The Role of Theories of Embodied Cognition in Research and Modeling of Emotions

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Abstract

The article analyzes the role of theories of embodied cognition for the development of emotion research. The role and position of emotions changed as philosophy developed. In classical and modern European philosophy, the idea of the "primacy of reason" prevailed over emotions and physicality, emotions and affective life were described as low-ranking phenomena regarding cognitive processes or were completely eliminated as an unknown quantity. In postmodern philosophy, attention focuses on physicality and sensuality, which are rated higher than rational principle, mind and intelligence. Within the framework of this approach, there is a recently emerged theory of embodied cognition, which allows to take a fresh look at the place of emotions in the architecture of mental processes – thinking, perception, memory, imagination, speech. The article describes and analyzes a number of empirical studies showing the impossibility of excluding emotional processes and the significance of their research for understanding the architecture of embodied cognition. However, the features of the architecture of embodied cognition remain unclear, and some of the discoveries of recent years (mirror neurons or neurons of simulation) rather raise new questions and require further research. The rigorously described and clear architecture of the embodied cognition can grow the theoretical basis that will allow to advance the studies of learning processes, language understanding, psychotherapy techniques, social attitudes and stereotypes, highlight the riddle of consciousness and create new theories of consciousness or even create an anthropomorphic artificial intelligence that is close to "strong artificial intelligence."

Keywords: theory of embodied cognition, simulation theory, theory theory, mirror neurons, neurons of simulation, emotions, modeling of emotions.

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Роль теорий воплощенного познания в исследованиях и моделировании эмоций

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Аннотация

В статье анализируется роль теорий воплощенного познания для развития исследований эмоций. Отношение к эмоциям менялось по мере развития философии – в классической и новоевропейской философии господствовала идея «примата разума» над чувствами и телесностью, эмоции и аффективная жизнь описывались как низкоранговые феномены относительно когнитивных процессов или вовсе элиминировались как неизвестная величина. В современной постмодернистской философии внимание, напротив, акцентируется на телесности и чувственности, ценящихся выше рационального начала, разума и мышления. В рамках такого подхода существует недавно возникшая теория воплощенного познания, которая позволяет по-новому взглянуть на место эмоций в архитектуре психических процессов: мышления, восприятия, памяти, воображения, речи. В статье описан и проанализирован ряд эмпирических исследований, показывающих невозможность исключения эмоциональных процессов и значимость их изучения для понимания архитектуры воплощенного познания. Однако особенности архитектуры воплощенного познания остаются неясными, а открытия последних лет – зеркальные нейроны или нейроны симуляции – скорее вызывают все новые вопросы и требуют дальнейших исследований. При этом необходимо помнить, что строго описанная и ясная архитектура воплощенного познания может стать той теоретической основой, которая позволит создать теорию, способную продвинуть изучение процессов обучения, понимания языка, техник психотерапии, социальных установок и стереотипов, осветить загадку возникновения сознания и создать новые теории сознания или даже создать антропоморфный искусственный интеллект в понимании программы «сильного искусственного интеллекта».

Ключевые слова: теория воплощенного познания, теория симуляции, теория теорий, зеркальные нейроны, нейроны симуляции, эмоции, моделирование эмоций.

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Introduction

Recently emerged theory of embodied cognition allows us to take a fresh look at the processing of emotional information. Studies show that reasoning of emotions include perceptual (associated with multimodal perception of emotions), somatovisceral (associated with the somatovisceral nervous system, which includes a skin analyzer, proprioceptive analyzer and visceral analyzer) and motor (associated with motor memory) components of the experience (collectively called "embodiment") of suitable emotions by the subject of perception.

The embodiment of emotions that are caused in the laboratory by changes in facial expressions and posture shows their connection with the processing of emotional information. The congruence between the bodily expression of the emotions of the "recipient" and the emotional tone of the language of the "subject-source" also promotes understanding and communication, while the discrepancy may violate understanding.

Studies show that the posture and overall emotional state of a person affects the perception of different kinds of information. People, who were told good news while sitting with their backs straight and in a assembled pose, reacted more positively to their success, than those subjects, who were told good news, when they sat bent over and relaxed [Stepper & Strack 1993]. In another experiment the subjects were presented with pictures that cause positive and negative emotions. Two groups of subjects received different instructions: one group had to pull the joystick on itself at each appearance of an incentive, and another – to push the joystick from itself. In the first group the rate

of reaction to positive stimuli was higher, and in the second group, on the contrary, the rate of reaction was higher to negative stimuli [Duckworth et al. 2002].

