Music and Movement: A View from Cognitive Science

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We know that there is a relationship between the music for a dance and the movements of the dance, but what sort of relationship is it? On the one hand, it seems doubtful that the relationship is as close as A.B. Marx described it in his early nineteenth-century account of the waltz. After noting that the turning figure typical of the dance comprised six steps which spanned two notated measures of music (a set of movements he called the "motive" of the dance) he observed that, as far as musical organization was concerned, "the waltz must bring into prominence this basic motive of movement. Each measure, or, better, each phrase of two measures, must answer to the dance motive marking the first step firmly, and also the swinging turn of the dance."[1] There are, however, any number of waltzes from the early nineteenth century that do not conform with Marx's guidelines: composers of the period clearly viewed the relationships between music and dance as being rather more flexible than did Marx. On the other hand, anyone who has had the experience of being unable to match movements to music (either through a profound lack of competence or through simply not knowing the steps of a dance) is aware that the relationship between movement and music is far from arbitrary. While the steps of a dance do not have to fit every detail of the music, there is still an expectation that correspondences should obtain between music and movement.[2]

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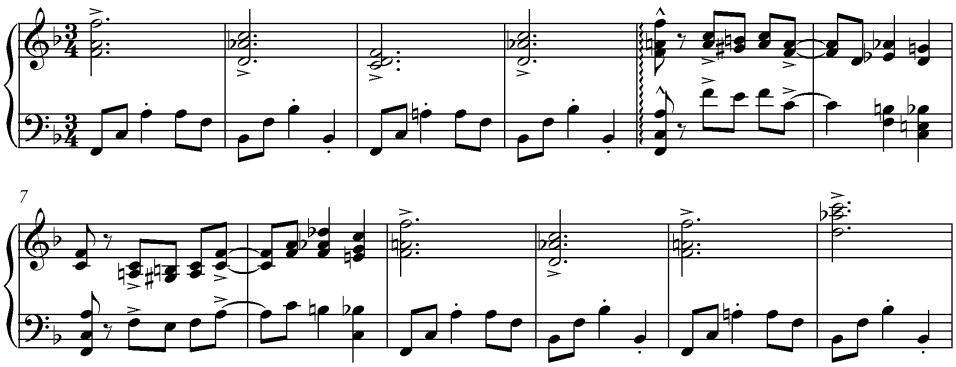
1. "Das Geringste, was der Walzer zu leisten hat, ist die Hervorhebung dieses Grundmotivs der Bewegung. Jeder Takt, oder besser: jede Klausel von zwei Takten muss also dem Tanzmotive entsprechen, den Antritt fest bezeichnen und die schwingende Wendung des Tanzes." Adolph Bernhard Marx, *Die Lehre von der musikalischen Komposition, praktisch theoretisch* (Leipzig: Breitkopf & Härtel, 1837–38), 2: 55.

2. As should be obvious, I am primarily interested in situations in which there *is* a relationship between music and movement. During the twentieth century, some choreographers called into question the value of such a relationship, or dispensed with music entirely. My perspective here is similar to that of Nicholas Cook, to the extent that, as is he, I am interested in music and movement as an instance of multimedia, in which

In what follows, I would like to propose that there is, at the very least, the potential for substantive connections between music and movement, and that the means to analyze and to study this connection can be found in recent research in cognitive science. As an example of this sort of connection, let me turn to a brief but telling moment in Fred Astaire's choreography for Jerome Kern's "Waltz in Swing Time" from the 1936 movie *Swing Time*, featuring Astaire and Ginger Rogers.[3] The moment comes about a third of the way through the scene featuring the dance, coincident with a reprise of the opening material of Kern's tune which, as shown in Example 1, is a sort of fanfare that sweeps down and then back up through musical space.[4] Up to this point Astaire and Rogers have been engaged in close dancing, but as the fanfare returns they move into a series of coordinated side-by-side steps which include a series of large sweeping gestures, shown in Example 2, that provide a striking visual depiction of the musical materials. The connection between dance and music seems completely undeniable—Astaire and Roger's movements simply *are* the fanfare from Kern's tune—and yet the basis for the connection is obscure: producing gestures of this sort gives rise to little if any sound, and creating the musical sounds need not entail any similar sort of gesture. Again, we have a sense that music and movement connect with one another, but why is this so? To explore this question I would like to turn to recent work in cognitive science that provides evidence for the way physical movements shape conceptual knowledge, and which provides a framework through which we can explain how functionally soundless movement can be correlated with functionally motionless sound.



