Correspondence

Spontaneity and diversity of movement to music are not uniquely human

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Spontaneous movement to music occurs in every human culture and is a foundation of dance [1]. This response to music is absent in most species (including monkeys), yet it occurs in parrots, perhaps because they (like humans, and unlike monkeys) are vocal learners whose brains contain strong auditory–motor connections, conferring sophisticated audiomotor processing abilities [2,3]. Previous research has shown that parrots can bob their heads or lift their feet in synchrony with a musical beat [2,3], but humans move to music using a wide variety of movements and body parts. Is this also true of parrots? If so, it would constrain theories of how movement to music is controlled by parrot brains. Specifically, as head bobbing is part of parrot courtship displays [4] and foot lifting is part of locomotion, these may be innate movements controlled by central pattern generators which become entrained by auditory rhythms, without the involvement of complex motor planning. This would be unlike humans, where movement to music engages cortical networks including frontal and parietal areas [5]. Rich diversity in parrot movement to music would suggest a strong contribution of forebrain regions to this behavior, perhaps including motor learning regions abutting the complex vocal-learning 'shell' regions that are unique to parrots among vocal learning birds [6]. Here we report that a sulphur-crested cockatoo (*Cacatua galerita eleonora*) responds to music with remarkably diverse spontaneous movements employing a variety of body parts, and suggest why parrots share this response with humans.

Soon after our original study [2] of synchronization to a musical beat in this parrot (named 'Snowball'), we became interested in his diversity of movements to music. This was because his owner (author I.S.) observed that Snowball was using new movements to music not present in our original study, and appeared to be in a period of 'movement exploration'. Importantly, this was not due to modeling by I.S., who does not make a wide range of movements when dancing with Snowball and tends only to engage in head bobbing and hand waving. Also, Snowball was never explicitly trained to make specific movements to music (for example, via operant conditioning with food rewards, as in [7]). During this period of exploration, Snowball seemed to favor movement diversity over synchronization accuracy: his rhythmic movements often seemed not highly synchronized to the beat, possibly because he was primarily exploring new movements rather than exploiting old ones.

To quantify Snowball's movement diversity we filmed him moving to two pop songs: "Another One Bites the Dust" and "Girls Just Wanna Have Fun", each presented three times (23 minutes of music in total). Filming took place in September 2008. Snowball was 12 years old and had not danced to these songs with anyone other than his owner. During filming, the owner was in the room and gave occasional verbal encouragement (such as "good boy!"), but did not dance or move rhythmically. Movement coding was performed using frame-by-frame analysis with the audio muted and was conducted by author R.J.J.K., a cognitive neuroscientist and classically and contemporarily trained dancer. The temporal onset and offset of each movement or sequence of repeated movements were recorded, focusing on 'dance movements', defined (following [8]) as movements that are clearly intentional but which are not an efficient means of achieving any plausible external goal, such as basic locomotion. Our analyses revealed that Snowball had a diverse repertoire of 14 dance movements and two composite movements (Table 1). An excerpt from one trial annotated with dance movements is provided in Supplemental Video S1 and Figure S1A. A compilation of the 14 dance movements is shown in Supplemental Video S2 (all six videos from the study, annotated by R.J.J.K., are available via a link in Supplemental Information.)

One important difference between Snowball's dancing and human dancing is that Snowball danced in short episodes rather than continuously (mean duration = 3.69 seconds, std = 2.72 seconds; N = 141), consistent with earlier reports [2]. Informal observations by author I.S. suggest that Snowball moves more continuously when a human dances with him, which we plan to examine in future work.

To determine if certain moments in each song triggered specific dance movements, time segments during which Snowball danced in all three trials were first identified (Figure S1B). We then examined each such segment to see if he used the same dance movement in all three trials. In both songs, there was not a single segment in which all three trials contained the same dance move. Thus, in addition to the diversity of his movement to music, another sign of Snowball's flexibility in moving to music is that his movements are not constrained by certain audio features of the music. We also found that Snowball used different proportions of dance moves in the two songs (Figure S2), though more data would be needed to determine whether this is a stable difference.