These experiments demonstrate that there is a direct link between the bodily expression of emotions and perceiving and interpretation of emotional information. Darwin also defined an attitude (predisposition of the subject to a certain social behavior) as a set of movements (mainly poses) that accompany the emotional response of the body to the object [Darwin et al. 1998]. Therefore, it assumes that he would not be surprised that the body is involved in receiving and using social attitudes and preferences. The following modern scientific data are in agreement with Darwin's ideas: 1) when people take postures that are characteristic for certain emotions, they begin to experience these emotions; 2) when people use facial expressions or emotional gestures, it affects their preferences and attitudes; 3) when people are encouraged to make movements, there is interference of motor activity in the experience of emotions and the processing of emotional information [Niedenthal et al. 2005]. Studies of the causal relationship between the embodiment and experience of emotions as well as the emergence and use of information about emotional states are the main object of interest in different areas of psychology, neuroscience and cognitive sciences in general.

Emotions and theory of embodied cognition

Studies of complex models of emotional information processing are only developing at present. Previously such models have received little attention, which is an omission, because emotional information determines the focus of human attention [Ohman et al. 2001], the availability of the meanings of words, principles of organization of data keeping in memory [Nygaard & Lunders 2002; Niedenthal et al. 1999]. For many scientists, the work with emotions as a field of research was extremely difficult.

To overcome these difficulties, a number of scientists have found a way out – to put emotions outside the models, that is, to refuse to study them. In the classical models of information processing, which arose in the bosom of cognitive sciences, the motor, sensory and emotional experience is described as devoid of empirical and perceptual basis. In the models implementing the metaphor of "brain as a computer," the information obtained from different modalities is presented in memory symbolically. Information is stored in a way that is function-

ally separate from the nervous system, which originally encodes this information, although the nervous system itself is involved in the processes of perception in separate modalities [Fodor 1975; Newell 1980; Barsalou 1999; Barsalou 2003]. Such models of information processing replace information about emotions with equivalent information about other processes that occur simultaneously or in parallel with emotional processes. These models do not take into account the priority and role of emotions in the processing of information. It turns out that affective, sensory and motor systems are not required for thinking or using language, which is not consistent with modern data.

But there is another approach to the study of information processing, which can be called holistic approach and combines different concepts under the title "theory of embodied cognition." This approach is based on modern data and technological innovations, but it is based at the same time on a well-known idea [Prinz 2002]. This idea is that high-level cognitive processes (such as thinking) use partial reactivation of states of other systems, namely affective, sensory and motor systems [Wilson 2002]. In other words, there is something that is in the basis of the knowledge about the object that are the primary states of the nervous system that appear at the moment when the information has just been received. If this position reflects real processes, then the use of information is partially similar to the experience of past practices enriched by information from different modalities. The hypothesis is that the brain "snatches out" the characteristics of the modalities, compares them with the characteristics stored in memory and, in case of coincidence, memory mechanisms are triggered, and the subject receives knowledge related to similar situations from past experience.

The theories of embodied cognition are now used to provide precise evaluation of emotions and to process information relating to emotions [Niedenthal & Barsalou 2005; Damasio 1994]. With their help, it was revealed that the experience of emotions, perception of emotional stimuli and the restoration of emotions in memory include many overlapping processes. Perception of an emotional stimulus, such as a roaring tiger, includes, among other things, visual and auditory perception and the conscious sense of fear of the tiger. Together, nervous, bodily and subjective experiences can be called "fear" of the perceived (although the same patterns can be called "arousal" for another perceived object or in another context). Sets of neurons in modal-specific sensory, motor, and affective systems are strongly related, and their activation

supports the integral and multimodal experience associated with the perception of tiger.

Later, even when remembering a meeting with a tiger, the nervous states that are responsible for the visual image of the tiger can be activated again. Restoring a combination of neurons in one network can cause cascading reactions in other systems and eventually cause a complete pattern. Due to the relationships between sets of neurons that were active during the initial experience, a partial multimodal reproduction of this experience occurs [Damasio 1989; Barsalou et al. 2003]. Critical to this observation is the fact that only part of the initial state is reactivated, since the attention is selective and the individual focuses only on certain aspects of the experience that are currently most significant. And exactly these aspects of the experience will be retained in memory for further reproduction [Barsalou 2003]. Since emotions are the component that provides the power of experience, they are "convex" and functional (provide adaptive function), so they will certainly be stored in memory [Niedenthal et al. 1999].

