Topics in Cognitive Science (2012) 1–8

ISSN: 1756-8757 print / 1756-8765 online
DOI: 10.1111/j.1756-8765.2012.01225.x

Four Applications of Embodied Cognition

Joshua I. Davis,[a,1] Adam Benforado,[b] Ellen Esrock,[c] Alasdair Turner,[d] Ruth C. Dalton,[e] Leon van Noorden,[f] Marc Leman[f]

[a]*Barnard College of Columbia University*
[b]*Earle Mack School of Law, Drexel University*
[c]*Rensselaer Polytechnic Institute*
[d]*University College London*
[e]*Northumbria University*
[f]*Institute for Psycho-acoustics and Electronic Music – IPEM, Ghent University*

Received 9 May 2012; received in revised form 31 July 2012; accepted 13 August 2012

Abstract

This article presents the views of four sets of authors, each taking concepts of embodied cognition into problem spaces where the new paradigm can be applied. The first considers consequences of embodied cognition on the legal system. The second explores how embodied cognition can change how we interpret and interact with art and literature. The third examines how we move through architectural spaces from an embodied cognition perspective. And the fourth addresses how music cognition is influenced by the approach. Each contribution is brief. They are meant to suggest the potential reach of embodied cognition, increase the visibility of applications, and inspire potential avenues for research.

Keywords: Law; Fairness; Art; Literature; Music cognition; Rhythm; Built environment; Spatial map; Embodied cognition

To help illustrate embodied cognition's potential sphere of influence, and to inspire alternative avenues for research, we provide four brief essays. These four essays suggest ways in which embodied cognition can be applied to law, art and literature, the built architectural environment, and music cognition, respectively.

Correspondence should be sent to Joshua Ian Davis, Barnard College of Columbia University. E-mail: jdavis@barnard.edu

[1]J.I.D. edited and organized the article. The order of other authors reflects the order of the subsections, which is alphabetical by first author's last name.

1. Law and embodiment

1.1. Adam Benforado

Law students are taught that judges and jurors are influenced by the power of arguments: outcomes in court are determined by how successfully each side marshals evidence and applies the relevant legal principles to the facts of the case. Thus, an attorney must appeal to the minds of his audience to win, but can safely ignore their bodies. An embodied cognition approach to law flips this traditional account on its head and asserts that the sensorimotor experiences of legal actors are intimately tied to their abstract thinking. Inside the courtroom, the hardness of the chairs, the brightness of the lighting, the smell of the floor polish, the placement of the jury box, and the weight of files may all affect the proceedings (Benforado, 2010).

Consider a murder trial in which the defense counsel requests a recess after photographs of the bloody crime scene are shown to the jury. During the break, jurors head to the bathrooms, where they use the facilities and then wash their hands. Although conventional dualist legal analysis implies that hand washing is immaterial to a juror's decision-making, an embodied cognition perspective suggests that it might be critical. Moral purity and physical purity are linked (Schnall, Benton, & Harvey, 2008). In one experiment, after watching a disgusting movie clip, participants assessed various moral dilemmas (e.g., keeping money found in a wallet). Half of participants were asked to wash their hands prior to making their judgments and half were not. The simple act of soaping up made a big difference: those who had cleansed themselves after being primed for disgust offered less-severe moral judgments than those who had not.

Even before trial, an embodied cognition perspective on law suggests that bodily experiences at key moments in our judicial processes may subtly bias proceedings and lead to outcomes that do not align with our purported values of fairness and equal treatment (Benforado, 2010). Subtle hand gestures by police officers may encourage eyewitnesses to make erroneous identifications (Broaders & Goldin-Meadow, 2010). And detectives drinking hot coffee, rather than ice water, may assess suspects as more trustworthy and credible during interrogations (Williams & Bargh, 2008).

