimuli, only changing the context of drumming (see procedure below). A single drumbeat was digitally sampled from the same drum that was later used by the child in the actual experiment. This sample sound was then repeated and strung together to form a 30-s long, isochronic beat, either starting at 100 bpm and increasing in tempo after 10 s to 150 bpm, or starting at 150 bpm and decreasing in tempo after 10 s to 100 bpm. In detail, the exact number and length of the interbeat intervals for the first stimulus file was 25 intervals of 400 ms, then 3 intermediate intervals of 450, 500, and 550 ms, followed by 30 intervals of 600 ms. The number and length of the interbeat intervals for the second stimulus file was 17 intervals of 600 ms, then 3 intermediate intervals of 550, 500, and 450 ms, followed by 45 intervals of 400 ms. In all conditions, the stimuli were played at the same volume. The order of presenting these two different stimulus files to each child was counterbalanced across conditions, gender, and round number.

Procedure. A new round started when E1 invited the child and E2 to take two new hens each from the roost, and put them on the two nests where they were going to lay their eggs. Then, E1 instructed the child to take a seat on the right and E2 to sit down on the left seat. Now E1 presented the cover story for the drumming task by saying (in the child's native language): "You know, these are special hens. To get them to lay their eggs, you first have to entertain them!" Finally, E1 introduced the actual drumming task differently according to the condition (Figure 1).

In the conditions Vis-à-Vis and Barrier, she said "[E2's name], to get your hen to lay eggs, you drum together with [child's name]," turning to the child, "And, [child's name], to get your hen to lay eggs, you drum together with [E2's name]." Right after these instructions, E2 secretly started the drumming playback and hit his "silent drum" in synchrony with the isochronic beats. The critical difference between the conditions Vis-à-Vis and Barrier was that in the latter, E1 closed the curtain at the moment the playback started, so that the child could still hear E2's drumming, see his head, but no longer see his body movements. Importantly, in the Barrier condition, E2 only pretended to continue his drumming movement after the curtain was closed. In fact, he stopped moving and placed his hand on his drum until the playback was over to rule out that any motor-coupling of hand movement and head posture might have provided additional visual cues for the child to synchronize with.

However, in the Solo condition, the task introduction differed. Here E1 explained the task by saying: "[E2's name], to get your hen to lay eggs, you draw a nice picture for it." She passed a sheet of paper and a crayon to E2, who instantly placed the paper on his drum and started drawing. Now E1 turned to the child with the words: "And, [child's name], to get your hen to lay eggs, you drum together with the drum sounds coming out of this radio," while pointing at E2's drum.

The moment the playback started, E1 closed the curtain so that the child's audiovisual perception was exactly the same as in the Barrier condition: hearing the drum sounds, seeing E2's head, but not his body movements.

Importantly, across all three conditions, E1 never instructed the child to actually drum in synchrony with the stimulus beat, as we were interested in differences in the children's spontaneous tendency to synchronize their drumming depending on condition.

During the time of the stimulus playback, E1 withdrew herself from the drumming scene and waited at the other end of the room, not facing the child and pretending to be busy reading until the drumming had ended. However, E2 smiled at the child, but alternated his gaze between the child and his own drum every 2.4 s (triggered by every sixth beat during the 150 bpm tempo, or every fourth beat during the 100 bpm tempo), regardless of whether he was drumming together with the child (Vis-à-Vis Condition), only pretending to drum behind the curtain (Barrier Condition), or drawing a picture (Solo Condition).

During the demonstration round, E2 stopped the playback right after 10 s and loaded the nest box, to keep the child in minimal suspense (the child's response during this round was not taken into account in the analysis). The moment the drumming playback stopped, E1 returned to the setup and invited the child and E2 to stand up and watch while she lifted the hens from their nests to check whether they had actually laid eggs. The final discovery of the eggs inside the two nests was stressed by both experimenters ("Great, it worked!" "Eggs!"). However, in Rounds 2 and 3, now that the child had already experienced the positive consequences of his or her actions, the stimulus files were played twice and in full length (30 s), before E2 secretly pulled the string on the nest box and added the eggs. Consequently, after the first playback, E1 had to return to the setup, lift the hens and inform the child and E2 that "It did not work, yet. You have to try it again!" before retreating a second time until the second playback was over.

Our reasons for letting the child drum twice in Rounds 2 and 3 were, first, because we wanted to enhance any predicted prosocial transfer-effects in the two social conditions by extending the time of joint drumming up to 1 min (2×30 s) per round, and second, because we wanted to increase the number of trials per participant to $n = 4$ (2 trials with a stimulus tempo changing from 100 to 150 bpm, 2 trials with a tempo changing from 150 to 100 bpm).

Individual trial analysis. Before comparing the average synchronization accuracy between conditions, we wanted to examine each participant's individual performance during each of the four drumming trials per participant (data collected during Play Rounds 2 and 3). We were particularly interested in how the child's instantaneous drumming tempo and synchronization accuracy proceeded over the course of the complete trial. We wanted to analyze how fast the children adopted the stimulus tempo at the beginning of a trial, how and when they responded to the sudden tempo change in the middle of drumming, and whether this response differed according to each condition. All of the following analysis steps were programmed with R version 2.10.1 (R Development Core Team, 2009).

First, to assess the child's instantaneous drumming tempo, we plotted the length of each inter-response interval at the time of each interval's second beat (black dots in Figure 2) against the tempo curve of the stimulus sequence (continuous lines in Figure 2). Second, to calculate the child's instantaneous synchronization accuracy, we applied circular statistics to a window of nine consecutive response beats and moved this analysis window beat by beat across the whole trial. As described in Kirschner and Tomasello (2009), circular statistics allow one to calculate and compare the mean and variance of asynchronies of a sequence of response beats, regardless of their phase direction, that is, whether one child was drumming to the stimulus beat and another child rather off the beat. For each window, we calculated the mean vector \mathbf{R} (for calculation see Fisher, 1993; Mardia & Jupp, 2000; Zar, 1999), which can be broken down into two nonparametric components; the vector's mean direction θ ("theta"), which can be used as a measure of the