Example 1: Fanfare theme from Jerome Kern's "Waltz in Swing Time"

both mediums participate (although not necessarily equally). See Nicholas Cook, *Analysing Musical Multimedia* (Oxford: Clarendon Press, 1998); and Lawrence M. Zbikowski, "Music Theory, Multimedia, and the Construction of Meaning," *Intégral* 16/17 (2002–03): 251–68.

3. A number of writers on dance have commented on this scene; see John Mueller, *Astaire Dancing: The Musical Films* (New York: Knopf, 1985), 106–8.

4. In point of fact, the authorship of the "Waltz in Swing Time" is slightly complicated. It appears that Kern developed most of the basic musical material but that it was put into its more or less final form by Robert Russell Bennett. For the sake of simplicity I will attribute the work to Kern, keeping in mind that Bennett's contributions may have been equally significant.

Example 2: Sweeping gesture in Fred Astaire's choreography for the "Waltz in Swing Time" from the 1936 movie *Swing Time*

Grounded Cognition

Although cognitive science emerged as a field more than thirty years ago, it has only recently had anything of substance to say to scholars in the humanities. One barrier was a difference in methodology between cognitive science and the humanities; another was the focus in cognitive science on the mind as individual and incorporeal, and on thought as the exclusive province of language. Although the difference in methodology remains, during the past two decades cognitive science has begun to recognize that the human mind is also a social mind, that experience shaped by the mediation of the human body does much to shape human cognition, and that language captures only a portion of what can properly be called thought. This newer approach has come to be called grounded cognition,[5] and reflects changed views of the relationship between the body and the mind, on the role of the imagination (broadly construed) in mediating this relationship, and on the role of non-linguistic constructs in human thought. As outlined in the following, each of these aspects of grounded cognition can help us to better understand connections between music and movement.

The Body and the Mind

Much of the initial impetus for developing an account of the relationship between the body and the mind came from researchers whose primary intellectual formation was in fields such as linguistics or philosophy rather than the sciences. In seeking to account for the role of individual and collective experience in the formation of knowledge these scholars developed the largely theoretical proposal that such experience was informed by the simple fact that minds were situated

5. Diane Pecher and Rolf A. Zwaan, eds., *Grounding Cognition: The Role of Perception and Action in Memory, Language, and Thinking* (Cambridge: Cambridge University Press, 2005); Lawrence W. Barsalou, "Grounded Cognition," *Annual Review of Psychology* 59 (2008): 617–45.

in bodies.[6] During the 1990s this proposal received empirical support from studies in a range of areas, including the neurophysiology of emotions,[7] the neural representation of motor actions,[8] relationships between motor processes related to visual rotation and the mental rotation of images,[9] and advances in neuroimaging (which made possible the study of the brain and central nervous system as parts of a living organism). From the perspective of connections between music and movement, however, perhaps the most interesting research is associated with what have come to be called mirror neurons.

In 1996 a group of researchers led by Vittorio Gallese reported discovering a group of motor neurons that became active both when macaque monkeys performed a given action and when the monkeys observed a similar action performed by the experimenter.[10] That is, simply seeing an action being performed caused certain groups of neurons to fire, an activation that was a mirror image of what occurred when the monkey performed the same action. Further research has demonstrated that mirror neurons can also be activated by aural stimuli: the same mirror neuron will discharge when a monkey observes an experimenter breaking a peanut and when the monkey hears the peanut being broken without seeing the action.[11] As an example of analogous processes in humans, a recent fMRI study by Valeria Gazzola and her associates showed similar patterns of brain activation when subjects performed a motor action (such as tearing a sheet of paper) and when they heard a recording of the motor action being performed.[12]

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6. Mark L. Johnson, *The Body in the Mind: The Bodily Basis of Meaning, Imagination, and Reason.* (Chicago: University of Chicago Press, 1987); George Lakoff, *Women, Fire, and Dangerous Things: What Categories Reveal About the Mind* (Chicago: University of Chicago Press, 1987).