Future research is needed to investigate the robustness of embodied cognition effects in specifically legal contexts and to understand the impact of interpersonal differences. Only then can we tackle tough questions like whether we should pass new procedural rules barring the imposition of certain sensorimotor experiences or redesign our courtrooms to offer experiences conducive to generosity, trust, and careful consideration. The further development of an embodiment perspective on law is not without costs. Certain individuals and entities—particularly those who can afford high-priced trial consultants—are likely to use insights from the field to manipulate jurors, judges, and others to stack the cards in their favor. Similarly, we must be conscious that in revealing that participants in our judicial system are not rational actors driven by reason alone, embodied cognition research presents a challenge to the legitimacy of our legal institutions and practices.

2. Embodiment in literature and visual art

2.1. Ellen Esrock

Imagine reading a fiction about a seamstress' hand moving through soft fabric or standing in a museum gazing at a painting of a woman embroidering a handkerchief. One might sense a physical tension in the fingers or the tactile quality of the cloth and feel somehow immersed bodily in the work. Here, one would be imitating bodily—though a simulation—what is represented in words or images. Twentieth century scholars paid little attention to such reports, for they regarded the cognitive activity of reading and viewing as fundamentally nonbodily. However, scholarly attitudes are changing under the influence of a broad set of scientific/philosophical theories that characterize cognition as embodied—as inextricably involving bodily processes and being situated in a particular time and space. Body-driven research into literature and the visual arts is now emerging, and it offers insights into more general areas of the sciences.

The experience of having one's bodily boundaries extended, of feeling immersed in literature and art receives attention in Esrock (2001, 2004, 2010, 2012), which proposes the ''transomatization'' as an alternative to simulation accounts of these experiences (Fischer & Zwaan, 2008; Gallese, Fadiga, Fogassi, & Rizzolatti, 1996; Glenberg et al., 2008). In transomatizations, a reader's/viewer's bodily processes serve as a nonimitative (''trans-somatic'') substitute for components of the verbal/visual world. These bodily processes include breathing, muscular tensions, and all over awareness of the internal milieu (interoception), which from some perspectives (Damasio, 1999) constitutes an emotion and carries a sense of selfhood. As illustration of this substitution, a text reads: ''Amy gazes at the rhythmic light beams stroking the floor.'' The reader who forms a transomatization would permit her rhythmic experience of breathing to stand for Amy's perceptual experience of the rhythmic light beams.

Bodily immersion is only one line of investigation into embodied reading/viewing. Keen (2007) investigates empathy in literature, using a model of embodied cognition that considers the emotions as bodily, and this focus on bodily expression informs research like Warhol's (2003) on crying when reading and Freedberg and Gallese (2007) on visual art perception. Such work draws implicitly on theories of language that have become foundational to embodiment studies: those of Lakoff and Johnson (1980, 1999), which hold that our bodily experiences in the world are reflected in metaphors that govern language use and concepts in all domains. This thesis has been the basis for Turner's investigations into the structures of narrative and the development of embodied cognitive architectures (Turner, 1996; Turner & Fauconnier, 2002).

The literary/visual investigations of embodied cognition might be useful to other disciplines by illuminating otherwise unrecognized areas of human thought, emotion, and behavior. This is because these esthetic works are complex constructions that afford especially nuanced experiences of affect and meaning. For example, by studying the processes of interpretation and creation, cognitive scientists might enhance their understanding of how somatosensory (trans-somatic) substitutes can help keep several streams of information

readily available and how even interoceptive awareness and breathing play a role in regulating our cognitive and affective processing of external objects. Furthermore, the methods for teaching embodied subjects how to read and view literature/art might reveal practices for developing cognitive and affective skills in other areas of life.

3. Experiencing the built environment: An embodied approach

3.1. Alasdair Turner and Ruth Conroy Dalton

Imagine visiting a building for the first time. This could be a building that encourages pleasurable exploration, such as a museum or gallery, or your purpose might be commonplace and functional, to a hospital or airport. On crossing the threshold into this novel environment, how do you begin to experience, understand, and structure the available sensory information? Conversely, imagine arriving in a new city: how do you start to construct an internal representation (or cognitive map) of the place? In other words, how is it that we experience the built environment, especially locations characterized by significant spatial complexity (numerous discrete spaces, highly interconnected, with indistinct overall structure, and the whole unperceivable from a single vantage point)?