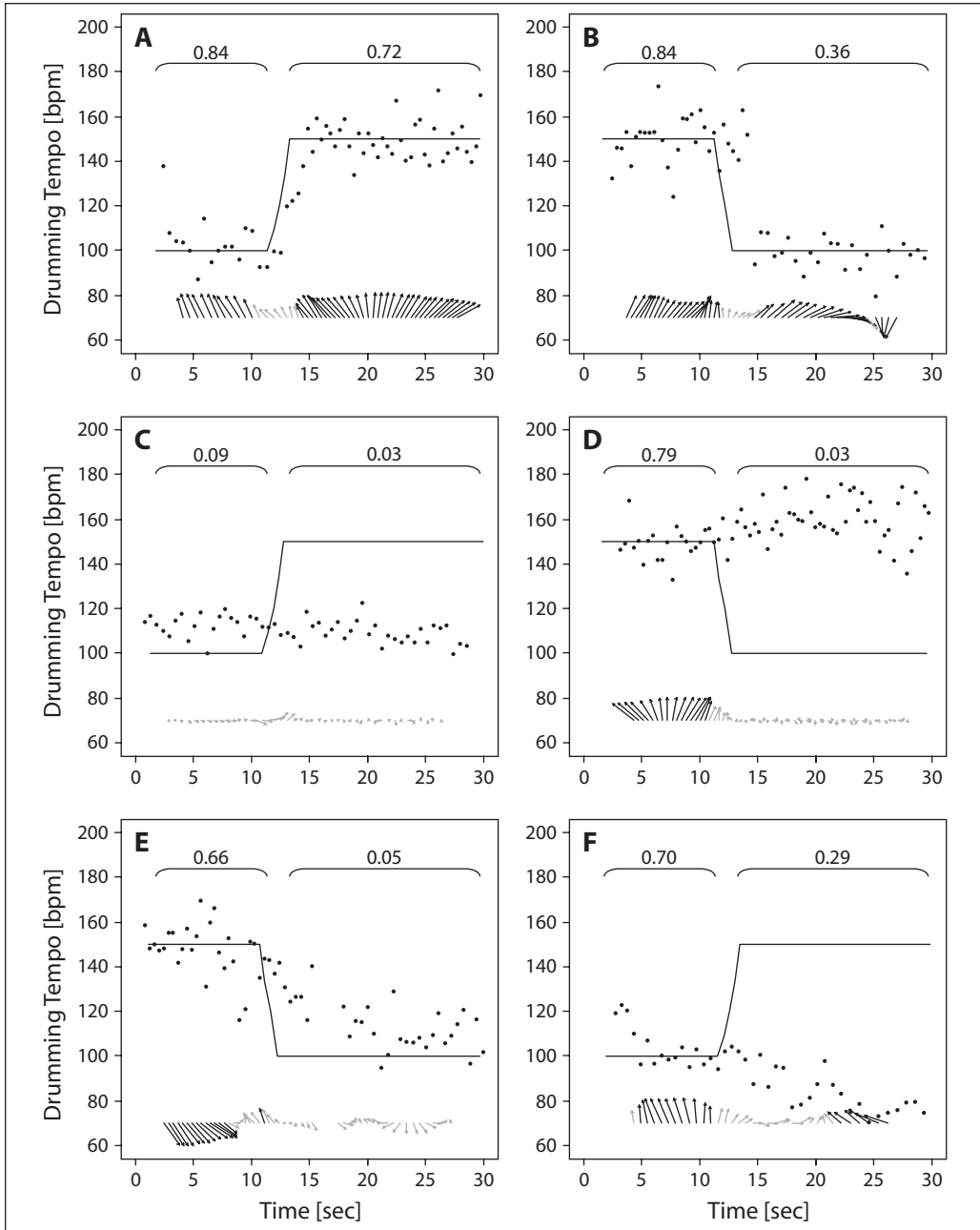


Figure 2. Individual trial analysis.

Note. Each panel represents a single trial from a different participant. The instantaneous drumming tempo (black dots) was plotted against the isochronic stimulus beat (continuous line), which changed its tempo after 10 s. Each participant's instantaneous synchronization accuracy was calculated from windows of 9 consecutive response beats shifting from beat to beat, using circular statistics. Each arrow represents the mean vector of a single analysis window, with its direction being a measure of the current drumming phase and its length being a measure of active synchronization. Black arrows represent significant synchrony according to Rayleigh's test, whereas gray arrows represent windows with no significant synchrony. The numbers above the brackets return the average synchronization accuracy (1 = perfectly synchronized, close to 0 = out of synchrony) before the pacing signal changed its tempo (left bracket) and after (right bracket).

participant's phase preferences, and the vector's mean resultant length \bar{R} . The latter varies between zero and one and, in terms of the current analysis, is a direct measure of synchronization accuracy during a particular window, notably independent of the mean direction of beats in that window: An \bar{R} of one would mean perfect synchrony and an \bar{R} close to zero would mean that the child did not actively synchronize his or her movements to the stimulus beat. To examine the course of synchronization during each single trial, we plotted arrows representing the mean vectors of all windows at the time of every window's fifth beat at the bottom of the plot described above (Figure 2).

In addition, to test whether a child was significantly synchronizing his or her drumming to the stimulus beat during a particular window, we applied Rayleigh's test for unimodal distribution of circular data points (according to Fisher, 1993). All the arrows in the scatterplot with a mean resultant length \bar{R} large enough to reach significance in Rayleigh's test were marked in black, whereas all vectors representing a window with no significant synchrony were marked in gray (Figure 2). However, because the arrows' color code in the final scatterplot represents multiple statistical tests using overlapping data points, the family-wise error rate can get considerably high. Therefore, any interpretation of an arrow should always consider its direction and color in relation to the neighboring arrows. For example, a series of black arrows all pointing in a similar direction likely represents a period of continuous synchrony. However, a single black arrow within a series of gray arrows more likely reflects a Type I error due to multiple testing.

Overall analysis. To test for any differences in the children's synchronization accuracy before and after the tempo change, we calculated \bar{R} separately for those response beats within the first 10 s of a particular trial and those response beats within the last 18 s of the trial. Next, for each participant, we averaged the \bar{R} values of all four trials, again separately for the time before and after the tempo change. Because the resulting mean \bar{R} ranges on a linear scale from 0 to 1, we could use a three-way ANOVA to test for the effects of Culture, Condition, Gender, and Tempo Change, after log-transformation, because visual inspection of plots of residuals against predicted values clearly indicated homogeneity of error variances. Considering \bar{R} as a measure of how accurate participants were when synchronizing their drumming, we predicted that it should be generally higher in the two social conditions Vis-à-Vis and Barrier compared with the Solo condition, and individually higher in those participants with relatively more active musical experience. For this and all following tests, we considered p values $\leq .05$ as significant. All following statistical analyses were performed using the statistical package SPSS 16.0 for Windows.

Correlational Measure: Active Musical Experience

Structured interview. A large proportion of young children's musical experience takes place in informal and noninstitutionalized settings, like the home, varied community spaces (Young & Ilari, 2012). Because young children are unlikely to be alone, much of what they experience in music is directly linked to what is provided by their families and community. Many factors are likely to affect how music is used by families with young children, including parental education and interest in music (Custodero et al., 2003; deVries, 2009), socioeconomic status, and media consumption (Ilari, Moura, & Bourscheidt, 2011; Young, 2008), to name a few. To get a more accurate picture of the musical experience of participating children, parents were interviewed according to a preset, structured questionnaire. We were particularly interested in children's active musical experience, and six main questions were created and devised for this purpose (Table 1). In other words, our measure of active musical experience was defined by parental answers to the following six questions.

Yet, given the relevance of contextual issues of cultural aspects of human experience (in the present case, musical interaction), it was vital to get as much information on the musical

Table 1. Six Questions With Rank-Based Answers, the Average of Which Was Taken as a Score for the Individual Child's Experience With Active Music Participation and Making.

(1) Is your child taking part in an early childhood music education program?

0	1
No	Yes

(2) Do you purposely listen to music together with your child?

0	1/3	2/3	1
Never	Rarely	Sometimes	Very often

(3) Do you and your child do anything while listening to music? (counting only musical exercises, like dancing, singing, playing instruments, singing along)

0	1
No	Yes

(4) On average, how many hours do you spend on a day with active music making? (singing, dancing, playing instruments, rehearsals)

0	1/3	2/3	1
<1 h	2-3 h	4-6 h	>6 h

(5) Do you sing for/together with your child?

0	1/3	2/3	1
Never	Rarely	Sometimes	Very often

(6) How frequently does the child experience live music? (church, concerts, street music, home music, theater, recitals, rehearsals, school programs)

0	1/5	2/5	3/5	4/5	1
Never	Rarely	Occasionally	Monthly	Weekly	Daily

experience of participating children as possible. These additional data would perhaps help to interpret the results. As an example, we suspected that it could prove useful to know not only the extent to which children were engaged in active music making but also the types of repertoires that they were exposed to, who accompanied them on a typical day and what sources were used for creating and listening to music. For this reason, the structured interview included questions on demographics, family structure, the child's prosocial behavior, music in the homes, and the child's participation in nonhome-based musical gatherings (e.g., taking part in any early childhood music program or attending live music concerts). As in previous studies (Custodero et al., 2003; Young, 2008), dichotomous, rank-based, and open questions were used to investigate the musical experience of participating children, according to parental reports.