7. Antonio R. Damasio, *Descartes' Error: Emotion, Reason, and the Human Brain* (New York: Avon, 1994); Antonio R. Damasio, *The Feeling of What Happens: Body and Emotion in the Making of Consciousness* (New York: Harcourt Brace & Company, 1999).

8. Marc Jeannerod, "The Representing Brain: Neural Correlates of Motor Intention and Imagery," *Behavioral and Brain Sciences* 17, no. 2 (1994): 187–245; Marc Jeannerod, *The Cognitive Neuroscience of Action*, Fundamentals of Cognitive Neuroscience (Oxford: Blackwell Publishers Ltd., 1997).

9. Mark Wexler, Stephen M. Kosslyn, and Alain Berthoz, "Motor Processes in Mental Rotation," *Cognition* 68, no. 1 (1998): 77–94.

10. Vittorio Gallese, Luciano Fadiga, Leonardo Fogassi, and Giacomo Rizzolatt, "Action Recognition in the Premotor Cortex," *Brain* 119, no. 2 (April 1996): 593–609. For a review of research on mirror neurons, see Giacomo Rizzolatti and Corrado Sinigaglia, *Mirrors in the Brain: How Our Minds Share Actions and Emotions*, trans. Frances Anderson (Oxford: Oxford University Press, 2008); for a critique of research on mirror neurons, see Gergely Csibra, "Action Mirroring and Action Understanding: An Alternative Account," in *Sensorimotor Foundations of Higher Cognition*, ed. Patrick Haggard, Yves Rossetti, and Mitsuo Kawato, Attention and Performance XXII (Oxford: Oxford University Press, 2008), 435–59.

11. Evelyne Kohler, Christian Keysers, M. Alessandra Umiltà, Leonardo Fogassi, Vittorio Gallese, and Giacomo Rizzolatti, "Hearing Sounds, Understanding Actions: Action Representation in Mirror Neurons," *Science* 297 (2 August 2002): 847.

12. Valeria Gazzola, Lisa Aziz-Zadeh, and Christian Keysers, "Empathy and the Somatotopic Auditory Mirror System in Humans," *Current Biology* 16 (19 September 2006): 1824–29. "fMRI" stands for functional magnetic resonance imaging.

It remains to be seen whether research on mirror neurons will have direct applications to humans; at present, all of the research has been conducted on monkeys using invasive techniques of a sort not suitable for human subjects. What this research has done, however, is to stimulate interest in relationships between motor actions and cognition. For instance, Beatriz Calvo-Merino and her colleagues recently showed that when expert dancers observed dance actions that were in their personal motor repertoire the motor areas in their brains showed more activity than when they observed kinematically comparable dance actions that were not in their repertoire.[13]

There is, in sum, evidence for close relationships, at the neuronal level, between performing motor actions, observing another person performing similar actions, and hearing sounds produced by motor actions. While this does not support a *necessary* connection between music and movement, it suggests that such connections reflect a thoroughgoing integration of thoughts, perceptions, and motor actions.

Simulations of Experience

The turn toward embodiment has no doubt yielded a more holistic view of human cognitive processes, and brought the interests of cognitive scientists closer to those of humanists. It is well to bear in mind, however, that in certain situations mental and bodily processes may be decoupled. The psychologist Merlin Donald, in a discussion of the cognitive supports necessary for the evolution of language, stressed the importance of being able to mentally rehearse action patterns so that they could be refined, a process which contributed to the development of the mnemonic structures upon which language relies.[14] In such cases performance of the action patterns would occur subsequent to their refinement. Lawrence Barsalou, in his work on the perceptual bases of human cognition, has developed a quite similar perspective, arguing for the importance of the capacity to simulate perceptual information (including that associated with motor actions) in the absence of actual percepts.[15] According to this perspective, remembering some thing—a chair, for instance—involves a partial reactivation of the perceptual information accumulated on previous encounters with the thing (or things similar to it). The information about the chair that we recall through memory is thus a simulation of the chair—not only how it appears but also its texture, the movements required to sit in it, what if feels like when it supports our weight, its mass when we attempt to move it, and a wealth of similar information.[16] Under normal circumstances, we would not mistake the simulation for the thing itself, but this does not make the simulation any less genuine. In a like fashion, there

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13. Beatriz Calvo-Merino, Daniel E. Glaser, Julie Grezes, Richard.E. Passingham, and Patrick Haggard, "Action Observation and Acquired Motor Skills: An fMRI Study with Expert Dancers," *Cerebral Cortex* 15 (August 2005): 1243–44.