If we start with a hypothesis that we cognize complex, spatial environments *by moving through them*, then two possible methodological approaches to this question are observing people's patterns of movement and simulative/experimental. In earlier work, Dalton recorded the paths of experiment participants navigating through virtual simulations of complex built environments (Conroy Dalton, 2003) and Turner programmed ''cognitive agents'' to simulate real-world, explorative tasks (Turner, 2007). Both sets of results were validated against pedestrian-movement data drawn from real settings. The resultant paths taken by Dalton's experiment participants and Turner's cognitive agents show a strong preference for straighter rather than meandering routes (even when paths with more changes of direction are of a shorter distance). Furthermore, evidence from spatial cognition/psychology suggests that we form some kind of mental representation of real-world places that, rather than being a literal ''map in the head,'' is a sparse and highly efficient representation of the environment in which certain features such as direct paths between locations, the egocentric angles at which paths cross, and visually salient features along routes and at path intersections (landmarks) are prominent (Golledge, 1999; Siegel & White, 1975).

This, of course, begs the question of why should highly linear routes be so fundamental to our cognition of an environment? Can an embodied cognitive approach explain people's apparent predilection for linearized spatial representations? Turner (2007) argues that this phenomenon *can only arise* from the combination of an embodied agent and its immediate spatial system. In addition, Dalton suggests that the experience of moving through spaces relates to physical characteristics of our bodies: our left–right symmetries, front–back asymmetries, the position of our eyes and associated field of view relative to our direction of gait (2005).

In this section, we proposed the composite theory that when moving through any novel environment, our disposition is to immediately attempt to structure environmental

information to form an internal representation for further use/retrieval and presented our findings that people favor strongly linear routes suggesting that any mental representations might be similarly linearized. This has important consequences for built environment design: first, for architects and urban planners designing complex environments, the knowledge that linear routes are preferred can guide the design process and help to predict resultant pedestrian movement rates; second, when designing physical maps, route guides, or producing verbal directions, the knowledge that straighter routes are cognitively privileged can serve as design guidelines or heuristics.

4. Embodied music cognition

4.1. Leon van Noorden and Marc Leman

Embodied music cognition sees music experience as based on perception and action. For example, many people move when they listen to music and in many cultures there is no clear distinction between music and dance. Through movement, it is assumed that people give meaning to music. This is different from the traditional (disembodied) approach to music cognition, which bases musical meaning on merely perception-based analysis of musical structure. Through measurement of sound, movement, human physiology, and computational modeling, music-embodied cognition is currently building up reliable knowledge about the role of the human body in meaning formation. A general introduction to embodied music cognition is provided by Leman (2007).

Embodied music cognition is potentially applicable to understanding the role of music in other forms of cognition, such as spatial cognition. For example, Leman and Naveda (2010) introduce the concept of spatiotemporal frames of reference, as an alternative to the (traditional) concept of mental representation. Frames of reference provide coordination points for movement in space and time, dependent on biomechanics of the human body. This provides for a new type of gesture analysis, based on topology of movements under spatiotemporal constraints (Godøy & Leman, 2009; Naveda & Leman, 2010).

Furthermore, embodied music cognition is potentially applicable to better understanding the role of music in social interactions. For example, De Bruyn, Moelants, Coussement, and Leman (2009) and De Smet, Leman, Lesaffre, and De Bruyn (2010) show that children move more in synchrony with music when they dance as a group. Of particular importance is the role of a resonant perception–action coupling around 2 Hz. van Noorden and Moelants (1999) have shown that subjective rhythmitization can be explained by this resonance. Styns, van Noorden, Moelants, and Leman (2007) have shown that changes in walking behavior happen close to 2 Hz. And, children 3- and 4-years old can synchronize only in the neighborhood of 2 Hz. By contrast, from 5 years on, they can synchronize gradually in a wider range of tempi. It is as if older children learn to put brakes on the resonator. This enables them to synchronize in a range from a bit faster to more extensively slower tempi (e.g., Drake, Jones, & Baruch, 2000). In addition, it may be that rocking babies at 2 Hz is the most effective frequency for putting them to sleep (Ter Vrugt & Pederson, 1973).