Procedure. When a new participant together with one or both parents arrived at the research facility, E1 picked them up at the entrance and brought them to a special warm-up area. On their way, she asked the parents whether they would help to gather some anonymous background information about the participants by answering some background questions before the actual study started. Upon arrival at the warm-up area, E1 interviewed the parents according to the structured

questionnaire while E2 started playing together with the child. It was not until after the child's mother or father had finished the interview that E1 explained the actual purpose of the study. All 36 questionnaires belonging to the German sample were filled out completely and correctly. One Brazilian girl came not with her parents but with her nanny, who took the questionnaire home, but the parents never returned it. The remaining 40 questionnaires associated with the Brazilian sample were filled out completely.

Coding and statistical analysis. Interview data were transcribed and coded condition-blind. As noted earlier, parental answers to the six most relevant questions (Table 1) were summarized into a single score reflecting each child's individual experience with live music and active music making. Because the number of ranks differed from 2 to 5 depending on the question, they were normalized to the same range from 0 to 1, with 0 always aligned to the lowest rank of musical experience and 1 aligned to the highest. Relations between the two variables of synchronization accuracy and active musical experience score were assessed with the Spearman's rank correlation test with a two-tailed significance level. Application of the various tests will be mentioned when describing the results. A full report on the remaining interview data will be published elsewhere (Ilari & Kirschner, 2013).

Results

Synchronization Accuracy

Individual trial analysis. As expected, we found a huge diversity in drumming behavior in both cultures: between individuals and between trials of the same participant. The scatterplots of six different trials from six different participants in Figure 2 exemplify this diversity.

Panel A shows a boy that tightly synchronized his drumming, even phase-locked, before and after the tempo change in the stimulus file. The boy in Panel B also synchronized his drumming, but with increasingly positive asynchronies toward the end of the trial—resulting in a continuous shift of the black arrows' direction toward 180 degrees, which means he was still synchronizing at the end of the trial, but rather offbeat. Panel C shows a trial where a boy was constantly drumming out of synchrony, meanwhile keeping his own individual tempo irrespective of the changing driving rhythm. Another frequent pattern is exemplified in Panel D, where a girl was initially synchronizing her drumming phase-locked with the stimulus beat, but failed to adapt to the tempo change at 10 s, instead continuing to drum roughly at the initial tempo of 150 bpm. Other children (Panel E, for example) successfully changed their own drumming tempo according to the change in the pacing signal, but never reached synchrony again after the tempo had changed. Finally, during three trials from two different participants, we observed that the children first synchronized their drumming to the starting tempo of 100 bpm, however, when the stimulus speeded up to 150 bpm, they reduced their own drumming to the half-time tempo of 75 bpm, thereby getting into synchrony again after about 5 s (Panel F). Importantly, however, the number of children who reached significance in Rayleigh's test in both analysis windows (such trials as shown in Panels A and B)—which means they actively synchronized their drumming before and after the tempo change—was much higher in the Brazilian sample than in the German sample (Figure 3).

Overall analysis. The ANOVA of synchronization accuracy across the entire sample of 41 children from Salvador and 36 from Leipzig revealed significant effects of Culture, $F(1, 65) = 29.1, p < .001$, and Condition, $F(2, 65) = 26.5, p < .001$, but no effects of Gender, $F(1, 65) = 0.006, p = .94$. Interestingly, the analysis revealed an interaction between the factors Culture and Condition, $F(2, 65) = 3.16, p = .049$, whereas all other possible interactions did not reach significance (all $F < 1.23$, all $p > .27$).

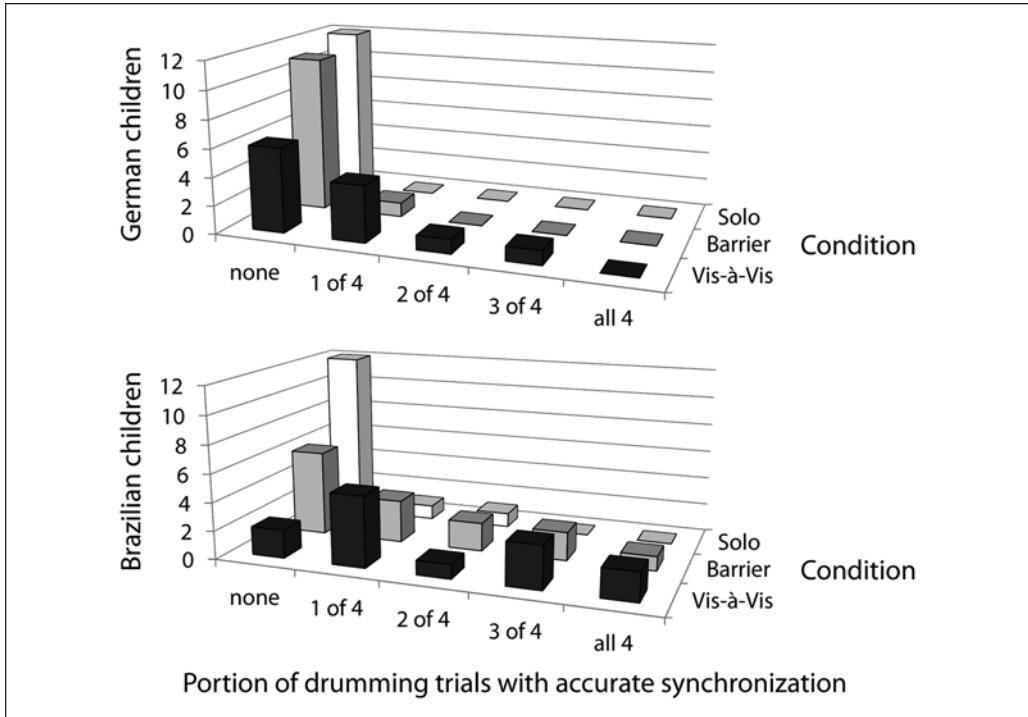


Figure 3. Trials with accurate synchronization according to Rayleigh's test.

Note. The size of each bar represents the number of participants per culture and condition who reached significance in Rayleigh's test for circular uniformity before and after the tempo change in X out of 4 trials per participant. Rayleigh's test asks whether the distribution of response taps significantly differs from a uniform distribution on the circle, indicating an active synchronization relative to the driving rhythm.

Post hoc tests between drumming conditions revealed that German children in the condition Vis-à-Vis were drumming with significantly higher synchronization accuracy compared with those in the Barrier condition, $F(1, 20) = 16.4, p < .001$, and the Solo condition, $F(1, 20) = 33.1, p < .001$. In addition, German children in the condition Barrier were also drumming with significantly higher synchronization accuracy than those in the Solo condition, $F(1, 20) = 4.86, p = .039$.

However, post hoc tests on the Brazilian sample alone revealed that—unlike in the German sample—the effect of Condition, $F(2, 35) = 12.9, p < .001$, was caused by a significant increase in synchronization accuracy in the conditions Vis-à-Vis, $F(1, 23) = 24.0, p < .001$, and Barrier, $F(1, 24) = 14.0, p = .001$, compared with Solo (see Figure 4B). But interestingly, Brazilian children in the conditions Vis-à-Vis and Barrier synchronized their drumming with equivalent accuracy, $F(1, 23) = 0.38, p = .54$. In other words, Brazilian children not only synchronized better in general but also increased their synchronization accuracy during joint drumming, regardless of whether they could see the experimenter drumming or just heard him. Finally, the ANOVA revealed a rather strong effect of Tempo Change, $F(1, 65) = 33.8, p < .001$, that did not interact with any other factor. In other words, children from both cultures were synchronizing with less accuracy after the tempo change had occurred, regardless of which condition they had been assigned to.

Active Musical Experience

In accordance with our prediction, we found ex post that children from Salvador scored higher on the active musical experience score than children from Leipzig (Figure 5, Mann-Whitney U test, $U = 433, n = 76, p = .003$, two-tailed).