In the theories of embodied cognition, using knowledge in the processes of reproduction from memory (recollection), drawing conclusions and making plans, the knowledge is called "embodied," since supposedly incomplete but cognitively useful reproduction occurs within the framework of the original sensorimotor systems, as if the individual was here and now in some situation or had an object of reflection [Gallese 2003]. The embodiment of anger can include tension in the muscles used to strike, the innervation of specific facial muscles to form a grin, and even the rise of diastolic blood pressure.

The concept of reproducibility and similar concepts such as simulation, resonance and emulation are widely used in the theories of embodied cognition, but very different mechanisms are proposed for them [Gallese & Lakoff 2005]. One possible explanation is that the simulation is provided by the work of "mirror neurons" or even the whole "mirror neural system," which displays the links between the observed and reproducible actions. In any case, there is disagreement about the localization of these neurons, the possibility of connecting them to the system, the need to allocate them to a separate class of neurons (perhaps ordinary neurons can perform the function of "mirror," if necessary). The original work on mirror neurons revealed the special role of neurons localized in the posterior parietal and posterior frontal cortex, which were activated simultaneously when the monkey performed actions and when it observed the actions of another monkey

or human [Gallese et al. 2004]. The findings of this work were immediately extended to people. Some scientists argue that people have discovered the "mirror neuron area," located around the area of Brodman 44 (the human analog of area F5 in monkey's brain). This zone of mirror neurons can be responsible for complex operations, such as mapping the relationship of themselves and others, or differentiation between intentional or unconscious actions. But it has raised rather than solved more questions about the architecture of embodied cognition. Identifying the features of the underlying architecture of this mechanism will be a critical challenge for neuroscience in the coming years.

Perception of emotions

One of the hypotheses concerning emotions is that the perception of emotional meaning – the identification of the facial expression of an emotion or the meaning of the words "growling tiger" – includes the embodiment of an implied emotion [Adolphs 2002]. Currently significant empirical data are found in favor of this hypothesis. In one study subjects inhaled substances that evoked the emotion of disgust [Wicker et al. 2003]. The same subjects then watched a video of other people being disgusted. As a result, it was found that in both cases the same areas of the cerebral cortex are activated. A neuroimaging study found that two processes – recognizing facial expressions of another person's emotions and experiencing the same emotion on their own – involve overlapping neural circuits.

Also behavioral studies have shown that the imitation of another person's poses and gestures caused typical emotions for these actions [Chartrand & Bargh 1999]. The theory of embodied cognition offers theoretical grounds for explaining these processes: the imitation of emotional expressions of another individual is a part of the bodily reproduction of the experience of the state of another individual. When imitation of emotions occurs smoothly, it serves as the basis for the emergence of empathy [Decety & Jackson 2004]. Imitation of facial expressions of a communication partner improves communication, and sometimes this means that over time partners begin to resemble each other, because they constantly use the same facial muscles, as stated in one of the studies [Zajonc et al. 1987]. There is also evidence that errors in emotional simulation processes, such as those in autistic patients, are associated with significant problems in social interaction [McIntosh et al. 2006].

The new section of philosophical research called "mindreading" is also engaged in researches of the processes of the modeling/simulation of mental activity (mainly reasoning) of another person. In the interpretation of the mindreading there are many different points of view and approaches, which are conventionally combined into two large groups: theory theory (TT) and simulation theory (ST). Theory theory is an approach to the explanation of mental activity of the subject, which dominated in the philosophy of consciousness until recently. According to this approach, our understanding of the thinking of others is based on the theory of "common sense" psychology (folk psychological theory), which in turn represents a set of generalizations and concepts, both meeting the needs of everyday life [Churchland 1991]. On the basis of this theoretical knowledge, the subject creates particular rules and patterns that allow to explain the intellectual behavior of another. Initially, in the tradition of positivism, these laws and rules were interpreted as a literal analogue of scientific laws or empirical generalizations, in recent years they are often interpreted as hidden, implicit laws. Quite often it is believed that these naive psychological theories are internalized by children at an early age in the learning process [Carruthers 1996].

Recently simulation theory has been actively developed as an alternative to TT. According to ST mindreading is not provided by some naive psychological theory but by "the resources of our own consciousness to simulate others" [Davies & Stone 1995]. Both of these theories can also be considered to explain the mechanisms of emotion simulation.