Embodied music cognition has a strong connection with technology development, which has extended its role within spatial and social cognition, and beyond. Mediation technology can give the human body, and the human mind, an extension in the digital musical domain. An example is DJogger (Moens, van Noorden, & Leman, 2010), which provides music at exactly the tempo of your walking or running. Another example is the ''Sync-in-team'' game (Leman, Demey, Lesaffre, van Noorden, & Moelants, 2009), which applies synchronization and entrainment in a social music interaction game. The embodied music cognition approach starts getting a tremendous impact in the field of interactive multimedia (Correia Da Silva Diniz et al., 2010; Deweppe, Lesaffre, & Leman, 2009), where natural (embodied) mappings between human gestures and control parameters of the system (Maes, Leman, Lesaffre, Demey, & Moelants, 2010) are essential for the experience of presence and flow (Nijs, Coussement, Müller, Lesaffre, & Leman, 2010).

In contrast with traditional music cognition, embodied music cognition might change how music is understood. Rather than focusing on perception, the embodied approach focuses on the tight coupling between perception and action in meaning formation. It considers how the biomechanics of the human body contributes to cognition, and provides a new way of addressing emotions, through movement. This approach also allows the development of models of social cognition, which link with recent neuroscience work (Leman, 2007), using concepts of movement and emotion synchronicity or entrainment.

Acknowledgment

This work was partially supported by National Science Foundation grant BCS – 1002595 (to J.I.D.).

References

Benforado, A. (2010). The body of the mind: Embodied cognition, law, and justice. *Saint Louis University Law Journal*, *54*, 1185–1216.

Broaders, S., & Goldin-Meadow, S. (2010). Truth is at hand: How gesture adds information during investigative interviews. *Psychological Science*, *21*, 623–628.

Conroy Dalton, R. (2003). The secret is to follow your nose: Route path selection and angularity. *Environment and Behavior*, *35*(1), 107–131.

Conroy Dalton, R. (2005). Space syntax and spatial cognition. *World Architecture: Space Syntax Monograph*, *11*(185), 41–45.

Damasio, A. R. (1999). *The feeling of what happens: Body and emotion in the making of consciousness*. New York: Harcourt Brace & Company.

De Bruyn, L., Moelants, D., Coussement, P., & Leman, M. (2009). *An interactive sound recognition game for primary school children*. Paper presented at the MERYC2009: 4th Conference of the European Network of Music Educators and Researchers of Young Children. ???????.

De Smet, F., Leman, M., Lesaffre, M., & De Bruyn, L. (2010). *Statistical analysis of human body movement and group interactions in response to music*. In ??? ??? (Ed.), *Advances in data analysis, data handling and business intelligence* pp. (399–408). ????????: Springer-Verlag.

Deweppe, A., Lesaffre, M., & Leman, M. (2009). *Discerning user profiles and establishing usability for interactive music applications that use embodied mediation technology*. Paper presented at the Triennial conference of the European Society for the Cognitive Sciences of Music Conference, 7th, Proceedings. ?????????. 7

Drake, C., Jones, M. R., & Baruch, C. (2000). The development of rhythmic attending in auditory sequences: Attunement, referent period, focal attending. *Cognition*, *77*, 251–288.

Esrock, E. (2001). Touching art: Intimacy, embodiment, and the somatosensory system. *Consciousness and Emotion*, *2*(2), 233–254.

Esrock, E. (2004). Embodying literature. *Journal of Consciousness Studies*, *11*, 79–89.

Esrock, E. (2010). Embodying art: The spectator and the inner body. *Poetics Today*, *31*(2), 217–250.