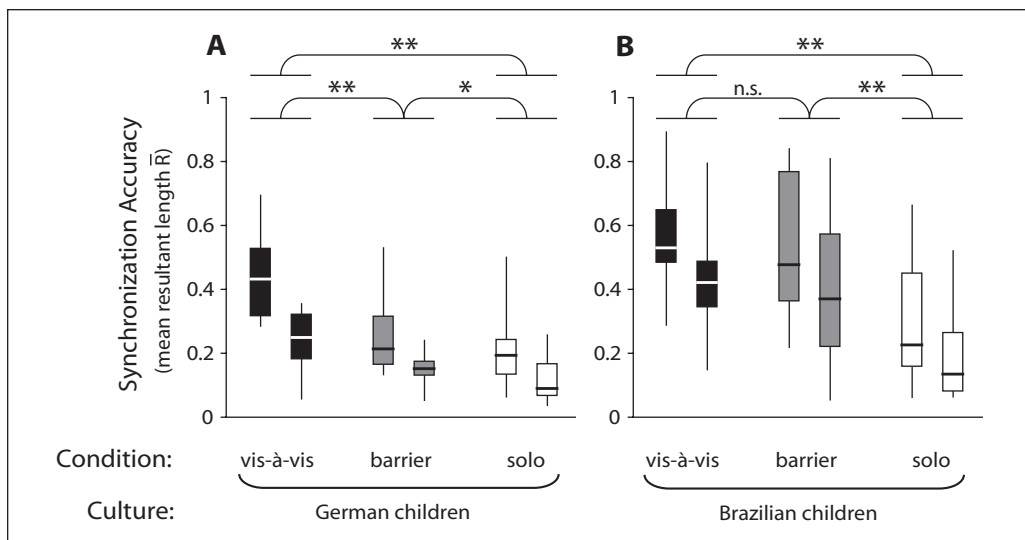


Figure 4. Synchronization accuracy.

Note. Comparisons of synchronization accuracy between children from Leipzig, Germany (Panel A) and children from Salvador da Bahia, Brazil (Panel B). The left bar of each pair represents the synchronization accuracy before the tempo change in the stimulus beat, whereas the right bar returns the synchronization accuracy after the tempo change. Distributional information shown are the median of a cell (crossbar), the range from the 25th to 75th percentile (box), and the minimum and maximum values (thin line). *n.s.* = not significant.

* $p < .05$. ** $p < .001$.

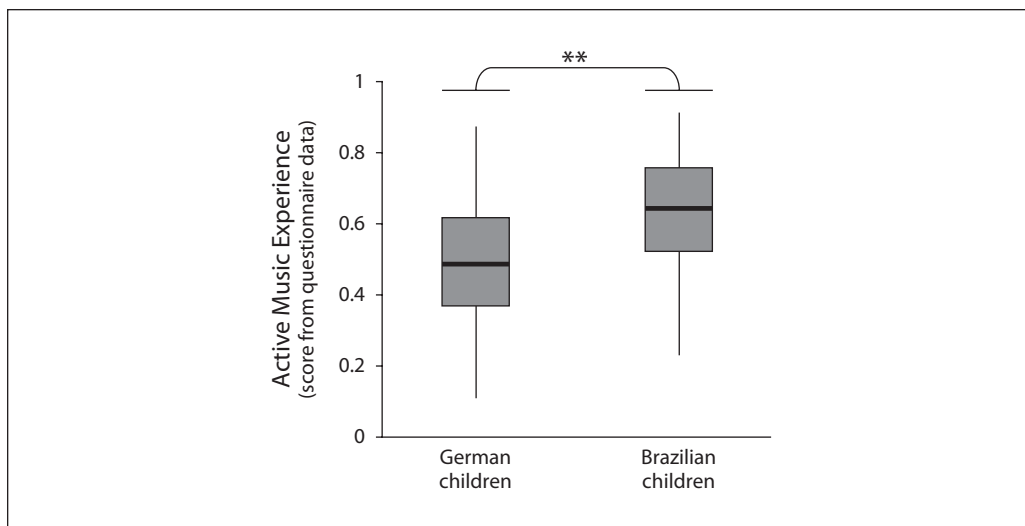


Figure 5. Cultural differences in musical experience.

Note. Comparisons of the score of active musical experience between the children from Leipzig, Germany, and the children from Salvador da Bahia, Brazil. Distributional information shown are the median of a cell (crossbar), the range from the 25th to 75th percentile (shaded box), and the minimum and maximum values (thin line).

** $p < .001$.

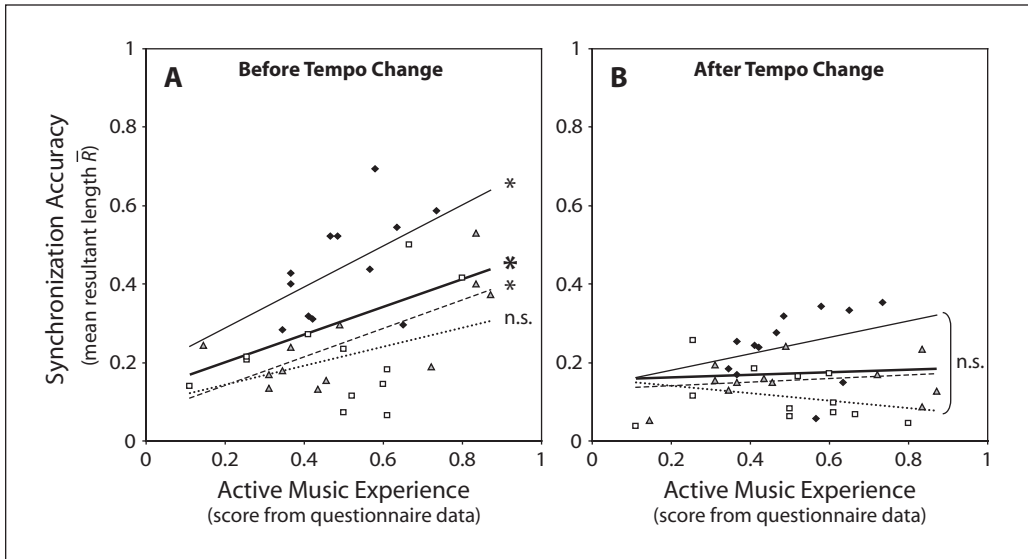


Figure 6. Musical experience and drumming performance in German children.

Note. Correlation between the German children's individual musical experience and synchronization accuracy, before (Panel A) and after (Panel B) the tempo change ($n = 36$, bold line). Also shown are three post hoc correlations per panel, each including only those participants within the same condition: Vis-à-Vis ($n = 12$, black rhombuses, continuous thin line), Barrier ($n = 12$, gray triangles, dashed line), Solo ($n = 12$, white squares, dotted line). n.s. = not significant.

* $p < .05$.

We also found that across the two samples of 36 German and 41 Brazilian children, the active musical experience score varied considerably between participants. This variation correlated significantly with the individual synchronization accuracy, yet only for the analysis window before the tempo change (German children: Spearman's $\rho = .38$, $p = .03$, Figure 6A; Brazilian children: $\rho = .31$, $n = 40$, $p < .05$, Figure 7A). After the tempo change, synchronization accuracy dropped significantly and, in the German sample, no longer correlated with the active musical experience score ($\rho = -.02$, $p = .89$, Figure 6B). In the Brazilian sample, the average synchronization accuracy also dropped significantly after the tempo change, $F(1, 65) = 33.8$, $p < .001$, but still correlated significantly with the active musical experience score, $\rho = .33$, $n = 40$, $p = .04$; Figure 7B).