It is interesting to note that recently a group of scientists published data that in the amygdala of chimpanzees was found a group of neurons, which are called "simulation neurons." The main function of these neurons is to participate in the simulation of decision-making process of partners in social interaction by converting the value of objects in the prediction of the future choice of a partner. Watching their social partners, primates learn about the value of the reward for choosing an object. It was found that the neurons of the amygdala of primates are involved in the process of receiving the values of objects from observations and using these values to simulate the decision-making process of monkey-partner. In the experiment chimpanzees took turns choosing objects based on the value of the reward, at this time, the neurons of the amygdala of each of the monkeys coded object-specific values obtained from observations. Further these values as a result of certain patterns of neuronal activity were transformed in the representation

of recorded choices of the monkey itself. It was found that the same patterns of activity developed spontaneously before choosing a partner in individual neurons, as if these neurons were simulating partner decision-making. These "neurons of simulation" encode signatures of computation of mutual prohibition decisions, including comparing values and converting values to the choice that led to accurate predictions of partner's choices. Population decoding has established the role of amigdala in this process. Biophysical modeling of the contours of the amygdala showed that the simulation neurons in natural way occur by convergence between the neurons responsible for the evaluation of the object and other neurons. By simulating decision-making process during observation these neurons allow primates to reconstruct the mental states of their social partners [Grabenhorst et al. 2019].

An important consequence of the ability to simulate emotions is their importance for learning processes through observation. When learning is carried out by observation, the positive and negative consequences of behavior are mastered in the process of observing the behavior of another person. Recent data obtained by imaging on fMRI revealed similar changes in brain activity in subjects-women in two different situations – with pain stimulation applied to their hands and in a situation where the stimulation was directed at the hands of their partners [Singer et al. 2004]. This suggests that learning through observation is supported by the observer through the reproduction of the emotional experience of the model. This hypothesis needs to be investigated for cases of unsupervised learning and by reading the instruction, however, a possible explanation may be a similar simulation mechanism, which is underlying the learning. In the case of learning by instruction, neither the person nor the other person experiences pain or pleasure. When children learn not to put their fingers in the socket or carefully cross the street, they are not taught this directly, their behavior is guided by verbal instructions. Therefore, they should be able to experience the emotion when they meet its description in the language. Consistent with this hypothesis, the modern studies of the activation of the amygdala in the processes of conditional teaching, observed teaching and teaching by instructions for causing fear situations have found that the emotional processes that accompany all three types of learning are similar [Phelps et al. 2001].

Emotions and memory, thinking, language

Laboratory studies have shown that the use of emotional information stored in memory includes embodiment [Niedenthal et al. 2009].

In one study, the subjects made judgments (answers "Yes" and "No") about whether the words related to specific objects (for example, "child," "slug") with any emotions. Then the objects were arranged by other subjects on the strength of their connection with any emotion – joy, disgust, anger or with any other emotions. The activity of four facial muscles was recorded during the task using electromyography. In another study, the same method was used, but the words were associated with abstract concepts, there were adjectives that described affective states ("joyful," "angry").

As a result, both studies showed that people embodied a suitable specific emotion, which was demonstrated by their facial expressions, when made a decision. The results showed that the subjects took very little time to decide that the "slug" refers to the emotion (less than three seconds) and they expressed disgust on their faces. Subjects made their conclusions on the basis of the physical embodiment of reference objects or emotional states. Additional confirmation of this fact are the data obtained in the second part of the study – the subjects from the second group were asked to answer the question – whether the words are written with a capital letter ("Yes" for a capital letter). In order to make such a conclusion, the subjects did not need to physically experience the emotional meaning of the words, which was shown – these subjects did not demonstrate a systematic activation of the facial muscles. The same conclusions were obtained in other studies – if information can be processed simply on the basis of associative or perceptual processes, embodiment does not occur [Solomon & Barsalou 2004; Strack et al. 1985].

The study of the costs of the switching between sensory modalities and areas of emotion has provided an additional evidence of the embodiment of emotional concepts. Studies have shown that switching from processing in one modality to processing in another involves time costs: subjects spent more time processing the location of visual stimuli if they previously processed the location of auditory stimuli than if the stimuli for processing were in the same modality [Spence et al.2001]. The cost of switching between modalities was also discovered by the compliance of a conceptual task – people have identified the typical characteristics of categories of objects slower, if these characteristics were from different modalities [Pecher et al. 2003]. Subjects needed more time to determine that the "bomb is loud" if they had previously given characteristics to objects in another modality, for example, in the modality of taste sensations ("sweet chocolate"). But if earlier they

determined the characteristics of objects in one modality (modality of sound sensations), then they needed less time to move from "bomb loud" to "crunchy flakes." This confirms the forward hypothesis by the theories of embodied cognition that people simulate objects in similar modalities when using them in language or thinking.

