Abstract

Embodied cognition considers that human cognition is fundamentally grounded in sensory-motor processes and in our body's morphology and internal states. In this paper, we discuss some of the features of this post-cognitivist approach and the challenges that follow for psychology and education. These challenges point to the need to reconsider cognition and the way we pursue education today. If we want to have an efficient educational system we have to look at fundamental research in cognitive science to have an accurate description of what cognition is. Only then can we design optimal educational settings for the development of thinking.

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1. Introduction

Cognition and education are definitely connected: we want to educate people to be able to better solve the problems they face. In order to achieve this goal we have to understand what cognition is and this is exactly one of the problems that psychology faces today: we witness the rise of post-cognitive approaches that question the very nature of cognition as the traditional cognitivism viewed it (Gomila, & Calvo, 2008).

Cognition is not considered amodal and fundamentally different from perceiving and acting anymore (L. B. Smith, & Sheya, 2010). Instead cognition is seen as being dependent on the body (i.e., sensory-motor systems, action, emotions and body's morphology) and on context (Barsalou, 2008a; Clark, 2011; Ionescu, 2011; Laakso, 2011; Schubert, & Semin, 2009; Stapleton, 2013). One of the main post-cognitivist approaches that supports and articulates this view is the embodied cognition approach. This approach considers the body as the main actor, and as
such, as a key factor in shaping our cognition. In other words, cognition is at any time influenced by the morphology of our bodies and by its sensory-motor systems (Glenberg, 2008a).

This new theoretical approach poses several challenges to both psychology and education. First, in psychology, embodiment may change the way we conceive cognition itself. In other words, when speaking about cognition we may have to go beyond cognitive processes and knowledge to include sensory-motor processes, action, emotions, and interoception in order to accurately describe cognition. Second, if embodiment reflects the way we process and store information, then education will have to change its methods for both children and adults: it may well be that we will have to rely on the concrete at older ages too instead of using more and more abstract ways of teaching (e.g., providing only verbal descriptions of the taught content).

The present article aims to discuss the challenges that embodied cognition raises for psychology and education, with a focus on the role of sensory-motor processes for cognition. Its structure is as follows: first, we will briefly present the embodied cognition approach. Then we will analyze the challenges faced by psychology and education in view of embodiment. We will end with conclusions and some open questions.

2. Embodied cognition

In traditional cognitivism, cognition is all about thinking and very different from sensing and acting (Barsalou, Breezeal, & Smith, 2007). In essence, cognition was seen as symbolic processing (Bickhard, 2008; Pylyshyn, 1980). One of the most important aspects of the human cognitive system is the ability to represent things, and moreover to have abstract representations. But the traditional view failed so far to explain how this ability arises in the developing cognitive system, and how and where abstract representations are implemented in the brain (Barsalou, 2008a, 2008b; Gallese, & Lakoff, 2005). Also, we do not know yet how do symbols get their meaning, and this is known as the symbol grounding problem (Harnad, 1990). Considering the cognitive system a purely symbolic one makes it difficult to pinpoint its specific mechanisms and their precise locations in the brain, and to understand its connection to the real world.

An accruing body of evidence supports a different view: an embodied view of cognition (Barsalou, Simmons, Barbey, & C. D. Wilson, 2003; Clark, 2011; Crollen, Dormal, Seron, Lepore, & Collignon, 2013; Maouene, & Ionescu, 2011; Riegler, 2002; Schubert, & Semin, 2009; M. Wilson, 2002). Data on numerical cognition (Crollen et al., 2013), conceptual knowledge (Barsalou et al., 2003; Boncoddo, Dixon, & Kelley, 2010; Borghi, Glenberg, & Kaschak, 2004; Vankov, & Kokinov, 2013), learning mathematics (Goldin-Meadow, & Singer, 2003; Goldin-Meadow, Wagner Cook, & Mitchell, 2009; Wagner Cook, 2011), language comprehension (Glenberg, Sato, Cattaneo, Riggio, Palumbo, & Buccino, 2008), language learning (Maouene, Sethuraman, Laakso, & Maouene, 2011), and cognitive development (L. B. Smith, 2009) show that the cognitive system is highly dependent on sensory-motor processes in a way that makes the latter ones an intrinsic part of higher level cognition. As a consequence, sensing and acting should be considered as parts of thinking itself.