14. Merlin Donald, "Preconditions for the Evolution of Protolanguages," in *The Descent of Mind: Psychological Perspectives on Hominid Evolution*, ed. Michael C. Corballis and Stephen E.G. Lea (Oxford: Oxford University Press, 1999), 140–43.

15. Lawrence W. Barsalou, "Perceptual Symbol Systems," *Behavioral and Brain Sciences* 22 (November 1999): 577–660.

16. Lawrence W. Barsalou, "Abstraction as Dynamic Interpretation in Perceptual Symbol Systems," in *Building Object Categories in Developmental Time*, ed. Lisa Gershkoff-Stowe and David H. Rakison, Carnegie Mellon Symposium Series on Cognition (Mahwah, New Jersey: Lawrence Erlbaum Associates, Publishers, 2005), 398–401.

are also simulations for actions and events (which would include the sort of mental rehearsal envisaged by Donald).

Because simulations of a thing or event are, of necessity, partial, they will also be somewhat approximate. The relative flexibility of such approximations makes possible correspondences with simulations from other domains of experience, which in turn support analogical relationships between these domains. For instance, patterns that emerge during the simulation of a series of physical movements, such as the steps of a dance, can be drawn into a relationship with patterns that emerge during the simulation of a series of musical sounds. A simulation of the experience of taking the weight of one's body on a single foot could thus be correlated with a simulation of the experience of hearing the coincidence of a number of coordinated sound phenomena at a single time point, an event that musicians call a strong beat.[17] And just as we regard simulations as thoroughly genuine, so such correlations may also come to be regarded as inevitable rather than accidental.

Non-linguistic Constructs

Knowledge about music and movement can be supported and articulated through language—indeed, much of our teaching of these "non-verbal" arts relies on language—but most practioners have a sense that language cannot exhaust the resources of these expressive media. The same could be said of the visual arts, and it was in fact in the rather more prosaic realm of the manipulation of visual objects that cognitive science first confronted the possibility that portions of human thought might be beyond the grasp of language.[18]

Support for the notion of non-linguistic cognitive constructs came, in an indirect way, from Mark Johnson's influential theory of image schemata.[19] Johnson developed his theory as a way to explain the origin of the broad patterns of thought he and George Lakoff identified in their book *Metaphors we Live By*.[20] The theory held that these patterns of thought, which Johnson and Lakoff came to call conceptual metaphors, had their basis in repeated patterns of bodily experience called image schemata (which, in Johnson's reckoning, were not restricted to experiences gathered from vision but reflected knowledge from all perceptual inputs, including proprioception). Expressions such as "My income is going *up*," or "Crime has gone *down*" reflect the conceptual metaphor MORE IS UP, LESS IS DOWN which in turn reflects the VERTICALITY image schema, a product of each individual's countless experiences with the contexts and consequences of a vertical orientation in space. Image schemata, while not in themselves conceptual, provided the means to make sense of

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17. It is worth mentioning that simulations afford the opportunity for a number of imaginative correlations between different domains. In the standard steps for the bourrée in the seventeenth and eighteenth centuries, for instance, the figure used for the initial upbeat and downbeat was a *demi-coupé*: a *plié*—gently bending the knees—followed by an *élevé*—gently stretching the knees to rise. The "strong beat" was thus marked by an upward motion. Pierre Rameau, *The Dancing Master*, trans. Cyril W. Beaumont (New York: Dance Horizons, 1970), 78. See also Wendy Hilton, *Dance of Court & Theater: The French Noble Style, 1690–1725*, ed. Caroline Gaynor (Princeton, New Jersey: Princeton Book Company, 1981), 183.