Esrock, E. (forthcoming 2012). The phantasmagoria of everyday life: The visceral-somatic viewer of Hiroshi Sugimoto and Adolph Menzel's art. In S. Anker & S. Flach (Eds.), *Embodied fantasies. from Awe to Artifice* (pp. ???–???). Berlin: Peter Lang Publishers. 8

Fischer, M. H., & Zwaan, R. A. (2008). Embodied language: A review of the role of the motor system in language comprehension. *The Quarterly Journal of Experimental Psychology*, *61*(6), 825–850.

Freedberg, D., & Gallese, V. (2007). Motion, emotion and empathy in aesthetic experience. *Trends in Cognitive Science*, *11*(5), 197–203.

Gallese, V., Fadiga, L., Fogassi, L., & Rizzolatti, G. (1996). Action recognition in the premotor cortex. *Brain*, *119*, 593–609.

Glenberg, A. M., Sato, M., Cattaneo, L., Riggio, L., Palumbo, D., & Buccino, G. (2008). Processing abstract language modulates motor system activity. *The Quarterly Journal of Experimental Psychology*, *61*(6), 905–919.

Godøy, R. I., & Leman, M. (Eds.). (2009). *Musical gestures: Sound, movement, and meaning*. New York, NY: Routledge.

Golledge, R. G. (1999). Human wayfinding and cognitive maps. In R. G. Golledge (Ed.), *Wayfinding behavior: Cognitive mapping and other spatial processes* (pp. 5–45). Baltimore: Johns Hopkins University Press.

Keen, S. (2007). *Empathy and the novel*. New York: Oxford University Press.

Lakoff, G., & Johnson, M. (1980). *The metaphors we live by*. Chicago: The University of Chicago Press.

Lakoff, G., & Johnson, M. (1999). *Philosophy in the flesh: The embodied mind and its challenge to Western thought*. New York: Basic Books.

Leman, M. (2007). *Embodied music cognition and mediation technology*. Cambridge, MA: The MIT Press.

Leman, M., Demey, M., Lesaffre, M., van Noorden, L., & Moelants, D. (2009). *Concepts, technology and assessment of the social music game 'sync-in-team'*. Paper presented at the Proceedings of the 2009 International Conference on Computational Science and Engineering. ???????. 9

Leman, M., & Naveda, L. (2010). Basic gestures as spatiotemporal reference frames for repetitive dance/music patterns in Samba and Charleston. *Music Perception*, *28*(1), 71–91.

Maes, P.-J., Leman, M., Lesaffre, M., Demey, M., & Moelants, D. (2010). From expressive gesture to sound: The development of an embodied mapping trajectory inside a musical interface. *Journal on Multimodal User Interfaces*, *3*(1-2), 67–78.

Moens, B., van Noorden, L., & Leman, M. (2010). D-Jogger: Syncing music with walking. *Proceedings of SMC Conference*, *2010*, 451–456.

Naveda, L., & Leman, M. (2010). The spatiotemporal representation of dance and music gestures using topological gesture analysis (TGA). *Music Perception*, *28*(1), 93–111.

Nijs, L., Coussement, P., Müller, C., Lesaffre, M., & Leman, M. (2010). The music paint machine: A multimodal interactive platform to stimulate musical creativity in instrumental practice. *Proceedings of the Computer Supported Education, 2nd International Conference*. ?????????. 10

van Noorden, L., & Moelants, D. (1999). Resonance in the perception of musical pulse. *Journal of New Music Research*, *28*(1), 43–66.

Schnall, S., Benton, J., & Harvey, S. (2008). With a clean conscience: Cleanliness reduces the severity of moral judgments. *Psychological Science*, *19*, 1219–1222.

Siegel, A. W., & White, S. H. (1975). The development of spatial representations of large-scale environments. In H. W. Reese (Ed.), *Advances in child development and behavior* (Vol. 10, pp. 9–55). New York: Academic Press.

Styns, F., van Noorden, L., Moelants, D., & Leman, M. (2007). Walking on music. *Human Movement Science*, *26*(5), 769–785.