The main features of the embodied cognition approach can be summarized in two general statements: (1) cognition is not abstract and amodal - in other words, representations are multimodal and thus fundamentally grounded in the sensorial modalities of the brain and in our actions (Barsalou, 2003, 2008a, 2008b; Boncoddo et al., 2010; Glenberg et al., 2008); (2) cognition is not just about thinking - in other words, if we recognize the important role of perceiving and acting for cognition, than we have to include the non-cognitive in the very definition of cognition (Barsalou et al., 2007; L. B. Smith, & Sheya, 2010). Emotions and affective processes are also an important contributor to cognition (Glenberg, 2008; Stapleton, 2013). As a consequence, our understanding of thinking will have to go beyond information processing in the symbolic sense. If these claims will prove to be true for all cognitive processing (e.g., for abstract concepts like freedom too, see for example Boroditsky & Prinz, 2008 and M. Wilson, 2008, for raising this issue) then cognitive psychology as we know it today and education as we practice it today will face important challenges.

3. Challenges for psychology and education in view of embodiment

We can group the challenges that result from an embodied perspective in two main ones. The first challenge (Challenge 1) concerns psychology: the definition of cognition should include non-cognitive processes too. This
challenge questions the purely symbolic nature of cognition. Several lines of research from neuroscience, robotics, cognitive psychology, and developmental psychology offer support for this idea. We will illustrate here with research on representations and on gesture’s role in learning new concepts.

The symbols that are processed by the human cognitive system have long been assumed to be amodal representations, but a large body of empirical data argues today that this assumption is problematic (Barsalou, 2010; E. E. Smith, & Kosslyn, 2007). If representations are amodal, they should be implemented in a specific area in the brain, different from the sensorial modalities through which they entered the cognitive system (Kiefer, & Trumpp, 2012). Researchers find that the implementation of our representations in the brain is not separate from its sensory-motor systems. Instead, representations seem to be mental simulations of the initial state the body had when learning about those objects or situations, and they are also related to the actions they afford (Barsalou, 2003, 2008b; Borghi, Glenberg, & Kaschak, 2004; Glenberg et al., 2008). In a study using transcranial magnetic stimulation (TMS) and the motor evoked potential (MEP) caused by TMS (Glenberg et al., 2008, experiment 2), subjects had to read the following types of sentences: nonsense sentences, and transfer (e.g., transfer toward the reader: carries the pizza to you, or away from the reader: you carry the pizza to... or no-transfer sentences (e.g., you smell the pizza with...), and to judge if these were sensible or non-sense sentences. Half of the sentences were referring to concrete objects and half to abstract objects (e.g., presents the argument to you). The TMS pulse was delivered either after the presentation of the verb, or after the sentence ended, and the MEPs were recorded from a muscle of the hand. The authors found that MEPs were greater in the case of transfer sentences, and that there was little evidence for differences among concrete and abstract sentences. These results support the idea that language comprehension activates motor areas of the brain (Glenberg et al., 2008). What’s more important is that this activation was seen for abstract sentences too. As a consequence, action schemas (i.e., embodied mechanisms) can be considered an integral part of understanding language about transfer (Glenberg et al., 2008). In other words, the representation of the concept of transfer is grounded in the motor systems of the brain.

Gesture studies demonstrate the role of our hand movements in solving, or learning how to solve, different types of tasks. Let’s take for example the spontaneous gestures schoolchildren produce while they explain how they solved an equivalence problem (i.e., $a + b + c = \_ + c$). One type of gesture commonly observed is grouping the terms “$a$” and “$b$” with the index and middle finger, and then pointing to the blank space. This gesture reflects the most efficient strategy for solving this exercise, but often children who gesture like this solve the problem incorrectly, and offer an incorrect verbal explanation as they gesture (e.g., I added all of them up, Broaders, Cook, Mitchell, & Goldin-Meadow, 2007). This mismatch between a child’s gestures and verbal explanations indicates that he/she will benefit and learn more from a lesson, compared to a child that also solves this problem incorrectly, but offers matching (and incorrect) verbal and gestural explanations (Broaders et al., 2007). Gestures can reveal the implicit knowledge that a child cannot yet verbally articulate or use to solve the problem. So, if we take into consideration their gestures, we can have a more complete image about their progress in learning (Goldin-Meadow & Wagner, 2005). Also, encouraging children to gesture, or even to imitate a “correct” gestural grouping of the equation elements, helps them to discover new strategies (Goldin-Meadow & Wagner, 2005; Broaders et al., 2007; Goldin-Meadow, Cook, & Mitchell, 2009). All in all, these studies demonstrate that gesture is correlated with and facilitates children’s learning in this kind of task. The same benefit was observed in children’s learning a variety of new concepts (Goldin-Meadow, 2006), and this suggests that, by using gestures and encouraging children to gesture, learning in different cognitive domains is facilitated.

