# The Evolution of Dance

Kevin Laland[1], Clive Wilkins[2] & Nicky Clayton[2]

1. School of Biology, University of St Andrews, UK
2. Department of Psychology, University of Cambridge, UK

Draft 1.4, Sept 10 2015

Main text: 2465 words

Abstract: 141 words

Box 1: Animal Dancers: 458 words

For submission as an Essay to Current Biology.

**Abstract.** Evidence from multiple sources reveals a surprising link between imitation and dance. As in the classical correspondence problem central to imitation research, dance requires mapping across sensory modalities, and the integration of visual and auditory inputs with motor outputs. Recent research in comparative psychology supports this association, in that entrainment to a musical beat is only observed in animals capable of vocal and motor imitation. Dance possesses representational properties reliant on the dancers' ability to imitate particular people, animals or events, as well as the audience's ability to recognize these correspondences.  Imitation also plays a central role in learning to dance, and the acquisition of the long sequences of choreographed movements are dependent on social learning. These, and other, lines of evidence suggest that dancing may only be possible for humans because its performance exploits existing neural circuitry employed in imitation.

Dance is observed in all human societies. People readily move their bodies to rhythm or music, frequently coordinating their motion with others. The apparent effortlessness and ubiquity of human dance, however, belies the complexity of the act. How is that we are able to dance, when cats, dogs or monkeys can't? The scientific answer to this question reveals a surprising connection between dance and imitation.

Dancing requires the performer to match their actions to music, or to time their movements to fit the rhythm – sometimes an internal rhythm, such as the heartbeat. This demands a correspondence between the auditory inputs that the dancer hears and the motor outputs they produce. Likewise, competent couple or group dancing requires individuals to coordinate their actions, in the process matching, reversing or complementing each other. This too calls for a correspondence between visual inputs and motor outputs. Convergent lines of evidence suggest that people solve these challenges by harnessing the same neural architecture as deployed in imitation.

**[Figure 1: Edgar Degas. The rehearsal]**

Like dance, imitation requires the performer to map across different sensory modalities to produce a corresponding output. For instance, when an individual learns through observation to ride a bicycle, they must connect the sight of someone else peddling the bike, with the utterly different sensory experience that they encounter when they themselves perform these actions. Even today, there is little consensus as to how this 'correspondence problem' is solved (see 1 for a recent review). Some researchers believe that imitation is mediated by special-purpose neural structures, whilst others maintain that imitation can be explained by general learning and motor control mechanisms (1). Imitative proficiency may have been favoured by selection for cognitive proficiencies that built upon and enhanced general learning mechanisms to promote social learning, as for instance, appears to have occurred with the evolution of motherese in language learning, or pedagogical cueing in instrumental learning (2,3). This debate has been stimulated by the discovery of mirror neurons - cells, or bundles of cells, that fire when the subject observes and executes a given action (4). It remains to be established whether mirror neurons evolved to allow imitation or for some more general function, or even whether mirror neurons are best regarded as cause or consequence of observational learning proficiency (1,5). However, solving the correspondence problem unquestionably requires links, in the form of networks of neurons, connecting the visual or auditory sensory regions of the brain with the motor cortex. It equally requires neural mechanisms that allow the learning of sequences of action units, and that 'recognize' the correspondence between the self's and another's performance of each action unit (5,6).

Contemporary theories suggest that while the potential for imitation is inborn in humans, competence is only realized with appropriate lifetime experience (1,5,6). Early experiences, such as being rocked and sung to as a baby, help infants to form neural connections that link sound, movement and rhythm, whilst numerous activities engaged in later in life, such as playing a musical instrument, strengthen such networks. The relentless motivation to copy the actions of parents and older siblings, which we all witness in our young children, may initially serve a social function, such as to strengthen social bonds (7), but it undoubtedly also trains the 'mirroring' neural circuitry of the mind, leaving the child better placed later in life to integrate across sensory modalities. Theoretical work suggests that the experience of synchronous action forges links between the perception of self and others performing the same act (5,6). Whether it is because past natural selection has tuned human brains specifically for imitation, because humans construct developmental environments in a way that promotes imitative proficiency, or both, there can be no doubt that, compared to other animals, humans are exceptional imitators. It may be no coincidence that a recent PET scan analysis of the neural basis of dance found that foot movement to music excited regions of neural circuitry (e.g. the right frontal operculum) previously associated with imitation (8). Dancing may only be possible for humans because its performance exploits the neural circuitry employed in imitation.