Vermeulen investigated the costs of switching between modalities in determining the properties of positive and negative abstract concepts ("triumph," "sacrifice") [Vermeulen et al. 2007]. The properties of these concepts were taken from the modalities of vision, hearing and affective system. Vermeulen estimated the costs of switching from one modality to another for neutral concepts as well as the costs for switching for positive and negative concepts. The study showed similar results to those described above. The reaction time and the number of errors (costs) were greater for positive and negative concepts in determining their properties from different modalities than in determining the properties from one modality. This effect was observed when subjects switched from affective to sensory modality, and vice versa. Switching costs increased if the subjects needed to determine that the "victim" could be "shocked" if the previous task required to determine that the "spider" could be "brown." But the costs did not increase if the previous task was about the "desperate orphan." These data can serve as evidence that affective properties of concepts are simulated in the emotional system at the moment when these properties are the object of active reflection, and that they participate in thinking "here and now" [Vermeulen et al. 2007].

Research data of theories of embodied cognition regarding language provide an opportunity to argue that understanding of language is partly associated to the embodiment of the conceptualization of the described situations [Glenberg & Robinson 2000]. The first step in understanding language is to specify words or phrases that describe embodied states related to objects. Then the observer simulates possible actions with objects. Finally, a message is understood when a consistent set of actions is created.

The evidence that supports such representations of the understanding of emotional language was introduced 20 years ago, although a complete model that interprets all facts has not been developed. In the study, subjects clamped a pen between their teeth while performing a laboratory task, which included making a rating of the most ridiculous cartoons [Strack et al. 1988]. The holding pen in the mouth this way covertly forced the subjects to smile. Other subjects were given

the task of holding the pen between their lips and were forbidden to touch it with their teeth, so being deprived of the opportunity to smile. The results showed that those subjects who were forced to smile rated cartoons as more funny than those subjects who could not smile. We can say that those subjects who smiled "grasped" the meaning of cartoons better or easier than those subjects who could not smile [Larsen & Kasimatis 1992].

Currently there are studies confirming the role of emotion simulation in understanding the meaning of sentences [Havas & Glenberg 2007]. The idea behind the study was that if understanding sentences with emotional meaning requires a partial replay of the emotional states of the body, then playing congruent (or non-congruent) emotions should promote (or interfere) understanding of the language. The subjects had to evaluate whether the sentence describes a pleasant or unpleasant event, simultaneously holding a pen in the teeth or between the lips. The reading time for understanding sentences describing pleasant events was shorter for those subjects who were inclined to smile. On the contrary, the time to understand sentences describing unpleasant events was shorter for those subjects who could not smile. The same effect was observed in the second series of experiments when the subject had to assess whether the proposal is easy or difficult to understand.

Conclusion

The study of relationships and interactions between the embodiment of emotions, emotion experience, the emergence and use of information about emotions are pivotal in various areas of neuroscience, cognitive sciences and philosophy of consciousness. The theory of embodied cognition takes a new look at the role of emotions in perception, thinking, speech and as a result reflects the position of postmodern philosophy, which made a return to physicality and sensuality. However, the features of the architecture of embodied cognition remain unclear, and the discoveries of recent years (mirror neurons, simulation neurons) rather raise new questions and require further research.

Early criticism of the theory of embodied cognition argued that feedback from the body is very slow and poorly defined to reflect emotional experience [Cannon 1927]. In fact, the motor system alone can support the definition of very subtle differences. But more importantly theories of embodied cognition avoid such criticism by focusing on systems based on brain-specific modalities not just motor and nervous systems. The patterns of interaction of neurons in modal-specific areas

of the brain are fast, complex and capable to handle a huge number of states. These states can be reactivated without the need to observe the consequences explicitly (in the form of demonstrated behavior). But we must understand that in order to create a theory that can promote the study of learning processes, understanding of language, techniques of psychotherapy, social attitudes and stereotypes, it is not enough just to name and describe several psychological phenomena – it is necessary to understand the underlying mechanisms and offer a suitable methodology.

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