The next step was then to look for correlations among those children within the same condition, as we expected higher correlations between individual synchronization accuracy and active musical experience among those participants in the social conditions Vis-à-Vis and Barrier compared with those children in condition Solo, because the social conditions more closely resemble such situations in which young children learn rhythmic entrainment. Within the analysis window before the tempo change, we found that the above correlation remained significant among those German children in the two social conditions Vis-à-Vis ($n = 12$, $\rho = .57$, $p < .05$) and Barrier ($n = 12$, $\rho = .60$, $p = .04$), but not in the condition Solo ($n = 12$, $\rho = .19$, $p = .56$). Yet, this pattern disappeared in the second analysis window (after the tempo change), as we found neither a significant correlation in the condition Solo ($\rho = -.26$, $p = .41$), nor in Barrier ($\rho = .12$, $p = .71$), nor in Vis-à-Vis ($\rho = .44$, $p = .15$).

Regarding the Brazilian children, we also found that the correlation coefficient in the analysis window before the tempo change remained positive among children in the social conditions

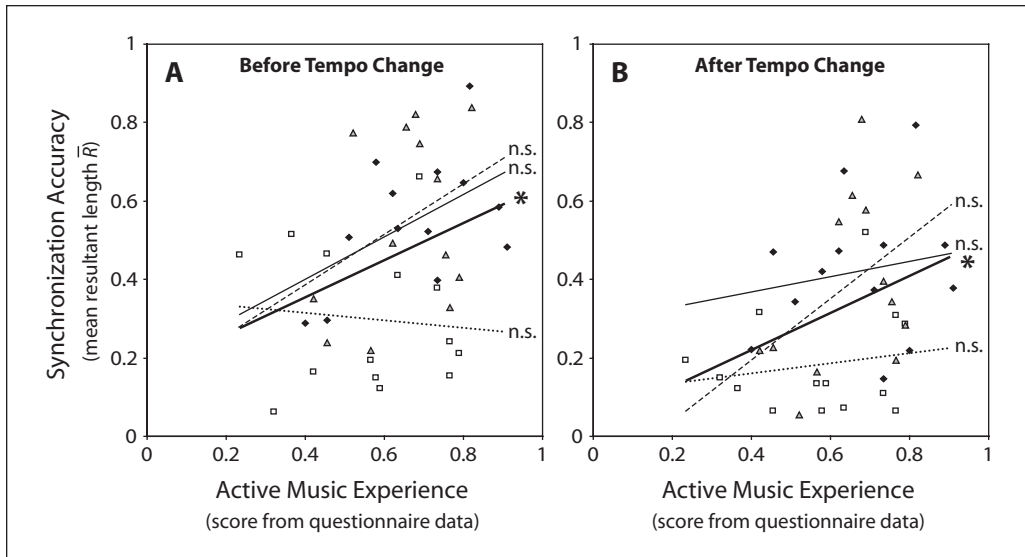


Figure 7. Musical experience and drumming performance in Brazilian children.

Note. Correlation between the Brazilian children's individual musical experience and synchronization accuracy, before (Panel A) and after (Panel B) the tempo change ($n = 40$, bold line). Also shown are three post hoc correlations per panel, each including only those participants within the same condition: Vis-à-Vis ($n = 13$, black rhombuses, continuous thin line), Barrier ($n = 13$, gray triangles, dashed line), and Solo ($n = 14$, white squares, dotted line). n.s. = not significant.

* $p < .05$.

Vis-à-Vis ($\rho = .39$, $n = 13$, $p = .19$) and Barrier ($\rho = .31$, $n = 13$, $p = .30$), but not in the condition Solo ($\rho = -.02$, $n = 14$, $p = .94$). With regard to the analysis window after the tempo change, we found that the above correlation coefficient again remained positive within the conditions Vis-à-Vis ($\rho = .20$, $n = 13$, $p = .51$) and Barrier ($\rho = .40$, $n = 13$, $p = .17$), but not in the condition Solo ($\rho = -.03$, $n = 14$, $p = .93$). However, in contrast to the German sample, none of the latter six post hoc, within-condition correlations was significant, which might be due to the fact that the overall range of active musical experience in the Brazilian sample was much smaller and shifted toward the upper end of the score—in comparison with the German sample. Such a cluster effect can, if the sample size gets too small, cause Spearman's rank test to find no statistical dependence between two variables.

In summary, these correlation patterns, as depicted in Figures 7 and 8, help to interpret the other findings of the study, suggesting that the differences in mean synchronization accuracy between conditions was predominantly caused by those individuals within conditions Vis-à-Vis and Barrier who had comparably more experience with active music making—whether growing up in Leipzig, Germany, or Salvador, Brazil.

Prosocial Tasks

The purpose of the two prosocial tasks was to measure any differences in the children's willingness to help and share resources with the experimenter depending on whether they had just drummed together with him (conditions Vis-à-Vis and Barrier) or drummed on their own, along with a background beat, while the experimenter was doing something else (condition Solo).

Regarding the children's behavior during the helping task, we found no significant main effects of culture or condition, nor any interactions (all $F < 1.344$, all $p > .251$). Regarding the sharing task, there was neither an effect caused by Condition nor any significant interaction of effects on the children's sharing behavior (all $F < 1.207$, all $p > .306$). However, the analysis revealed that children from Leipzig generally shared more cookies with the experimenter than children from Salvador, $F(1, 65) = 5.456, p = .023$. This result may well be due to the fact that E2 was native to the German language but not to Portuguese. Even though E2 had learned his Portuguese sentences by heart during the procedure, and a Brazilian native speaker judged the intelligibility of his utterances every morning prior to testing, there may still have been a subtle foreign accent in his voice, possibly causing Brazilian children to behave less prosocially in the sharing task (Kinzler, Shutts, Dejesus, & Spelke, 2009). Regarding the third variable, Gender, we found no difference in girls' and boys' helping behavior toward E2, $F(1, 65) = 0.16, p = .69$, but boys from both countries shared significantly more cookies with the experimenter than girls, $F(1, 65) = 4.728, p = .033$. However, this result is probably also an experimenter effect, because E2 was male, may be causing boys to affiliate more with him and thus share on average more cookies than girls.

Discussion

Summary of Findings

The aim of this study was to address two different questions (after Tinbergen, 1963) about rhythmic entrainment, that is, the human behavior of synchronizing body movements during musical instances. First, we were interested in the role of the cultural environment during the developmental course of rhythmic entrainment. Second, we wanted to test a hypothesis concerning the adaptive function of rhythmic entrainment, namely, its role in coordinating the actions of several people at once, thereby creating social cohesion, which ultimately promotes cooperation and mutual assistance among participants. Here, we asked whether such an effect can be found already in preschool children.

Concerning the developmental course of rhythmic entrainment, we found that preschool children from Salvador, Brazil, were more likely than those from Leipzig, Germany, to spontaneously synchronize their drumming in a social setting even if the codrummer was hidden from view—although there was much variation within both samples. However, the variation in individual synchronization accuracy between and within the two samples can be partly explained by differences in children's individual experience with active musical practice, as revealed by interview data. Specifically, in both cultural samples, those participants with more access to music in social contexts that presumably comprise intentionally shared and rhythmically entrained behavior (joint dancing and drumming at home, visiting live music shows, attending a music education program, etc.) were more likely to spontaneously synchronize their beats during joint drumming with the experimenter. These findings are in line with the hypothesis that rhythmic entrainment during music making and dancing is essentially a cultural convention (Tomasello, 1999; Tomasello et al., 1993; Vygotsky, 1978), meaning that young children learn how to synchronize movements to rhythmic sound during social interactions, where they intentionally imitate the synchronized actions of others (dancing, shaking, drumming, clapping) to the pulse of a shared musical stimulus (Overy & Molnar-Szakacs, 2009; Parncutt, 2009; Patel, 2006, 2008; Phillips-Silver & Keller, 2012; Trainor, 2006, 2007).