Comparative evidence is remarkably consistent with this hypothesis. A number of animals have been described as dancers, including snakes, bees, birds, bears, elephants, and chimpanzees. However, whether animals can truly be said to dance remains a contentious issue, which depends at least in part on how dance is defined. In contrast, the more specific question of whether animals can move their bodies in time to music or rhythm has been extensively investigated by researchers, with clear and positive conclusions. Strikingly, virtually all of those animals that pass this test are known to be highly proficient imitators (9,10; see **Box 1**).

**[Box 1: Animal dancers]**

Dance often tells a story, and this representational quality provides another link with imitation. For instance, in the astronomical dances of ancient Egypt, priests and priestesses, accompanied by harps and pipes, performed stately movements that mimed significant events in the story of a god, or imitated cosmic patterns, such as the rhythm of night and day (17). Africa, Asia, Australasia and Europe all possess long-standing traditions for masked dances, in which the performers assume the role of the character associated with the mask and enact religious stories (17). America in the 1920s was obsessed with a cult of animal dances, including the 'Grizzly bear', 'Turkey trot' and 'Bunny hop', which requires the dancer to imitate animal movements. This tradition continues right through to the present. For instance, in 2009, the Rambert Dance Company, a world leader in contemporary dance, marked the bicentenary of Charles Darwin's birth and 150th anniversary of his seminal work *On the Origin of Species* by collaborating one of us (NC) to produce *Comedy of Change*, which evoked animal behaviour on stage with spellbinding accuracy. In all such instances, the creation and performance of the dance requires an ability on the part of the dancer to imitate the movements and sounds of particular people, animals, machines, or worldly events. Such dances re-introduce the correspondence problem, since the dancer, choreographer and audience must be able to connect the dancers' movements to the target phenomenon that they represent.

[**Figure 3. Dancers from the Rambert Dance Company in Comedy of Change**]

The most transparent connection between dance and imitation, however, will be readily apparent to anyone who has ever taken or observed a dance lesson: dance sequences are typically learned through imitation. From beginner ballet classes for infants to professional dance companies, the learning of a dance routine invariably begins with a demonstration of the steps from an instructor or choreographer, which the dancers then set out to imitate. It is no coincidence that dance rehearsal studios around the world almost always have large mirrors along one wall. These allow the learner rapidly to flit between observing the movements of the instructor or choreographer and observing their own performance. This not only allows them to see the correspondence - or lack of it - between the target behaviour and what they are doing, but also allows them to connect the proprioceptive and kinesthetic feedback they are getting from their muscles and joints to visual feedback on their performance, allowing error correction and accelerating the learning process.

In professional dance companies, prospective new members of the company are given challenging auditions in which they evaluated for their ability to pick up new dance routines with alacrity - an essential skill for a dancer. Dancing is not just about body control, posture, grace and power, but also demands its own kind of intelligence. A key element in whether or not a trainee dancer makes the grade essentially comes down to how good they are at imitating. A professional dancer at Rambert[1] once told us that she had recently taken up sailing, and her instructor was flabbergasted at how quickly she had picked up the techniques involved. What the instructor failed to appreciate was that dancers earn their living by imitation.

That is not to suggest that imitation is the only cognitive faculty that is necessary for dance learning. Also important is sequence learning, particularly in choreographed dances, which require the learning of a long, and often complex, sequence of actions. Even improvised dances such as the Argentine tango require the leader to plan a sequence of movements that provide the basis for the exquisite conversation between leader and follower, allowing them to move as a 'four-legged animal with two beating hearts'. Once again, scientific evidence connects this sequence learning ability to social learning. Recent theoretical work suggests that long strings of actions are very difficult to learn asocially, but that social learning substantially increases the chances that individuals will acquire the appropriate sequence (18). Hominins may be predisposed to be highly competent manipulators of strings of behavioural elements because many

---

[1] Formerly Ballet Rambert until 1966 and then Rambert Dance Company until 2013

of their tool-manufacturing and tool-using skills, extractive foraging methods, and food-processing techniques required them to carry out precise sequences of actions, in the right order. These sequence-learning capabilities are clearly exploited in learning dance.

