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Chimpanzee drumming: a spontaneous performance with characteristics of human musical drumming

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Valérie Dufour^{1,2,3}, Nicolas Poulin⁴, Charlotte Curé⁵ & Elisabeth H M Sterck^{3,6}

Despite the quintessential role that music plays in human societies by enabling us to release and share emotions with others, traces of its evolutionary origins in other species remain scarce. Drumming like humans whilst producing music is practically unheard of in our most closely related species, the great apes. Although beating on tree roots and body parts does occur in these species, it has, musically speaking, little in common with human drumming. Researchers suggest that for manual beating in great apes to be compared to human drumming, it should at least be structurally even, a necessary quality to elicit entrainment (beat induction in others). Here we report an episode of spontaneous drumming by a captive chimpanzee that approaches the structural and contextual characteristics usually found in musical drumming. This drumming differs from most beating episodes reported in this species by its unusual duration, the lack of any obvious context, and rhythmical properties that include long-lasting and dynamically changing rhythms, but also evenness and leisureliness. This performance is probably the first evidence that our capacity to drum is shared with our closest relatives.

Producing music, performing, singing and dancing along with others is a universal part of human behaviour¹. Scientists generally agree that several features are common to most human musical production², including intentionality, decontextualisation, formality (evenness, isochrony) and joint coordination. To address the evolutionary origins of our musical skills, anthropologists, biologists and musicologists have examined the similarities between human performances and sound production in non-human animals³, and most agree that several features of our musical abilities are found in other species^{4–6}. Bird or whale songs are considered analogous to music, because like many human songs they are complex vocalizations with a potential for cultural evolution, i.e they can be learned from others^{7,8}. In great apes, manual beating is considered homologous to human drumming, because this shared capacity may reflect a common ancestral predisposition to produce music⁴.

However, manual beating by great apes generally lacks an essential characteristic of human drumming, namely evenness⁹. Isochrony, the fact of beating at regularly spaced time intervals makes the occurrence of the next beat(s) predictable, and gives a formal quality to the performance. The evenness together with leisureliness facilitates temporal coordination from others, and more generally entrainment. This remarkable feature of human music is far from being widespread in our closest relatives. Beating on tree

¹Institut Pluridisciplinaire Hubert Curien, University of Strasbourg, 23 rue Becquerel 67087 Strasbourg, France.

²Centre National de la Recherche Scientifique, UMR 7178, 67087 Strasbourg, France. ³Biomedical Primate Research Center, Ethology Research, Lange Kleiweg 161, 2288 GJ Rijswijk, the Netherlands. ⁴CeStatS, Institut de Recherche Mathématique Avancée, UMR 7501, Université de Strasbourg & CNRS, 7 rue René-Descartes, 67000 Strasbourg, France. ⁵CEREMA - DTer Est, Acoustics Group, F-67035 Strasbourg Cedex 2, France. ⁶Utrecht University, Animal Ecology, Padualaan 8, 35845 CH, Utrecht, the Netherlands. Correspondence and requests for materials should be addressed to V.D. (email: valerie.dufour@iphc.cnrs.fr)