Another major finding was that on average children drummed with less synchronization accuracy after the tempo change occurred in the stimulus signal. However, against our expectations, this effect did neither interact with the participants' cultural background nor with the assigned

drumming condition. Instead, this finding suggests that many children had difficulties in corresponding to or even detecting the sudden tempo shift in the pacing signal, wherefore future studies should implement more natural (i.e., rather gradual and narrower) shifts in the stimulus tempo, if predictions are to be made concerning how experience and drumming condition may alter children's instant tempo flexibility during rhythmic entrainment. However, our results reflect a classic signature of basic entrainment activity, namely, that the impact of a preceding entrained state persists to influence an individual's adaptation to a subsequently changed tempo (e.g., see individual trials in Figure 2D-F).

Concerning the adaptive function of rhythmic entrainment, we found no differences in children's prosocial tendencies toward the experimenter depending on whether they had just synchronized their drumming with his or whether they had drummed along to a prerecorded drumbeat. However, this null finding may be limited to the current design. Perhaps, the prosocial effects of simple interpersonal synchrony previously observed in adults (Hove & Risen, 2009; Wiltermuth & Heath, 2009) could be elicited in children with a more advanced procedure that increases the intensity and duration of the shared rhythmic experience. For example, in an ongoing study by Cirelli, Einarson, and Trainor (2012), 14-month-old infants were held by experimenter A in an infant carrier facing outward and bounced to the beat of a melody for 145 s, while experimenter B faced the infant, heard the melody via headphones, and thus bounced either synchronously or asynchronously to the infant's movements. After the "joint dancing," infants were tested in various situations in which they had the opportunity to help Experimenter B by handing over desired objects. The authors found that infants who were bounced in synchrony with the experimenter's movements were significantly more helpful than those who did not.

Cultural Similarities and Differences

The comparison of parental responses in the interviews revealed more similarities than differences between children from Leipzig and Salvador with regard to general lifestyle and socioeconomic background. Typically for both samples, children lived in urban middle-class households, together with both parents and with no or just one sibling ($M = 0.6$ siblings). Questions about children's access to musical media at home also revealed similar patterns between samples. Most children possessed several CDs and recordings of children's music, toy instruments such as drums, flutes or xylophones, songbooks, and some even had access to their parents' instruments like keyboards, pianos, or guitars. Likewise, preferred musical repertoires of parents and children were similar to those reported in previous studies on musical parenting in Western societies (Custodero et al., 2003; Young, 2008).

All participating children attended day care centers and about half in each sample took part in weekly early childhood music education classes. However, there was no significant difference in overall synchronization abilities between children who were attending such music education courses and those who were not, $F(1, 72) = 1.72, p = .20$. Yet, the synchronization accuracy before the tempo change alone tended to be higher among those children who attended early music education courses in both countries, $F(1, 72) = 3.26, p = .075$. While the latter result could be explained by confounding variables (e.g., the parents' appreciation of formal musical training), it is also in line with the idea that early music training may enhance rhythmic development (Gerry, Faux, & Trainor, 2010).

Interview data also showed cumulative evidence that the children's everyday experience with music differed between samples, albeit less so in their access to public, live music performances (Mann-Whitney $U = 623, p = .30, n = 76$ for this and all following tests), but more with

respect to the children's experiences in their family homes. For example, Brazilian parents reported spending more time per day engaged in active music making, such as singing, dancing, or playing instruments, than German parents ($U = 581, p < .05$). Second, Brazilian parents differed from German parents in how much they liked to dance ($U = 537, p = .041$), although not in their preference for singing ($U = 616, p = .23$). Third, even if parents from both cultures reported similar amounts of time spent singing for their child and purposely listening to music together with their child, Brazilian parents apparently engaged their offspring more often in active participation, such as playing instruments, dancing, or singing along with the music ($U = 300, p < .001$). Consequently, Brazilian children in our sample also expressed their musicality significantly more often during spontaneous singing ($U = 406; p < .001$) and spontaneous dancing ($U = 369, p < .001$) than German children, once again according to parental reports. These reports suggest that culture-specific social learning processes that are part of transmitted musical conventions possibly play a major role in the development of children's rhythmic entrainment skills.

Important to mention here are also possible differences in German and Brazilian children's access to everyday musical performances on one hand and institutionalized music education on the other (Sloboda, 1985). While Germany has a long tradition in the institutionalized teaching and learning of choir singing and instrumental play (Gruhn, 2004), listening to or even participating in musical live performances—either at home or in public—plays only a marginal role in today's German society (Wingerter, 2005). In contrast, many Brazilian preschoolers learn to sing, dance, and drum through participation in activities of their daily lives (see Young & Ilari, 2012). Salvador is quite particular in this sense as children are frequently exposed to groups of people playing drums and dancing together, live and on TV. Maybe children from Salvador form the concept of synchronous drumming as a collective endeavor early on. By contrast, drumming is not as predominant in the musical tradition of people living in Leipzig, which may lead children to learn the association of synchronous drumming as a group activity only later on in childhood. Perhaps this could explain why German children showed the highest synchronization accuracy in the Vis-à-Vis condition. Of course, this is mainly speculative at this point and deserves further investigation.

Limitations and Future Directions

Vieira and colleagues (2010) warned of the dangers of equating culture with nationality when conducting cross-cultural research, with little attention given to the inherent variability within populations. This leads to a common criticism, namely, that cross-cultural psychology runs the risk of stereotyping cultural groups (Heine & Norenzayan, 2006). We tried to avoid this risk, first, by taking into account as much contextual data as possible, and second, by emphasizing that further investigation is needed to determine whether the interview results discussed below could be generalized to other parts of Germany, Western Europe, Bahia, or Brazil as a whole.

Another potential drawback in the cross-cultural approach is the usual difficulty in defining and controlling all cultural variables that are responsible for the differences between the observed cultural groups (Matsumoto & Jones, 2009). With regard to the present data set, the score of active musical experience—calculated from six parental questions we regarded as indicative—did not account for all relevant cultural variables, as the differences between conditions remained significant if this score was included as a covariate in the analysis. In other words, our score of active musical experience was indicative but not sufficient to explain the differences in joint drumming behavior between children from Salvador and Leipzig. Therefore,

if the current cross-cultural approach helped to disclose the important role of individual experience during the development course of rhythmic entrainment, it is now the challenge of longitudinal and intervention studies to test more specific predictions, because they allow for a better elimination of confounding variables.

Evidence From Comparative Psychology

Patel (2006) was the first to suggest that the human capacity for synchronizing movement to sound is basically a learned behavior, a cultural convention, only exploiting cognitive skills that originally evolved for other, nonmusical purposes (e.g., auditory scene analysis, motor pattern generation, vocal learning). Empirical support for Patel's (2006) hypothesis comes from three recent comparative studies showing that rhythmic entrainment is not unique to humans, but can be learned by other vocal learning species, if these are acculturated or trained in a human environment (Hasegawa, Okanoya, Hasegawa, & Seki, 2011; Patel, Iversen, Bregman, & Schulz, 2009; Schachner, Brady, Pepperberg, & Hauser, 2009).

It should be noted that none of the 15 vocal learning species so far identified as sharing our rhythmic entrainment capacity has ever been observed synchronizing to rhythmic sounds in the wild. Even more curiously, 14 out of the 15 synchronizing species were parrots. The only nonfeathered dancer was an Asian elephant (Schachner et al., 2009). Future comparative studies should investigate, which further prerequisites other than their open-ended vocal learning skills, as advocated by Patel (2006), predestine particularly members of the parrot clade to learn how to synchronize their limb moves, head bobs and body sways with the pulse of human music (Schachner, 2010). In line with the current findings, we hypothesize that the capacity of parrots to imitate actions, from conspecifics as well as from their human caretakers (Zentall, 2004), and their proclivity for social interaction per se (Emery, 2006) are crucial in this acquisition process. Spurring ideas for future comparative studies, we predict that simply exposing a naive parrot to human music will not allow it learn how to dance in synchrony, but frequent exposure to a human model who dances together with the parrot will do so.