Dancing also requires remarkably precise and controlled body movements, and recent studies of brain evolution suggest that this control evolved with increased brain size. Mammalian brains change in internal organization as they get larger, becoming more modular and asymmetrical with size (19). With increasing size, larger brain regions typically become better connected and start to exert control over the rest of the brain (20). This occurs because developing axons often compete with one another for access to target sites and this competition is generally won by those axons that collectively fire the target cells, giving large brain regions a competitive advantage. The net result is an increase in the ability of the larger brain regions to influence other regions.

The dominant structure in the human brain is the neocortex, which accounts for approximately 80% of the human brain by volume, more than in any other animal (19). In the primate lineage to humans, the neocortex has got larger over evolutionary time, and has exerted increasing control over the motor neurons of the spinal chord and brain stem, leading to increased manual dexterity, and more precise control of the limbs (19). The cerebellum, the second largest region of the human brain, also plays an important role in motor control, and has enlarged during recent human evolution (21). This motor control is what allows humans to dance easily and spontaneously, and in such precise ways.

Dance is often pleasurable, generating a feeling of release, arousal and excitement. Why should dance induce a positive mood? Part of the explanation may be the release of endorphins that accompanies any form of exercise, and of neurohormones, like oxytocin, with increased arousal and social behaviour (22). Another factor is the thrill of courtship in dancing with someone attractive, or for the observer, the voyeurism associated with observing lithe, athletic and appealing young bodies move with grace and beauty. Yet people enjoy dancing with individuals to whom we are not sexually attracted and when the physical demands are too modest to lead to an endorphin rush. Of particular interest here is social dance, for instance, dancing with a partner, or in a group, especially where the dancing is coordinated and synchronised, as for instance, *ceilidh* or *river dance*. Such dance often appears to lead to a sense of bonding, or shared pleasure, and can induce positive emotions in an audience (22). While some properties of dance that make people feel social close are very general, such as sharing attention and goals with others (23), others may be dance-specific, such as the externalization through music making of predictable rhythms, which helps people to synchronize their movements (22). An empirical link between synchronous activity and social bonding is now well-established (22).

Here an intriguing relationship between imitation and cooperation may be relevant. Recent psychological research has found that imitation enhances social interaction and induces positive moods, even when the imitated individual is unaware of being copied and the imitator does so unintentionally (24,25). The relationship between imitation and cooperation is bidirectional: being imitated makes individuals more cooperative, whilst being in a cooperative frame of mind makes one more likely to imitate others (24). These bidirectional causal relationships may function to maintain cooperation, collective action and information sharing between members of a social in-group (24). If positive rewards to synchronous behaviour have been favoured by selection to facilitate cooperation, then that might explain why dancing in a synchronous manner would induce warm feelings. The same imitative neural networks in our brains, which link sight, sound and rhythm, and thereby allow us to dance to music, are also almost certainly what explains our tendency to tap or clap to music, and the pleasure that experience affords.

Dancing probably originated as an exaptation, rather than an adaptation: that is, as a character that was fashioned by natural selection for a different role - a byproduct of imitative proficiency. Whether dancing ability was subsequently directly favored by natural or sexual selection remains unclear, although that is certainly a possibility. However, historical data suggest that dance initially functioned as an ethnic marker that promoted within-group identity and alliances, and only relatively recently took on roles in the communication of religious and historical knowledge and sexual display (17).

If the above reasoning is correct, and dance is genuinely reliant on imitative capabilities, then a series of empirically tractable predictions follow. These include that (*i*) good dancers ought to be unusually skilled imitators and synchronizers; (*ii*) good imitators ought to acquire dance more readily than poor imitators; (*iii*) those animals that exhibit either vocal or motor imitation will be those that show entrainment; (*iv*) dancing skills will develop in childhood to coincide with (or follow) the emergence of imitative capabilities; and (*v*) those brain regions activated when dancing will overlap with those central to imitation. Some provisional support for these hypotheses has already been presented, but there are clearly opportunities to test these hypotheses more rigorously. There are also likely to be implications for understanding some of the properties of music, as music and dance seemingly originated together (17), and some aspects of musical rhythm, such as syncopation, can only be fully understood as features that originated in a dancing context (26).