Concluding Challenge 1, we agree that, as L. B. Smith and Sheya (2010) puts it, the cognitive system might be in fact a complex system of non-cognitive processes operating in real time. What this means is that for a complete understanding of what cognition is we will need to look at it only in interaction with perception and action. Although we did not present in this short paper evidence for the role of affect, social interaction, context effects, and development for cognition, we may have to include all of these too in the description of cognition (Barsalou et al., 2007).

The second challenge (Challenge 2) concerns education and points to the need to move from abstract teaching and learning to grounded teaching and learning. This challenge is more speculative, because there are few educational interventions designed after the principles of embodied cognition so far (see for instance Glenberg, 2008b). Nevertheless, if we take into consideration the above mentioned evidence and accept a new view of cognition, then the way in which we educate children and adults should change radically. To take a simple example,
if spatial proximity influences the correct order of mathematical operations in adults (Landy & Goldstone, 2007) then we should pay attention to perceptual aspects when we teach mathematics, an area previously taken as paradigmatic for abstract thinking (Nunez, 2008). In an elegant review of research on embodiment in different cognitive domains, Kiefer and Trumpp (2012) show that reading is also embodied. The writing techniques we use affect reading performance, because of the activation of the motor programs and sensory experiences of writing during reading. As a consequence, people who use handwriting have better letter recognition in a reading test than those who use typewriting. This supports the claim that meaningful sensory-motor experiences result in "stronger sensory-motor memory traces that facilitate learning" (Kiefer, & Trumpp, 2012, p. 16).

There are studies that show benefits for learning when other types of active bodily movements are involved. Cook, Mitchell, and Goldin-Meadow (2008) requested children to mimic the experimenter’s gestures when receiving instructions about how to solve equivalence problems. They found that these children solved more problems correctly at a follow up test one month later, compared to a group of children that only mimicked the experimenter’s verbal strategy. This suggests that gesturing while learning aids in maintaining knowledge in long term memory. Kontra, Goldin-Meadow and Beilock (2012) found a benefit of action experience in learning a Physics concept. Participants (undergraduate students) that actually performed a relevant action for understanding that concept had a better performance at posttest, compared to participants who just passively observed the same action.

Concluding Challenge 2, contemporary education uses concrete teaching with young children, based on the Piagetian theory of cognitive development; going beyond Piaget, we argue that we should continue to use this kind of teaching with older children and adults too. Complex thinking is sense-based and higher level cognition needs "appropriate sensory-motor experiences" to develop (Kiefer, & Trumpp, 2012, p. 19). As a consequence, education needs to change its methods of teaching if it wants to have well-educated people, namely more individuals who really understand and rely on abstract and complex ideas. It is possible that the abstract ways of teaching (i.e., knowledge not grounded in direct experience) offer fewer chances for learners at any age to thoroughly comprehend concepts, to transfer the learned content, and to maintain this content longer in their memory.

4. Conclusions and further questions

The present paper summarized one of the main post-cognitive approaches, the embodied cognition approach, and discussed the important challenges that follow from this for both psychology and education. The critical analysis of these challenges is important because of the theoretical and practical implications they have: at a theoretical level, embodied cognition could bring us closer to a complete understanding of what cognition is; at a practical level, embodiment may lead to more individuals who are well educated and can use the knowledge they learned in school in real life settings.

Embodiment itself faces some challenges too. For example, will it properly explain abstract cognitive content too (Wilson, 2008)? Will this approach become mainstream cognitive science as some already argue (Laakso, 2011)? We do not have answers for these questions yet and we are aware of the need for sound empirical tests to verify the claims of embodiment. Nevertheless embodiment has begun to change the way we conceive cognition in cognitive science today, and this is the reason for the need to think about changing education too.

It seems plausible that ontogenetically, we do not simply move from concrete to abstract thinking, in other words that we do not leave the concrete thinking behind in the way that the Piagetian theory proposed (Piaget, 1945). Instead maybe we learn to use the concrete more efficiently and at an implicit level. Piaget was the first to point out the important role of the sensory-motor processes for the development of intelligence; on the other hand, it was also him who considered abstract thinking together with abandoning the sensory-motor processes and concrete thinking as the major goal in the development of reasoning (Schaffer, 2004). This focus on abstract thinking and abstract contents in education may have led to the difficulties many individuals face when being in school settings. We can speculate that our “feeling” of abstractness regarding our cognition may reveal in fact a better neural integration of concrete processing, overlearned sensory-motor patterns, or a better reading of contextual cues. If this will prove to be the case, then education will have to change its focus to adjust teaching to the way people really think.
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