The Cultural Learning Hypothesis

As outlined in the introduction, the goal of the developmental systems approach is to identify the specific ways in which the levels of the developmental system (genetic, neural, behavioral, and environmental) interact over the course of ontogeny to generate the phenotypic behavior of interest (Gottlieb, 2007; Lickliter, 2008). Regarding rhythmic entrainment, the interaction between cultural environment and neural activity starts way before birth, as the fetus can hear the mother's voice (e.g., during singing) and feel her movements (e.g., during dancing) while still being in the womb (Parncutt, 2009; Trehub & Hannon, 2006). Trainor (2007) was the first to propose that the early association between auditory rhythms and repetitive movement observable in infants (Zentner & Eerola, 2010) could be wholly experience-driven, as the fetus and the young infant learn to correlate beat and movement as they are walked, bounced, and rocked to the pulse of parental singing and other musical sounds provided by their caregivers (but see Winkler, Háden, Ladinig, Sziller, & Honing, 2009). Recent work suggests that the vestibular system may be particularly important in this perceptual learning stage (Phillips-Silver & Trainor, 2005, 2008). Specifically, infants might learn to associate the periodic accentuations in musical sounds with periodic peaks of vestibular stimulation during passive and unintended movement to music, as, for example, when being swayed to the father's lullaby (Trainor, 2007). In a later social learning stage, toddlers and

preschoolers might find out, during shared musical activities, how to create the familiar vestibular stimulation themselves, simply by imitating the synchronized actions of their caregivers, as, for example, when a toddler points to the stereo and starts to hop with his mother (Tomasello, 1999; Tomasello et al., 1993; Vygotsky, 1978).

But if synchronized behaviors were to hinge entirely on the vagaries of local culture, how could joint dancing have become a human universal? The present results point to the importance of cumulative cultural evolution (Mesoudi et al., 2006; Richerson & Boyd, 2005) to understand the phylogenetic origins of rhythmic entrainment in humans. More specifically, to explain the manifestation and preservation of musical group rituals including interpersonal synchrony across human societies—irrespective of their possible beginnings as incidental inventions—one should search for some *culturally adaptive* function, be it in social cohesion, coalition signaling, territory defense, mother–infant coordination, or a bit of everything (Brown, 2000). With such a bundle of benefits, rhythmic entrainment during music and dance can indeed become a human universal during cultural evolution without any music-specific gene activity being necessarily involved (Patel, 2008).

Finally, musical rituals that involve collective synchronization not only have an ancient history (Conard, Malina, & Munzel, 2009) but also continue to evolve in modern societies. Therefore, studying rhythmic entrainment and how its developmental course is influenced by the surrounding cultural practices may help us not only understand where human music came from but also reflect on where it is heading (Morrison & Demorest, 2009).

Appendix

Dependent Measure: Spontaneous Helping

Setup and procedure. Similar to the helping task developed by Kirschner and Tomasello (2010), E2 had a sudden (inoffensive) accident that presented the child with the choice of either helping E2 or continuing to pursue his or her own play activity. Like in the referenced study, the present task was designed to elicit spontaneous helping behavior while creating actual costs for helping; however, the cover story here was to “bake cookies with the hens’ eggs.” For this task, the child and E2 each had to sort their eggs (6 marbles) into a tube, and then carry their tubes simultaneously toward a novel apparatus (“magic oven,” functioning as the distracter during the actual test), where the marbles could be used in a fun game, irrespective of the other person. They were to pour the marbles into the chimney so that they would roll through a transparent runway before disappearing inside the apparatus and making a clanking sound (by striking a hidden wind chime).

After E1 guided the sorting of the marbles, she left the room for 1 min, allowing the child and E2 to “go and pour the eggs” into the distracter by themselves while she was gone. However, E2’s tube was prepared such that, during the test round, the bottom fell off at the moment he and the child began carrying their tubes toward the distracter. As a result, all the marbles fell out from inside onto the floor (Figure 8). E2 emphasized his bad luck with the words “Oh no!” and without looking at the child, instead immediately starting to reconnect the bottom to the tube and collect the marbles one by one within a fixed time window of 20 s, before he continued his way toward the distracter. At that stage, the oven served as a distracter by creating explicit costs for the child if he or she should decide to wait for E2 or help him gather up his marbles, because he or she would have to postpone any private goals. Consequently, we only assessed the child’s behavior between the moment he or she observed E2’s accident and the moment he or she poured his or her own marbles into the distracter.

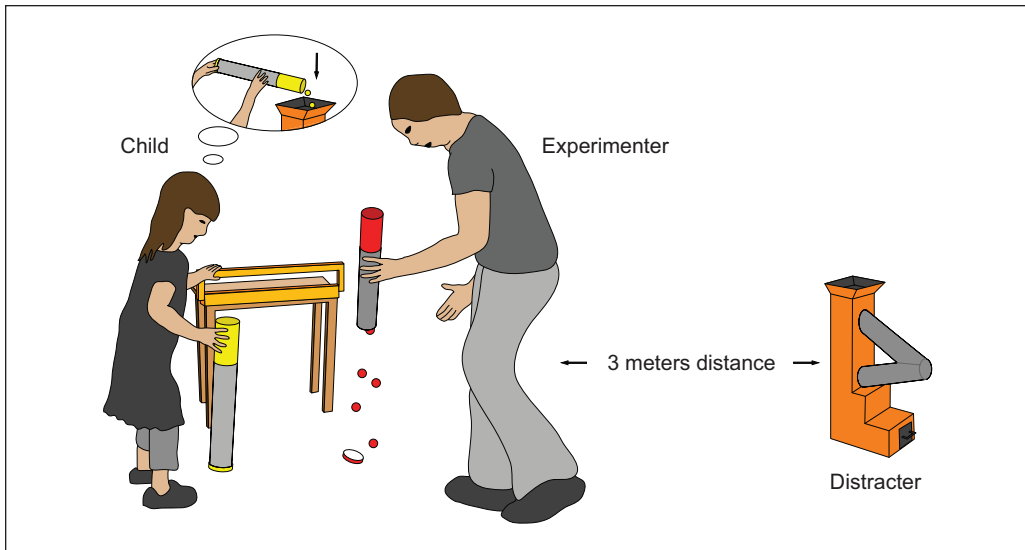


Figure 8. Setup of the helping task.

Note. We modified the helping task from Kirschner and Tomasello (2010) such that the experimenter pretended to have an unlucky accident (the bottom of his tube fell off and all of his red marbles rolled over the floor), presenting the child with the choice of waiting and/or helping the experimenter to gather up the marbles or ignoring his problem and proceeding with her own play activity (pouring her own yellow marbles into the distractor).

Coding and statistical analysis. All sessions were recorded with a Sony digital video recorder. All coding was done from short video clip extractions displaying the moment of test only. To assure condition-blind coding, all clips were labeled with an arbitrary index number to conceal the condition from the coders. To assess interrater agreement, 20% of trials were independently coded by a hypothesis-blind research assistant. For the helping task, we reached an interobserver agreement of $\kappa = .92$.

We coded the child's reaction to the accident according to the effort he or she made to help E2 solve his problem and categorized three ranks of helpfulness. The highest rank was ascribed to children who actively contributed to the solution of E2's problem and also waited until it was finally solved. Such "active helping" included picking up marbles, putting them back into E2's tube, suggesting strategies to fix the tube, or picking up and holding the tube while E2 collected the marbles. We defined the problem as "being solved," as soon as all red marbles were back in the red tube and E2 could proceed with pouring his eggs into the distractor. The lowest rank of helpfulness was ascribed to those children who observed E2's accident, but instantly turned away without any verbal leave-taking or excuse. Instead he or she walked over to the distractor and immediately poured all of his or her own marbles into the apparatus.