Curiously, in common parlance, the term imitation often has a derogatory quality, being associated with mindless and uninspired action, and contrasted with innovation. Historically the arts have placed value on creative and *avant guard* movements that push against established convention, and the inspiration for much dance innovation, as it has been for innovation more generally, has been precisely a reaction against 'mere imitation'. For instance, modern dance pioneers like Isadora Duncan and Martha Graham positioned themselves against the stylized dance strictures exemplified in classical ballet. Only now, in the light of scientific evidence, can we appreciate how smart copying is, and how vital are imitation, and other forms of social learning, to dance.

**Box 1: Animal dancers**

This ability to move in rhythmic synchrony with a musical beat, for instance, by nodding our head or tapping our feet - a universal characteristic of humans - is actually very rarely observed in other species (10). The most compelling explanation for why this should be, known as the 'vocal learning and rhythmic synchronization' hypothesis (9), suggests that entrainment to a musical beat relies on the neural circuitry for complex vocal learning, an ability that requires a tight link between auditory and motor circuits in the brain (11,12). This hypothesis predicts that only species of animals capable of vocal imitation - such as humans, parrots and songbirds, cetaceans, and pinnipeds, but not nonhuman primates and not those birds that do not learn their songs - will capable of synchronizing movements to music.

Consistent with this hypothesis, the internet is teeming with videos of birds, mostly parrots, moving to music, but compelling footage of other animals doing so is rare. Some of these 'dancing' birds have acquired celebrity status - the best known being Snowball a sulphur-crested cockatoo (*Cacatua galerita eleonora*), whose performances on YouTube have 'gone viral'[2]. Experiments manipulating the tempo of a musical excerpt across a wide range have conclusively demonstrated that Snowball spontaneously adjusts the tempo of his movements to stay synchronized with the beat (13).

[**Figure 2. Snowball – the dancing cockatoo**]

Another compelling experimental demonstration is found in lyrebirds, the males of which will often match subsets of songs from their extensive vocal repertoire with different combinations of tail, wing and leg movements to form predictable ‘gestures’, and thereby devise their own choreography (14).

---

[2] Snowball can be seen to move with astonishing rhythmicity, head banging and kicking his feet in perfect time to Queen's *Another One Bites The Dust* (see https://www.youtube.com/watch?v=cJOZp2ZftCw).

Lyrebirds are famous for their ability, unmatched in the animal kingdom, to imitate just about any sounds, including dog barks, chainsaws and car alarms. Thus far, evidence for spontaneous motor entrainment to music has been reported in at least nine species of birds, including several types of parrot, and the Asian elephant, all of whom are renowned vocal imitators (9,13-15). The sole exception is the California sea lion (16), but this species is situated in a clade of animals all of which have been shown to be capable of vocal learning.

Clearly, there is more to human dance than entrainment to music, and coordination with others' movements would seemingly draw on the neural circuitry that underlies motor, rather than vocal, imitation. However, a recent analysis of the avian brain suggested that vocal learning evolved through exploitation of pre-existing motor pathways (12), implying that vocal and motor imitation are reliant on similar circuitry. The animal data provides convincing support for a causal link between the capabilities for imitation and dance.

## Acknowledgements

Research supported in part by ERC Advanced (EVOCULTURE, ref: 232823) and John Templeton Foundation grants to KNL. We are indebted to Mark Baldwin, Nadia Stern and the dancers and rehearsal directors of Rambert for helpful discussion.

## References

1. Brass M & Heyes C 2005. Imitation: Is cognitive neuroscience solving the correspondence problem? Trends in Cognitive Science 9: 489-495.
2. Csibra G & Gergely G 2006. Processes of Change in Brain and Cognitive Development. Munakata Y, Johnson MH (Eds).Oxford University Press, pp 249-274.
3. Fitch WT 2010 The Evolution of Language. Cambridge University Press.