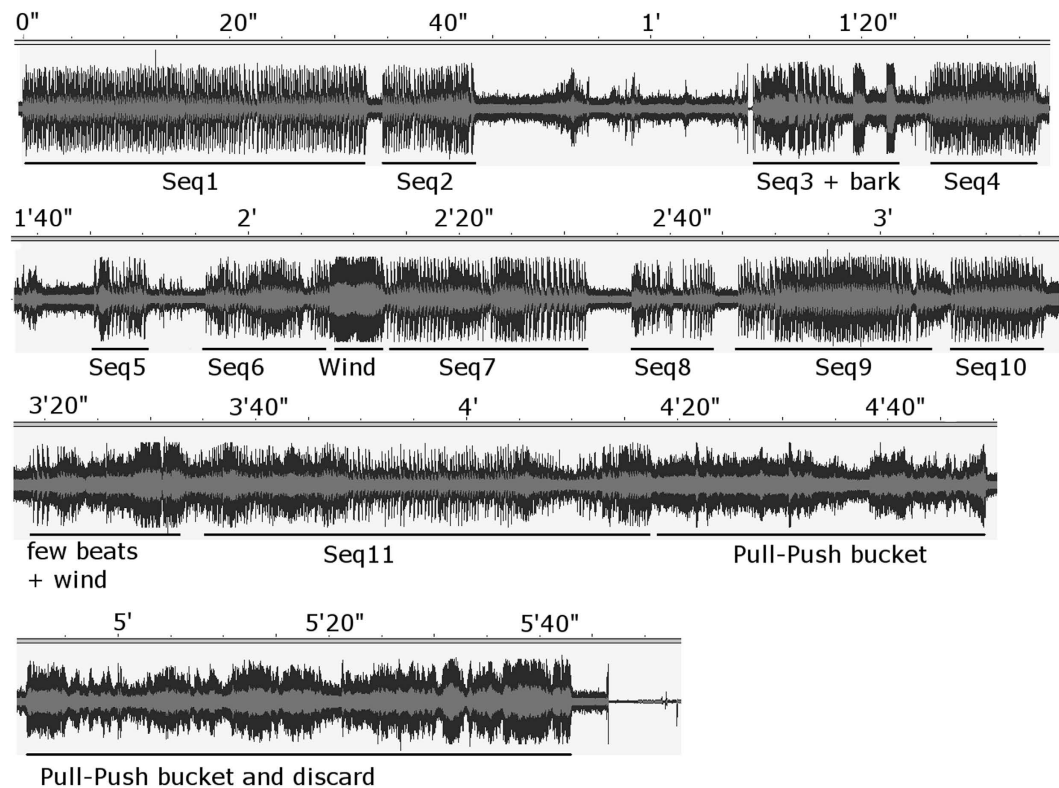


Figure 1. Illustration of the total drumming bout and its division into 11 sequences. Sequence 5 has less than 20 inter-beat durations and was not analyzed. At the end of the bout, the chimpanzee is on his arms and legs, quietly pushing and pulling the barrel on the floor in slow and wide circular movements. This part was not analyzed. Moving averages of the inter-beat duration of each sequence can be found in Supplementary Figure S1.

buttresses, cans, body parts or objects, as wild chimpanzees, bonobos and gorillas do^{10–15}, may be the sign of a link between body movement and vocal production¹ and is sometimes called “drumming”^{4,10}. In essence, however, it is more a spectacular noise-making display than a structurally isochronous performance⁹. These behaviors therefore have little in common with the structural, and contextual characteristics found in the musical human drumming⁹. Here, we report an unusual performance of a chimpanzee named Barney. Barney was observed beating repeatedly and spontaneously on an upturned bucket for several sequences within a period of few minutes (Supplementary Audio file and Fig. 1). We evaluated his performance to establish which features fit with the type of characteristics generally associated with human drumming², i.e. intentionality, decontextualisation and formality, and explored if and how this particular event differed from previously reported manual beating displays by apes.

Results

Intentionality. Assessing intentionality in non-verbalizing beings is a complex task. While means can be found to investigate it within non-human social interactions¹⁶, it is more difficult to pinpoint in solitary acts without an objective method of investigation. Yet in this particular drumming, Barney produced more than 685 drumbeats spread over 11 sequences for over four minutes (Fig. 1, and Supplementary Fig. S1). He remained in a seated position with the bucket between his feet, sometimes using his mouth to keep it in place (Fig. 2). The focus he showed during beating indicates that it was more than just a short, uncontrolled noise-making display. In this respect, it differs from most of the drumming episodes described in chimpanzees, who generally produce intense beating bouts of only few seconds¹².

Decontextualization. Human drumming does not necessarily have a particular purpose or context. This decontextualisation is not seen in great apes, whose manual beating is generally associated with play¹⁵, aggressive display, sexual arousal¹² or travel¹¹. In contrast, Barney had isolated himself from the others in his outside enclosure. He did not show any facial expression or postures typical of play (play face, excitement), nor did he move or exhibit aggressive display (body hair was not raised). One short but remarkable sequence (sequence 3) exhibited a change in the beating pattern and was punctuated by a bark, which could indicate a display context, but this explanation is not likely as no pilo-erection was observed. Barney did not move from his seated position, and resumed drumming after a few seconds of



Figure 2. Illustration of Barney’s position when drumming manually on the barrel. The facial expression was neither tense nor playful, and the feet (and sometimes the mouth) were used to firmly hold the barrel. Illustration by *Camille Martin (School of Decorative Arts, Strasbourg)*.

silence for another long sequence. This situation supports the notion that the performance was indeed decontextualized.