Snowball is not unique: other examples of diversity in parrot movement to music can be found on the internet (see links in Supplemental Information). A key question, however, is how such moves are acquired. Parrots can imitate movements [9], and if their movements to music are due to imitation (for example, from seeing humans dance), it would suggest that parrots can solve the 'correspondence problem' [1] in a remarkably sophisticated way (watching an individual with a very different body morphology perform a motor pattern, then mapping that pattern across modalities onto one's own motor system, without direct reinforcement). Another possibility is that some moves may reflect creativity. This would also be remarkable, as creativity in nonhuman animals has typically been documented in behaviors aimed at obtaining an immediate physical benefit, such as access to food or mating opportunities. Snowball does not dance for food or in order to mate; instead, his dancing appears to be a social behavior used to interact with human caregivers (his surrogate flock).

Table 1. Dance movements and descriptions.

Movement[a]	Description	'Girls'	'Another'
Body Roll (B)	Wave passes through head, then body	x	x
Counter-Clockwise Circle (CCW)	Head moves in a circular trajectory in counter-clockwise direction	x	
Downward (D)	**Head bobs up and down**	x	x
Down-Shake (DS)	**Head shakes while bobbing down, 3 frames of shaking at lowest dip**	x	
Foot-Lift (F)	Foot lifts, body remains stationary	x	x
Foot-Lift Down Swing (FL)	**Foot lifts while head swings diagonally downward**	x	x
Headbang (H)	Head is thrown forward and backward, sometimes in pattern-8	x	
Head-Foot Sync (HF)	**Head moves in sync with foot**	x	x
Headbang w/ Lifted Foot (HL)	**Foot lifts while head bangs**	x	x
Pose (P)	Body poses/holds a stationary position	x	x
Side-to-Side (S)	Foot lifts while head moves from side-to-side with rebound in neck	x	x
Semi-Circle Low (SCL)	Both feet remain close to or in contact w/ surface; head follows a semi-circle (lower half) trajectory	x	
Semi-Circle High (SCH)	**Both feet remain close to or in contact w/ surface; head follows a semi-circle (upper half) trajectory**	x	x
Vogue (V)	**Head moves from one side of lifted foot to the other**	x	x
Downward/Head-Foot Sync (D/HF)	Head bobs up and down interspersed with head moving in sync with foot	x	
Headbang/Semi-Circle Low Inter-changed (H/SCL)	Head is thrown forward and backward interspersed with head following a semi-circle (lower half) trajectory	x	

[a]Predominant movements are in bold text. These are movements with durations comprising at least 10% of the overall dance movement duration for any given trial. In right two columns, x = occurred during that song.

Building on ideas articulated in [1], we suggest that spontaneous and diverse movement to music arises when five traits converge: A) complex vocal learning, B) the capacity for nonverbal movement imitation, C) a tendency to form long-term social bonds, D) the ability to learn complex sequences of actions, and E) attentiveness to communicative movements. Parrots are unusual in sharing all of these traits with humans [4,9,10], which could explain why (to date) only humans and parrots show spontaneous and diverse dancing to music.

SUPPLEMENTAL INFORMATION

Supplemental Information includes two figures, two videos, supplemental experimental procedures, and links to other videos of parrots moving to music, and can be found with this article online at https://doi.org/10.1016/j.cub.2019.05.035.

ACKNOWLEDGMENTS

Filming and initial data analysis were supported by Neurosciences Research Foundation as part of its program on music and the brain at The Neurosciences Institute (San Diego, CA). We thank Irene Pepperberg and Erich Jarvis for their input on issues of parrot behavior and neurobiology.

AUTHOR CONTRIBUTIONS

J.R.I. and A.D.P. designed the experiments, I.S. conducted the experiments, R.J.J.K. analyzed the data, R.J.J.K, J.R.I. and A.D.P. wrote the paper.

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