4. Rizzolatti G, Fogassi L & Gallese V 2001. Neurophysiological mechanisms underlying the understanding and imitation of action. Nat. Rev. Neurosci. 2: 661–670.

5. Laland KN & Bateson PPG 2001. The mechanisms of imitation. Cybernetics & Systems 32: 195-224.

6. Heyes C & Ray E 2004. Spatial S-R compatibility effects in an intentional imitation task. Psychonomic Bulletin & Review 11: 703-708.

7. Carpenter M 2006. Instrumental, social and shared goals and intentions in imitation. In Imitation and the Social Mind: Autism and Typical Development. Edited by SJ Rogers & JHG Williams 48-70. New York: Guilford Press.

8. Brown S, Martinez MJ & Parsons LM 2006. The neural basis of human dance. Cerebral Cortex. 16: 1157-1167.

9. Patel AD 2006. Musical rhythm, linguistic rhythm, and human evolution. Music Percept. 24, 99–104.

10. Fitch WT 2011. The biology and evolution of rhythm: Unraveling a paradox. In Language and Music as Cognitive Systems, P Rebuschat, M Rohrmeier, J Hawkins & I Cross, eds. Oxford: Oxford University Press.

11. Jarvis ED 2004. Learned birdsong and the neurobiology of human language. Ann. N Y Acad. Sci. 1016, 749–777.

12. Feenders G, Liedvogel M, Rivas M, Zapka M, Horita H, Hara E, Wada K, Mouritsen H & Jarvis ED (2008) Molecular Mapping of Movement-Associated Areas in the Avian Brain: A Motor Theory for Vocal Learning Origin. PLoS ONE 3(3): e1768. doi:10.1371/journal.pone.0001768

13. Patel AD, Iversen JR, Bregman MR & Schulz I 2009. Experimental Evidence for

Synchronization to a Musical Beat in a Nonhuman Animal. Current Biology 19, 827–830.

14. Dalziell AH, Peters RA, Cockburn A, Dorland AD, Maisey AC & Magrath RD 2013. Dance choreography is coordinated with song repertoire in a complex avian display. Curr. Biol. 23, 1132–1135.

15. Schachner A, Brady TF, Pepperberg IM & Hauser MD. 2009. Spontaneous Motor Entrainment to Music in Multiple Vocal Mimicking Species. Current Biology 19, 831–836.

16. Cook P, Rouse A, Wilson M & Reichmuth C 2013 A California sea lion (Zalophus californianus) can keep the beat: motor entrainment to rhythmic auditoru stimuli in a non-vocal mimic. J. Comp. Psychol. 127(4): 412-427.

17. Clarke M & Crisp C 1983. The history of dance, 5th Edition. Crown Publishers: New York.

18. Whalen A, Cownden D & Laland KN 2015. The learning of action sequences through social transmission. Anim. Cogn. DOI 10.1007/s10071-015-0877-x

19. Striedter GF 2005. Principles of Brain Evolution. Sunderland, MA: Sinauer.

20. Deacon, T.W. 1997. The symbolic species: The coevolution of language and the brain. New York: Norton.

21. Barton RA 2012. Embodied cognitive evolution and the cerebellum. Philosophical Transactions of the Royal Society of London. Series B 367:2097-2107.

22. Tarr B, Launay J & Dunbar RIM 2014. Music and social bonding: ‘self-other’ merging and neurohormonal mechanisms. Frotiers in Paychology. doi: 10.3389/fpsyg.2014.01096

23. Tomasello M, Carpenter M, Call J, Behne, T & Moll H 2005. Understanding and sharing intentions: the origins of cultural cognition. Behav. Brain Sci. 28, 675–691; discussion 691–735.

24. Heyes CM 2012. What can imitation do for cooperation? In B Calcott, R Joyce & K Sterelny, eds. Signalling, Commitment & Cooperation. MIT Press.

25. van Baaren R, et al. 2009. Where is the love? The social aspects of mimicry. Phil Trans R Soc B 3641528: 2381-2389.

26. Fitch WT (Submitted). Dance, music, meter and groove: a forgotten partnership. Frontiers in Human Neuroscience.