Formality. In measured music, drumming has a formal quality² where sounds are produced in organized patterns such as periodicity or rhythm. Isochrony of the inter-beat intervals is one way to achieve evenness, a necessary quality to allow entrainment. In the drumming we recorded, 10 of the 11 recorded sequences were long enough to be analyzed for their rhythmical properties, with an average inter-beat duration of 245 ms (Table 1). Recorded sequences were considered as time series in which lag denotes the range between the equally spaced instants of measurement. Here our instants of measurement are the beats and the measure is the inter-beat duration. First, we performed a portmanteau test for each recorded sequence, i.e. a Ljung-Box test, to detect potential non-random patterns in the time series. Five sequences showed non-random patterns (Supplementary Fig. S2). In four of them, these patterns were still detectable over at least 15 consecutive lags, indicating a long-lasting dependency over the course of the sequence (for sequences 1, 4, 9 and 11). In the last sequence (sequence 6), patterns occurred over the next lag, thus changing more frequently. We then ran an autocorrelation procedure for the sequences where non-random patterns were detected, in order to test the linear dependency between each consecutive inter-beat duration (Supplementary Fig. S3). Dependency up to lag 3, for example, indicates that whatever the position in the sequence, the duration of the next three lags can be predicted. Significant dependencies were found in the five sequences, ranging from dependency between one inter-beat duration and the next (sequence 6) to dependency between 12 consecutive inter-beat durations (sequence 4). This shows that the beating in these 5 sequences was not only regular, but was even extremely so on occasions, with an average tempo of 257 beats per minute (bpm). This pace is close to human tempo for rhythmic music¹⁷. Given that this pattern is probably due to a bimanual beating, it can therefore be argued that the basic tempo averages 128 bpm, a tempo typical of rhythmic popular dance music in many humans¹⁷. Remarkably, there is an alternation of positive and negative correlations in sequence 4, meaning that a long inter-beat duration was followed by a short inter-beat duration, or vice-versa. Given the unexpected regularity of this pattern, we provide a musical notation for this sequence, which illustrates a binary rhythm that musicians can now replicate (Fig. 3). Finally, a fluctuation analysis tested for linear trends (acceleration or deceleration) in the dynamic of each sequence. Changes in dynamics, i.e. a deceleration, were observed in sequences 1, 9 and 11. Thus, the rhythm varied from one sequence to the next, which counters the possibility that the rhythm may simply result from endogenous synchronization or from a “motoric ceiling effect” in the frequency of slapping to maximize the noise output⁹. On the contrary, Barney demonstrated evenness at leisurely, spaced time intervals. This is a novel finding, as these two characteristics are not generally associated with typical manual beating by chimpanzees.

	Descriptive data				Ljung-Box Test			Auto-correlation for the next n beats ^(b)	Dynamics		
	Mean Inter-beat (Ib) Duration (in ms)	min Ib Duration (ms)	max Ib Duration (ms)	Total N° of beats	Value ^(a)	khi	P _{value} (at 1 st lag)		T value	R Square	P
Seq1	212.9	95	432	155	15	14.52	<0.01	2	4.17	0.09	<0.01
Seq2	253.9	86	489	34	na	0.09	0.76	na	-0.45	-0.02	0.66
Seq3	211.9	53	1156	34	na	0.12	0.72	na	0.69	-0.01	0.49
Seq4	222.7	130	312	47	15	16.5	<0.01	12	0.17	-0.02	0.87
Seq6	217.3	88	617	57	1	6.57	0.03	1	1.78	0.04	0.08
Seq7	267.4	79	470	71	na	0.37	0.54	na	0.1	0.0001	0.32
Seq8	274.6	96	1048	28	na	0.48	0.48	na	1.23	0.02	0.229
Seq9	258.2	66	709	71	15	9.8	<0.01	4	3.05	0.11	0.01
Seq10	276.3	96	421	32	na	0.002	0.96	na	-0.9	-0.01	0.37
Seq11	253.8	98	726	155	15	29.09	<0.01	10	2.37	0.03	0.02

Table 1. Descriptive data. Descriptive data on inter-beat (Ib) duration, number of beats, value and results of the Ljung-Box test, the auto-correlation test and the dynamic results for each sequence. For example, in Sequence 1, the Ljung-Box test indicates a significantly non-random pattern at the first lag, checking for the next lags indicates that non-random patterns are detectable within up to 15 lags (Supplementary Fig. S2). The autocorrelation test indicates that whatever the position in the sequence, the time at which the next 2 beats will occur can be predicted (Supplementary Fig. S3). Here, the dynamic analysis shows a significantly positive linear trend, thus an increase in the duration between two beats (deceleration).^(a)Number of lags within which non-random patterns can be detected (Supplementary Fig. S2).^(b)Number of beats where dependency between two beats is statistically significant (Supplementary Fig. S3).