Ter Vrugt, D., & Pederson, D. R. (1973). The effects of vertical rocking frequencies on the arousal level in two-month-old infants. *Child Development*, *44*(1), 205–209.

Turner, M. (1996). *The literary mind*. Oxford: Oxford University Press.

Turner, A. (2007). The ingredients of an exosomatic cognitive map: Isovists, agents and axial lines? In C. Hölscher, R. C. Dalton & A. Turner (Eds.), *Space syntax and spatial cognition: Proceedings of the workshop held in Bremen, 24th September 2006* (pp. 163–180). Bremen, Germany: Universität Bremen.

Turner, M., & Fauconnier, G. (2002). *The way we think: Conceptual blending and the mind's hidden complexities*. New York: Basic Books.

Warhol, R. R. (2003). *Having a good cry: Effeminate feelings and pop-culture forms*. Columbus: Ohio State University Press.

Williams, L. E., & Bargh, J. A. (2008). Experiencing physical warmth promotes interpersonal warmth. *Science*, *322*, 606–607.

Author Query Form

Journal: TOPS

Article: 1225

Dear Author,
During the copy-editing of your paper, the following queries arose. Please respond to these by marking up your proofs with the necessary changes/additions. Please write your answers on the query sheet if there is insufficient space on the page proofs. Please write clearly and follow the conventions shown on the attached corrections sheet. If returning the proof by fax do not write too close to the paper's edge. Please remember that illegible mark-ups may delay publication.

Many thanks for your assistance.

Query reference	Query	Remarks
Q1	**AUTHOR: Please provide full address details for this corresponding author.**	
Q2	**AUTHOR: An embodied.....thinking. Would it be appropriate to introduce an adjectival hyphen between 'embodied' and 'cognition' in instances such as 'embodied cognition approach', 'embodied cognition perspective' etc? Please check in all such occurrences.**	
Q3	**AUTHOR: Correia Da Silva Diniz et al., 2010 has not been included in the Reference List, please supply full publication details.**	
Q4	**AUTHOR: Conroy Dalton (2005) has not been cited in the text. Please indicate where it should be cited; or delete from the Reference List.**	
Q5	**AUTHOR: Please provide date, month and location for the conference for reference De Bruyn et al. (2009).**	
Q6	**AUTHOR: Please provide editor names and city location of publisher for reference De Smet et al. (2010).**	

Q7	**AUTHOR: Please provide date, month and location for the conference for reference Deweppe et al. (2009).**	
Q8	**AUTHOR: Please provide page range for reference Esrock (2012).**	
Q9	**AUTHOR: Please provide date, month and location for the conference for reference Leman et al. (2009).**	
Q10	**AUTHOR: Please provide date, month and location for the conference for reference Nijs et al. (2010).**	

Proof Correction Marks

Please correct and return your proofs using the proof correction marks below. For a more detailed look at using these marks please reference the most recent edition of The Chicago Manual of Style and visit them on the Web at: http://www.chicagomanualofstyle.org/home.html

Instruction to typesetter	*Textual mark*	*Marginal mark*
Leave unchanged	under matter to remain	stet
Insert in text the matter indicated in the margin	∧	∧ followed by new matter
Delete	through single character, rule or underline or through all characters to be deleted	
Substitute character or substitute part of one or more word(s)	through letter or through characters	new character or new characters
Change to italics	under matter to be changed	ital
Change to capitals	under matter to be changed	caps
Change to small capitals	under matter to be changed	sc
Change to bold type	under matter to be changed	bf
Change to bold italic	under matter to be changed	bf+ital
Change to lower case		lc
Insert superscript	∨	∨ under character e.g. ∨
Insert subscript	∧	∧ over character e.g. ∧
Insert full stop	⊙	⊙
Insert comma		
Insert single quotation marks		
Insert double quotation marks		
Insert hyphen		
Start new paragraph		
Transpose		
Close up	linking characters	
Insert or substitute space between characters or words	#	#
Reduce space between characters or words		