An intermediate rank was coded for those trials where the child (a) did not actively contribute to the solution of E2's problem, but withheld from pouring his eggs in the oven until E2 had solved his problem; (b) started to actively help, but then decided to abort helping, although E2's problem wasn't yet solved, and proceeded without excuse; or (c) neither helped actively nor waited until E2's problem was solved, but did however use explicit verbal leave-taking or excuses (e.g., "Mine did not fall, I am going to bake cookies now.") before continuing with pouring his or her eggs into the distractor alone.

For the statistical analysis, we applied a three-way ANOVA, to test for the effects of Culture, Condition, and Gender on the children's helping behavior, because visual inspection of plots of residuals against predicted values indicated homogeneity of error variances.

Dependent Measure: Spontaneous Sharing

Setup and procedure. The purpose of the sharing task was to present the child with the choice of either sharing some of his or her items with E2 or continuing to spend them all by him or herself in a fun game (after Warneken & Tomasello, 2009). Like in the reference study, we designed this task to elicit spontaneous sharing behavior while creating actual costs for sharing. However, to adapt the original task for older children, we introduced a cover story, which was to "feed cookies to the hungry cows." For this task, the child and E2 each had to get their personal cookie tray out of the magic oven (the same apparatus used as the distracter in the helping task), place their tray in front of one out of two identical cardboard cows, and feed their personal cow with the cookies from their tray (Figure 9). At the test, E2 ran out of tokens and we aimed to assess how readily children shared their "cookies" with E2.

Importantly, to prevent the child from using up his or her resource too quickly during the actual test, the cookies could only be inserted into the apparatus one by one, and at minimal time intervals of 5 s. This was accomplished by reducing the cow's oral cavity (a red box) to the size of one cookie and attaching this box to a lever installed inside the cow's body. Every time a cookie was placed into the cow's mouth, its weight caused the lever to move downward until the cookie fell out of the box, remaining inside the apparatus. Consequently, the child had to wait until the lever moved up again, before he or she could feed the next cookie. To further increase the attractiveness of the feeding action, the cookies struck a xylophone inside the apparatus when falling off the lever, creating a chiming sound.

After E1 helped the child and E2 to pull their personal cookie trays out of the oven, she left the room, allowing the child and E2 to "go and feed the cows" by themselves while she was gone. However, in the test round, the cookies were not evenly distributed across the two trays. Instead, the child's tray contained 10 cookies, whereas E2's tray only contained 2 cookies. Without commenting on this imbalance, E2 placed his tray in front of his own cow and started feeding his two cookies simultaneously with the child's feeding his or her cow the first two of their cookies.

After E2's resources (two cookies) were spent and the child still possessed eight cookies, the actual test started, and was divided into three stages. At Stage 1, E2 just said "Empty. What a pity!" while looking at his empty tray. If the child continued feeding its own cow, E2 kept his gaze at his tray and waited until the child had spent another two cookies before repeating the first utterance with more detail, "I don't have any more cookies. What a pity!" However, this time, he briefly looked at the child and showed his or her empty tray while speaking. Again, if the child continued feeding his own cow, E2 took his tray back again, kept looking at it, and waited until the child had spent another two cookies before repeating the second utterance with reference to the child's situation: "You still have some cookies. I don't have any left. What a pity!" Like at Stage 2, E2 briefly looked at the child and showed his empty tray while speaking. Again, if the child continued feeding his own cow, E2 took his tray back again, kept looking at it, and waited until the child had spent the remaining four cookies, before he ended the task by calling E1 back into the room.

Importantly, in all three stages, E2 never addressed the child with the direct request to share cookies, instead he only stressed his current situation and regret. This way, the child could freely choose whether and how he or she would react to E2's dilemma. In the case of the child deciding to share one or some of his or her cookies with E2 at the first or second stage, E2 said, "Thank you!," took the cookie, fed it to his own cow and kept his gaze again on his empty tray. Only after the child had fed another two cookies to his or her own cow was the next verbalization stage uttered by E2.

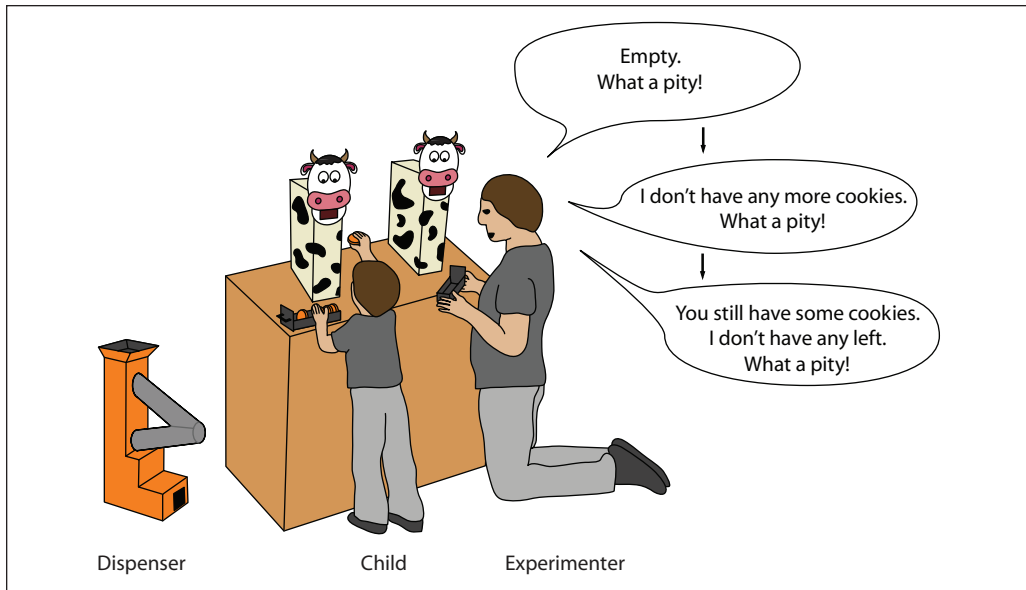


Figure 9. Setup of the sharing task.

Note. We designed this task to measure the children's willingness to voluntarily share their own limited resources with the experimenter. The task required child and experimenter to each feed cookies (wood chips) one after the other to a separate cardboard cow. During the test, the experimenter ran out of cookies, leaving her with the choice of either sharing some of her cookies with the experimenter or feeding them all alone. Importantly, the experimenter never explicitly asked for cookies, instead communicated his dilemma with three distinct sentences that only indirectly expressed his desire for the limited resource.

Coding and statistical analysis. As in the helping task, coding was done from short video clips with an arbitrary index number to conceal the condition from the coders. In the reliability coding, we reached an interobserver agreement of $\kappa = 0.90$. We coded the child's reaction to E2's behavior according to the effort he or she made to compensate for E2's problem and categorized five ranks of prosociality. The highest rank was ascribed to children who instantly handed one or more of their cookies to E2 or put them into E2's tray right at the first stage. The second rank of prosociality was ascribed to children who shared cookies for the first time at the second stage after E2's second utterance. The third rank was ascribed to children who shared cookies only after E2 communicated his misfortune 3 times (Stage 3). Among those participants who never shared any of their cookies during the test, some children gave explicit excuses for not sharing (e.g., "You just got two, these are mine.") or provided alternative solutions to E2's problem (e.g., "Then we have to bake new ones," while pointing at the oven). These reactions were coded as the fourth rank of prosociality, whereas the fifth and lowest rank of prosociality was ascribed to children who neither shared any cookies nor verbally reacted to E2's depletion of cookies. We applied a three-way ANOVA to test for the effects of Culture, Condition, and Gender on the children's sharing behavior across those five ranks, because visual inspection of plots of residuals against predicted values indicated homogeneity of error variances.

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