18. Barsalou, "Grounded Cognition," 619; Stephen M. Kosslyn, William L. Thompson, and Giorgio Ganis, *The Case for Mental Imagery*, Oxford Psychology Series (New York: Oxford University Press, 2006).

19. Johnson, *The Body in the Mind*.

20. George Lakoff and Mark L. Johnson, *Metaphors we Live By* (Chicago: University of Chicago Press, 1980).

experience through providing an embodied grounding for concepts.[21] In some cases, those experiences might be non-linguistic: thus musical pitches are oftentimes (but not exclusively) described in terms of orientation in physical space, with pitches that are the result of more rapid vibrations of the sounding medium characterized as "higher" than pitches that result from slower vibrations of the sounding medium.[22]

My contribution in this area developed from the proposal that basic musical materials (at the level, say, of a theme or short sequence of chords) could be thought of in terms of processes of categorization.[23] A theme could thus be construed as a category, with each different statement of the theme a member of that category. In that some cognitive scientists draw a very close connection between categories and concepts, this led to the idea of concepts specific to music that were independent from language. In subsequent work I have expanded this idea, with the musical materials proper to a category conceived in terms of dynamic properties.[24] From this perspective, the musical materials upon which musical organization is based serve as an analog for a dynamic process. As one relatively straightforward example, the materials Marx identified as being essential to a properly-written waltz serve as an analog for the steps of the dance as they are performed—thus Marx's emphasis on the proper means of composing these materials, taking care to insure that they mark "the swinging turn of the dance."

Settling the issue of whether music, dance, and other non-linguistic forms of expression are "conceptual" will not, I believe, change significantly the practice of those forms. What it can change are aspects of the way they are studied, especially to the extent that such forms of expression are products of human cognitive capacities generally. What this study can also change is the shape of cognitive science, since to consider the cognitive bases of non-linguistic forms of expression will require that cognitive science move beyond the perspective that the exclusive province of thought is language and toward the notion that language is but one of a range of human communicative resources.

Grounded Cognition, Music, and Movement

Within the past two decades cognitive science has begun to address, in a systematic way, relationships between the body and the mind, the relationship between imagination (or, in Barsalou's somewhat more carefully defined terms, simulation) and motor actions, and the status of non-linguistic constructs. As a consequence, cognitive science is now better able to provide resources for the exploration of topics that are of interest to humanists, including relationships between music and movement. Prior to offering my own perspective on links between music and movement, I would

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21. The theory of image schemata can be seen to anticipate important aspects of Barslou's Perceptual Symbol Systems theory; see Barsalou, "Perceptual Symbol Systems".

22. Lawrence M. Zbikowski, *Conceptualizing Music: Cognitive Structure, Theory, and Analysis* (New York: Oxford University Press, 2002), 63–65; Lawrence M. Zbikowski, "Metaphor and Music," in *The Cambridge Handbook of Metaphor and Thought*, ed. Ray Gibbs, Jr. (Cambridge: Cambridge University Press, 2008), 502–24.

23. Zbikowski, *Conceptualizing Music*, 58–62.

24. Lawrence M. Zbikowski, "Dance Topoi, Sonic Analogues, and Musical Grammar: Communicating with Music in the Eighteenth Century," in *Communication in Eighteenth Century Music*, V. Kofi Agawu and Danuta Mirka (New York: Cambridge University Press, 2008), 283–309.

like to briefly consider the cognitive capacity that I view as key to understanding how these two different modes of communication come to be linked: analogy.

Analogy

Douglas Hofstadter placed analogy at the very core of human cognition, arguing that it provided the means by which concepts are assembled and connected to one another.[25] At the very least, there is considerable overlap between judgments of similarity, making analogies, and processes of categorization, all of which contribute to the distinctiveness of human intelligence.[26] Perhaps more striking is that the capacity for analogy is apparently unique to our species. Although other species are able to make some very sophisticated similarity judgments, and there is research suggesting that chimpanzees can make recourse to analogy for spatial reasoning, current evidence indicates that no other species comes close to making or using analogies with the facility and speed of humans.[27]

The characteristic feature of the sort of analogies that distinguish human cognition is the cross-domain correlation of structural elements and relationships *between* structural elements. For example, I described the opening material of Kern's "Waltz in Swing Time" as a fanfare that sweeps down and then back up through musical space. The analogy upon which this description rests draws correlations between musical pitches and points in vertically-oriented space, and between relationships between pitches and relationships between points in space (such that one pitch can be "higher" than another).[28] Once this framework has been established it is but a short step to a characterization of the succession of pitches in terms of a motion between points in space: because there is considerable "distance" between the pitches and because their succession happens at a relatively leisurely pace, "sweeping" seems an apt way to describe this motion.