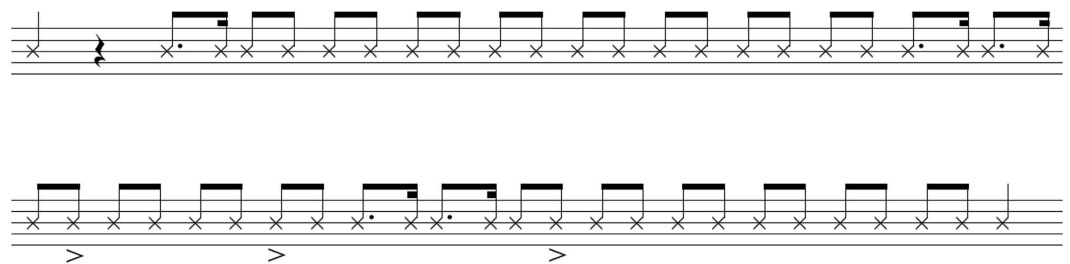


Figure 3. Musical translation of sequence 4. This illustrates the binary rhythm (from 1'25" in Supplementary Audio S1).

Discussion

Patterns in periodicity or rhythm such as those described above may help other musicians or the audience to “join in” during communal music making. We have no evidence that Barney’s drumming could have elicited any joining from others, or was even designed to do so, as he performed at a distance from the rest of his group. His performance nevertheless shares many of the characteristics of human drumming. Within other animal species, joint coordination is found in sound-mimicking birds like cockatoos¹⁸ and parrots^{19,20}, but also in sea lions²¹, which can be trained to bob their head in rhythm to a song. Most studies suggest that it is difficult for monkeys to even perceive a beat, let alone synchronize their movements with it^{22,23}. The great apes may be capable of synchrony, as seen when the chimpanzee Ai spontaneously pressed two keys in time to a 600 ms inter-beat interval auditory stimulus without previous training²⁴. We do know that in the wild, chimpanzees can show loose behavioral coordination when rain dancing²⁵, chorusing (when the call of one aroused individual elicits joining from others) or engaging in carnival displays^{26,27}, but we have no evidence that these behaviors could be beat-based rather than simply due to emotional contagion^{28,29}. They cannot therefore be directly compared to the type of “on-the-beat” synchrony shown by humans when they play music¹. In comparison, human children can synchronize to external drumming from around the age of three onwards with an accuracy that increases as they grow older³⁰.

It is rare for animal sound production to simultaneously possess more than one of the previously cited characteristics found in human music². In this respect, Barney's drumming is exceptional. It was not only decontextualised and showed formality, but also appears to be intentional. Barney's drumming is a rare example, as other reported musical drumming in great apes, although suggestive, did not address each of these features separately. Musical drumming has been reported in a language-trained bonobo called Kanzi³¹, but published data are lacking. A recent report describes how two young chimpanzees¹⁴ repeatedly hit a nearby clay pot, and appeared to be attracted by the sound it made, hitting it 199 times, but no analysis of its rhythmical pattern has been provided. Barney's performance confirms that the chimpanzee, our closest relative, could indeed be capable of drumming like a human.

According to Mithen⁵, music played a crucial role in our evolution before the existence of articulated language and improved communication between humans. By conveying emotions, and thus meaning, it is thought to have further bonded human groups, improving coordination and cohesion. Some authors have suggested a similar cohesive outcome in the drumming of great apes¹¹. Other researchers also suggest that synchronized beating and chants by groups of individuals would have made the performance louder and more likely to be heard by travelling females, the dispersing gender in humans and chimpanzees¹. Although there is very little fossil evidence regarding the birth of our musical abilities, our data are probably the first strong evidence of an evolutionary link between wild beating in chimpanzees and our own musical origins.

