



Body, mind, and how to figure all that out

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“The body influences the way we think”; “The mind is embodied”; “Thoughts that we can produce ultimately have their foundation in our embodiment”. For many years I have been working – as a cognitive scientist interested in abstraction and conceptual systems – with such views of thought and mind. I have been involved in many projects investigating children’s thinking, abstract concepts in indigenous people from West Africa and the Andes, and mathematicians teaching and solving problems. So far, what I have seen and read seems to support the view that thought and mind are indeed very much embodied. The statements above, however, are not quotes from the usual literature I encountered in psychology, linguistics, or neuroscience. Rather, they are from documents produced at a lab that for two decades has been investigating robots! That’s right, Rolf Pfeifer’s AI Lab at the University of Zurich.

It was more than a decade ago or so, that I started to learn about the views on embodiment at the AI Lab in Zurich. By then I had finished my graduate work in Switzerland and I was heading to Berkeley and Stanford for post-doc appointments where I would be learning about fascinating new foundations for the study of mind and body, of cognition and flesh, behavior and matter. I was especially interested in understanding the nature of human abstraction, in comprehending how we systematize knowledge of domains that transcend immediate sensory experience. And in particular, I was intrigued by the question of the nature of mathematics: What makes that amazingly clear, rigorous, abstract, and objective human body of knowledge possible? What is an infinitesimal or imaginary number, if – by definition – we cannot experience them? What mechanisms allow us to create them in such a precise, efficient, and productive way? It turned out that part of the answer came from the investigation of human everyday cognitive embodied mechanisms that make imagination possible, such as metaphor, analogy, metonymy, and so on. Indeed, we systematically conceive emotion, for instance, in terms of thermic bodily experience (which shows up in expressions like “he is a cold person” or “send her my warm hellos”) or temporal entities as being spatial in nature (as in “He left his past behind” or “she has a promising future in front of her”). And in order to create mathematics, we build on these very mechanisms, conceiving numbers as locations in space (which is the basis for the number-line, giving the meaning to expressions like “pi is between 3.1 and 3.2”), sets as containers (as in “a is in B”), and actual infinite entities such as transfinite numbers as non-finite yet complete entities. During those years, along with Berkeley linguist and cognitive scientist George Lakoff, we investigated in detail many areas of mathematics, from basic arithmetic to infinitesimal calculus to abstract algebra to hyperset theory to transfinite cardinals, most of the time finding the same grounding: human everyday bodily experience extended via specific mechanisms such as conceptual metaphor to give rise to imaginary entities. Many of these results appeared in a book published in 2000 entitled *Where Mathematics Comes From: How the Embodied Mind Brings Mathematics into Being*. The moral was that the

body does influence the way we think! Our thoughts and concepts are ultimately realized through our embodiment. Thus, we can think of the future as being in front of us, or the past behind us, because we have a body that has a front and a back. Morphology does matter! Had we had blobish jellyfish-like body we couldn't have possibly conceived time in such a way. Moreover, in those years, I was starting to work with the Aymara people of the South American Andes, and via the study of their psycho-linguistic and gesture production I would also realize that depending on the bodily properties picked from front-back relationships entire communities of human beings – with the same human bodies – could have entirely different conceptions of time. Indeed, unlike most cultures around the world studied so far, we found that Aymara people conceive the future as being behind them and the past as being in front of them! These Aymara concepts are deeply grounded on human morphology that has frontal binocular vision: what is seen, and therefore known (like past events) lie in front of the observer, and what is behind them, outside of the visual field is not perceivable, not known (like future events). But, ultimately, Aymara or not, temporal entities like future and past are conceived as spatial ones in bodily related terms. Thought, mind, and cognition are thus genuinely embodied.

Towards the end of the 90s, in one of my trips to Switzerland, I decided to contact Rolf. I e-mailed him basically saying “I'm interested in embodiment, too. My work also shows that the body influences the way we think.” He immediately invited me to give a talk at his lab in Zurich. It would be the first, of a long series of conversations and exchanges over more than a decade. Throughout these years I have had the chance to visit their truly interdisciplinary lab at several occasions, meet the collaborators, understand their methodologies, their theoretical assumptions, the underlying philosophical principles, the engineering problems. I would have a chance to share with them my (more high-level and top-down-ish) problems and questions, get feedback from them, and learn from them the subtleties and intricacies of more bottom-up-ish methods (not always simple matters to deal with!) And I would meet with Rolf and several of his collaborators in many places and conferences in Europe, always finding refreshing thoughts and intriguing problems to discuss. As a cognitive scientist interested in conceptual abstraction, one of the most beautiful lessons I have learned from the AI lab has been to grasp how deeply morphology and material properties of bodies shape minds, and how important it is to encompass approaches that allow understanding through actual building. I hope that such insights and research programs enrich our lives for many years to come!