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25. Douglas R. Hofstadter, "Epilogue: Analogy as the Core of Cognition," in *The Analogical Mind: Perspectives from Cognitive Science*, ed. Dedre Gentner, Keith J. Holyoak, and Boicho N. Kokinov (Cambridge, Massachusetts: MIT Press, 2001), 499–538.

26. Douglas L. Medin, Robert L. Goldstone, and Dedre Gentner, "Respects for Similarity," *Psychological Review* 100, no. 2 (1993): 254–78; Sam Glucksberg and Boaz Keysar, "Understanding Metaphorical Comparisons: Beyond Similarity," *Psychological Review* 97, no. 1 (January 1990): 3–18.

27. Josep Call and Michael Tomasello, "Reasoning and Thinking in Nonhuman Primates," in *The Cambridge Handbook on Thinking and Reasoning*, ed. Keith Holyoak and Robert G. Morrison (Cambridge: Cambridge University Press, 2005), 607–32; Dedre Gentner, "Why We're So Smart," in *Language in Mind: Advances in the Study of Language and Thought*, ed. Dedre Gentner and Susan Goldin-Meadow (Cambridge, Massachusetts: MIT Press, 2003), 195–235; Keith J. Holyoak and Paul Thagard, *Mental Leaps: Analogy in Creative Thought* (Cambridge, Massachusetts: MIT Press, 1995), chap. 3; David L. Oden, Roger K. R. Thompson, and David Premack, "Can an Ape Reason Analogically?: Comprehension and Production of Analogical Problems by Sarah, a Chimpanzee (*Pan Troglodytes*)," in *The Analogical Mind: Perspectives from Cognitive Science*, ed. Dedre Gentner, Keith J. Holyoak, and Boicho N. Kokinov (Cambridge, Massachusetts: MIT Press, 2001), 471–97.

28. It is worth remembering that not all cultures characterize pitch relationships in terms of "higher" and "lower." For a theoretical account, see Zbikowski, *Conceptualizing Music*, chap. 2; for empirical work on analogical characterizations of musical motion (which draws on contemporary research on metaphor) see Zohar Eitan and Roni Y. Granot, "How Music Moves: Musical Parameters and Listeners' Images of Motion," *Music Perception* 23, no. 3 (2006): 221–47.

It bears mention that analogies are always framed relative to some goal.[29] There are, for instance, any number of similarities between the domains of musical pitch and vertically-oriented space—both are invisible, and each is a continuum—but for the purposes of describing musical motion only those features relevant to that goal are placed in correlation with one another. And so while analogical mappings may seem inevitable—for most musicians in the West, the "high" and "low" of pitch relationships seem incontrovertible, even when the cellist's hand moves toward the floor as she plays "higher" notes—they in fact reflect relatively specific goals.

Music and Movement

Let me now return to my opening example—the sweeping gesture that Astaire correlated with Kern's fanfare—to consider what cognitive science might have to tell us about connections between music and movement.

In line with Marx's guidelines for composing a waltz, Kern's music is grouped into two-measure units. In measures 1–4 and 9–12 the melody alternates between the first and fifth steps of the scale (F5–C5–F4–C5, then F5–C5–F5–C6), which gives a clear sense of moving, in a quite deliberate way, through the diatonic space of F major. The harmonies also alternate, but between chords built on the first and *fourth* notes of the scale: F major and B♭, a harmonization that yields a much less clear sense of direction within the key of F major. When taken together this succession of melodic and harmonic material creates an apt analog for a swinging dance, one whose motion is both inevitable and yet not particularly directed. Measures 5–8, by contrast, provide momentary animation through the introduction of eighth notes, a syncopated figure, and (within each two-measure block) movement from tonic to dominant (a harmonic progression that has long been viewed as the motive force behind tonal music).