Methods

Subject & procedure. At the time of our study, Barney was a captive-born, 24-year-old male belonging to a group of 5 adult male chimpanzees raised at the Biomedical Primate Research Centre in the Netherlands. Barney was a rather low-ranking male but was not particularly withdrawn from the group and had not been seen to display stereotypical behaviors. All members of this group often noisily manipulated plastic bottles, buckets and branches while performing display (VD, personal observations). Environmental noises included road traffic and construction building noises close by. The chimpanzees also sometimes had a radio playing in the building. The drumming was spontaneous (not artificially elicited or encouraged by human presence) and occurred in January 2005 in the outside part of their enclosure. The observer (VD) was nearby at the start of the drumming, and quietly approached Barney's enclosure to record it on a voice recorder (type Sony M527V). No camera was available within reach to film this episode. The barrel used for the drumming was part of the objects available at all time in the enclosure and was neither new, nor newly introduced to the chimpanzee. We delimited sequences as follows: first, after a pause of two seconds, we considered the following beats to be the beginning of the next sequence. Second, if sound pollution occurred (caused by wind or when the noise of the beat was covered by background noise), the inaudible part of the sequence was not analyzed, and we considered the following audible part as a new sequence. For example, because the first few beats of Sequence 6 were difficult to extract from the background noise, we started the analysis at the 6th beat. The recording of Sequence 6 was interrupted by the wind. The following beats were treated separately as Sequence 7. Additionally, the analysis started from beat 3 in Sequence 4 due to a discontinuity between the second and the third beats (a one second pause). To analyze rhythmical patterns, we selected sequences with more than 20 beats (thus discarding sequence 5). Note also that the recording was stopped after the end of sequence 2, as the observer thought that the bout was over. It was immediately restarted when Barney began drumming again a few seconds later, but the first few beats of sequence 3 are missing.

The analysis was conducted using Reaper software. We used the transient detection settings tool (threshold detection was set at -24 dB and sensitivity at 25%, 60% and 75%) to measure the inter-beat durations in each sequence. For each sequence, data were analyzed using R³². P level of significance was set at 0.05.

Ethics. The study was conducted in accordance with the approved scientific reports guidelines. Due to the observational nature of this study (the audio recording of a spontaneous behavioral sequence initiated by the chimpanzee), this study does not classify as an experiment as assessed by the Biomedical Primate Research Centre Animal welfare officer. Thus no additional permission from the institutes animal experiment committee was required. The study was conducted in accordance with relevant Dutch laws and in agreement with international and scientific standards and guidelines.

References

- Merker, B., Morley, I. & Zuidema, W. Five fundamental constraints on theories of the origins of music. *Phil. Trans. R. Soc. B* **370**, 2014.0095 (2015).
- Arom, S. [Prolegomena to a biomusicology] *The Origins of Music* [Wallin, N. L., Merker, B., Brown, S. (eds)] [27–29] (MIT Press, London, 2000).
- Brown, S., Merker, B. & Wallin, N. L. [An introduction to evolutionary musicology] *The Origins of Music* [Wallin, N. L., Merker, B., Brown, S. (eds)] [3–24] (MIT Press, London, 2000).
- Fitch, W. T. The biology and evolution of music: A comparative perspective. *Cognition* **100**, 173–215 (2006).
- Mithen, S. The music instinct: the evolutionary basis of musicality. The neurosciences and music III: disorders and plasticity. *Ann. N.Y. Acad. Sci.* **1169**, 3–12 (2009).
- Geissmann, T. [Gibbon songs and human music from an evolutionary perspective] *The Origins of Music* [Wallin, N. L., Merker, B., Brown, S. (eds)] [27–29] (MIT Press, London, 2000).