The still picture of Example 2 captures, of course, but a fleeting moment in a highly dynamic sequence of movements. Perhaps most important is the immediate context for this moment: Example 2 illustrates the point of maximum extension for a movement that begins with the body compact and lightly balanced, and culminates with both arms and the left leg extended, poised on the toe of the right foot. Immediately after this the dancers return to a relatively compact disposition of the body, creating a pivot point for two rapid turns that lead to a repetition of the sweeping gesture. Although the coordination of music and movement is, as one might expect with a choreography this demanding, something less than perfect, the performance of these two sweeping gestures corresponds quite closely with the performance of measures 1 and 3 of Example 1; the performance of the recovery and quick turns corresponds with the performance of measures 2 and 4.

With respect to analogical mappings, the relatively long duration of the melody notes of measures 1 and 3 correlates with the physical extension typical of the sweeping gesture; the counterbalance provided by measures 2 and 4 correlates with the dancers' recovery from the sweeping gesture; and each two-measure unit (the melody of which "descends" through musical space) correlates with a sequence of movements performed by the dancers that progress from expansion to contraction. There are, in sum, a host of analogical mappings between the music and movement—it is indeed not surprising that Astaire and Roger's movements are, to all appearances, the living embodiment of Kern's tune. As the music and dance routine continue, however, these mappings become comparatively fewer. Although the sequence of sweeping gesture and recovery

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29. Holyoak and Thagard, *Mental Leaps*, chap. 1; Medin, Goldstone, and Gentner, "Respects for Similarity."

continues against the contrasting material of measures 5–8, the fit seems less apt: the sweeping gesture now serves only to mark the two-measure units of the music, and most of the emphasis seems to be on the quick turns, which match the more animated music. When the fanfare returns in measures 9–12 the dance routine moves into a new phase, with Astaire and Rogers, dancing side by side, describing large circles that fit with the four-measure unit of the fanfare but which otherwise proceed independently from the music.

As noted above, analogical mappings of the sort I have just described reflect correlations—both structural and relational—that appear to be beyond the cognitive capacities of other species: connecting music with movement appears to be a uniquely human activity.[30] Equally important, the knowledge involved in these mappings is not simply abstract. As we observe Astaire and Rogers dance, the part of our own motor cortex that is associated with similar movements becomes active; apart from such activations we can imagine a range of movements which correlate with music, and such simulations could become the basis for a novel choreography; and most, if not all, of this knowledge—extending from patterns of musical sound through the dynamic processes analogized by such patterns to the movements that come to be correlated with such sounds—is non-linguistic. As fascinating as Astaire's choreography is to watch, it is equally fascinating to contemplate the role of human cognitive capacities in the creation and appreciation of such an artful connection of music and movement.

It is to be hoped that a perspective such as this will open up new possibilities for exploring relationships between music and movement. It may also help us to understand the problem of "mickey-mousing,"[31] since the resources of cognitive science offer us a means to study with more precision both the alignment and non-alignment of music and movement. More broadly, thinking in terms of a range of analogical correspondences between music and movement invites the re-examination of any number of historical sources, since such correspondences can extend beyond an account of the specific steps of a given to the social and cultural circumstances under which different sorts of dynamic processes are brought into alignment.

Throughout, my basic assumption has been that there is a relationship between music and movement. My intent is not to insist that, in all cases, such a relationship exists, but only to suggest that to the extent we speak of music *and* movement it is well to keep in mind the cognitive resources that make possible the connection of these two dissimilar media, and the rich expressive possibilities that follow from such a relationship.

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30. Other species can, of course, be trained to move to music—by *humans*. There is, however, scant evidence that other species make connections between patterned sound and movement without human intervention, especially when the movement itself produces little if any sound.

31. Inger Damsholt, "Mark Morris, Mickey Mouse, and Choreomusical Polemic," *The Opera Quarterly* 22, no. 1 (2006): 4–21; Barbara White, "'As If They Didn't Hear the Music,' or: How I Learned to Stop Worrying and Love Mickey Mouse," *The Opera Quarterly* 22, no. 1 (2006): 65–89.