7. Slater, P. J. B. [Birdsong repertoires: their origins and use] *The Origins of Music* [Wallin, N. L., Merker, B., Brown, S. (eds)] [49–63] (Mit press, London, 2000).
8. Payne, K. [The progressively changing songs of humpback whales] *The Origins of Music* [Wallin, N. L., Merker, B., Brown, S. (eds)] [135–150] (Mit press, London, 2000).
9. Merker, B., Madison, G. & Eckerdal, P. On the role and origins of isochrony in human rhythmic entrainment. *Cortex* **45**, 4–17 (2009).
10. Arcadi, A. C., Robert, D. & Boesch, C. Buttress drumming by wild chimpanzees: temporal patterning, phrase integration into loud calls and preliminary evidence for individual distinctiveness. *Primates* **39**, 505–518 (1998).
11. Boesch, C. Symbolic communication in wild chimpanzees? *Hum. Evol.* **6**, 81–90. (1991)
12. Goodall, J. *The Chimpanzees of Gombe: Patterns of Behavior* (Bellknep Press of the Harvard University Press, Boston, 1986).
13. Schaller, G. E. *The Mountain Gorilla: Ecology and Behavior*. (University Chicago Press, Oxford, 1963).
14. De Waal, B. M. The communicative repertoire of captive bonobos (*Pan paniscus*), compared to that of chimpanzees. *Behaviour*. **106**, 183–251 (1988).
15. Matsuzaka, T. Playful drumming by immature wild chimpanzees at Mahale: Do they enjoy making sounds? *P. A. N.* **19**, 23–25 (2012).
16. Schell A. M., Townsend S. W., Machanda Z. & Zuberbühler K. Chimpanzee alarm call production meets key criteria for intentionality. *PLoS One* **8**, e76674 (2013).
17. Moelants D. Preferred tempo reconsidered. Paper presented at the 7th International Conference on Music Perception and Cognition, Sydney, Adelaide: causal production (2002, July).
18. Patel, A. D. Iversen, J. R., Bregman M. R. & Schulz, I. Experimental evidence for synchronization to a musical beat in a nonhuman animal. *Curr. Biol.* **19**, 827–830 (2009).
19. Schachner, A., Brady, T. F., Pepperberg, I. M. & Hauser, M. D. Spontaneous motor entrainment to music in multiple vocal mimicking species. *Curr. Biol.* **19**, 831–836. (2009).
20. Hasegawa, A., Okanoya, K., Hasegawa, T. & Seki, Y. Rhythmic synchronization tapping to an audio-visual metronome in budgerigars. *Sci. Rep.* **1**, 120 (2011).
21. Cook, P., Rouse, A., Wilson, M. & Reichmuth, C. A. California sea lion (*Zalophus californianus*) can keep the beat: motor entrainment to rhythmic auditory stimuli in a non vocal mimic. *J. Comp. Psychol.* **127**, 412–427 (2013).
22. Zarco, W., Merchant, H., Prado, L. & Mendez, J. C. Subsecond timing in primates: comparison of interval production between human subjects and rhesus monkeys. *J. Neurophysiol.* **102**, 3191–3202 (2009).
23. Honing, H., Merchant, H., Haden, G. P., Prado, L. & Bartolo, R. 2012. Rhesus monkeys (*Macaca mulatta*) detect rhythmic groups in music, but not the beat. *PLoS One.* **7**, e51369.(2012)
24. Hattori, Y., Tomonaga, M. & Matsuzawa, T. The Spontaneous synchronized tapping to an auditory rhythm in a chimpanzee. *Sci. Rep.* **3**, 1566 (2013).
25. Goodall, J. My life among wild chimpanzees. *Nat. Geog. Mag.* **124**, 272–308 (1963).
26. Ghiglieri, M. *The Chimpanzees of Kibale Forest: A Field Study of Ecology and Social Structure* (Columbia University Press, New York, 1984).
27. Fedurek, P., Machanda, Z. P. A. M. & Slocombe, K. E. Pant hoot chorusing and social bonds in male chimpanzees. *Anim. Behav.* **86**, 189–196 (2013).
28. Koski, S. E. & Sterck, E. H. M. Empathic chimpanzees: A proposal of the levels of emotional and cognitive processing in chimpanzee empathy. *Eur. J. Dev. Psychol.* **7**, 38–66 (2010).
29. Parr, L. A. Cognitive and physiological markers of emotional awareness in chimpanzees (*Pan troglodytes*). *Anim. Cogn.* **4**, 223–229 (2001).
30. Kirschner, S. & Tomasello, M. Joint drumming social context facilitates synchronization in preschool children. *J. Exp. Child Psychol.* **102**, 299–314 (2009).
31. Kugler, K. & Savage Rumbaugh, S. Rhythmic drumming by Kanzi an adult male bonobo (*Pan Paniscus*) at the language research centre. *Am. J. Primat.* **57**, 62 (2002).
32. R Core Team. R. A. language and environment for statistical computing: <http://www.R-project.org/> By, R Foundation for Statistical Computing, Vienna (2013). (Date of access: 25/09/2013).

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Author Contributions

VD collected the data, analyzed and wrote the paper. E.S wrote the paper, NP designed the statistical analysis, and CC provided critical feedback and the musical translation of sequence 4.

Additional Information

Supplementary information accompanies this paper at <http://www.nature.com/srep>

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