

RELATIONAL THINKING IS AT THE CORE OF THE CONSTRUCTIVE, TOP-DOWN PROCESSES IN HUMANS

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Abstract: *In almost all domains of psychology and cognitive science, two distinct points of view oppose each other: the first one is that the understanding of the phenomena of the human cognitive system should be sought in the peculiarities of the biological organization of the people; the second one places the emphasis on our memory – our knowledge and beliefs. This article discusses the second paradigm, the so-called constructivism, in the domains of vision, social relationships, emotions, decision-making, and language. The hypothesis is that the constructivist phenomena are associated not with the individual elements but with the relations between them. A logical consequence from this hypothesis is that some part of the human relational knowledge should be innate and speculatively, some possible sources of such knowledge are discussed. In addition to the general theoretical framework, the article also presents some computer simulations that better highlight the possible underlying mechanisms behind these processes.*

Keywords: Cognitive science; constructivism; relations.

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INTRODUCTION

According to the constructivist approach to cognition (von Helmholtz, 2013; Gregory, 1980; Neisser & Harsch, 1992; Riener, 2019), most of the work of our cognitive system consists of top-down processes of projection of our knowledge to the environment. One of the theories under the large umbrella of constructivism assumes that perception, memory, decision-making, conceptualization, and other cognitive processes could be described as processes of continuous generation of hypotheses of what is in the world and their further verification through perceptions and thinking. The hypotheses emerge from our memory structures, the goals we have, the current context, and our current point of view.

The constructive paradigm opposes the classical approach in its assumption that there are some essences in the world; some objects, relations between them, etc., and the people, equipped with perceptions and abilities to think and analyze, may see and understand these essences. The extreme version of the constructivism proposes a different point of view. There are only elementary particles around us, whereas the way we group them into objects, properties, and relations, depends on our memory and previous knowledge. Most of the points in this article, as well as additional references to the respective theoretical assumptions, and more empirical or simulation data could be found in Petkov (2016).

Although the researchers who study different domains of cognition, often use different terminology, the emphasis of the top-down processes could be found in empirical and theoretical papers on vision, social relationships, emotions, high-level cognitive processes, and many other domains.

In all these domains, there is a whole continuum of suggestions and theories about whether the top-down or the bottom-up processes dominate the cognition. Also, there are lots of models concerning how exactly they could possibly interact with each other. For example, Firestone & Scholl (2016) fully deny that top-down processes play any role in the early visual processes. From the other side, Grego-

ry (1980), Rock (1997) emphasize on a higher dominance of the active, top-down processes in vision. Other theories try to balance the two extremes and propose models of their possible interaction. The predictive coding approach (Barron, Aukstulewicz, Friston, 2020; Friston et al., 2012) suggests the *free-energy principle*. According to it, the basic building block of cognition is the principle of minimizing the surprise. More specifically, the brain continuously creates prediction of what will happen in the world (including in our own body) and responds to the eventual discrepancies between the predictions and the reality. All the cognition could be understood as a result of these responses. Similarly, the modern Bayesian approach (for example, see Clark, 2020) suggests equality of the two directions of the cognitive processes. The behavior, according to the Bayesians could be understood as a function of both the incoming information and our beliefs.

Whereas rarely the studies of the relational thinking and analogy-making point directly to the top-down versus bottom-up debate, they may propose a valuable hypothesis. The importance of relational thinking on almost all aspects of human cognition have become more and more highlighted recently (Penn & Povinelli, 2012; Penn et al., 2008; Hofstadter, 2001; Kokinov & French, 2003; Day & Gentner, 2007; Petkov et al., 2011; Halford et al., 2010). Having in mind that relations seem highly top-down influenced in many cases, it is reasonable to look for eventual closer and more direct connection between the relational thinking and the top-down processes.

This paper discusses explicitly the evidence for the hypothesis that exactly relational thinking is the core of the manifestations of the top-down processes in various domains of cognition.

CONSTRUCTIVE PHENOMENA IN VARIOUS DOMAINS

Constructive vision

Gregory (1980) asks the simple question: "What does object mean?" and searches for the common characteristics of all elements

of a single object. This turns out to be a difficult task. Maybe all elements of every single object move synchronically and in the same manner. However, imagine movers who carry a piano and one of the men has put his jacket on the top of the piano while moving it. The elements of the jacket move in exactly the same way as every part of the piano but nobody will see the jacket as a part of that piano. This is because people already know what piano means. People's perceptions are biased from their initial knowledge about the objects.

However, often we see things that we have never seen before. In such a case, people are consistent when separating the space into objects and their parts. The Gestalt psychologists (Palmer, 1999; Stevenson, 2013 for a review) assume that there are perceptual primitives somehow incorporated in our brain. In this way, the perceptual system captures initially these primitives – relatively large holistic groups of elements, and further on divides them into parts. Some of the principles of this holistic grouping involve proximity, continuity, similarity, symmetry, etc.

The Gestalts' approach receives support from the neurobiological data obtained by Hubel & Wiesel (1960). They discovered special neurons in the monkey cortex. These neurons react on very special stimuli – light rings with dark interior. When there is no visual stimuli in front of the monkey, the respective neuron does not react. When the animal sees a light circle, the neuron does not react again. The neuron reacts only if there is a ring of light and the interior is dark. Hubel (1962, 1978) assumes that by combining such neurons, the perceptual system could potentially contain detectors for lines with different orientation, continuous contours, and probably more of the Gestalt principles.

However, Goldstone (Goldstone et al., 2005; Goldstone et al., 2015) demonstrated that maybe this organization of the perceptual system is not innate but it rather develops and changes in accordance to the different stimulation we have! Goldstone et al. (2005) train the participants in their experiment to categorize different combinations of horizontal and

vertical lines into two groups. After learning to do that, people become sensitive to specific combinations that define the categories, although they never see them alone. With other words, people had learned to see these combinations and their perceptual system had created detectors for them.

Summarizing, to see and understand the world, we need perceptions. However, the perceptions themselves depend on our goals, concepts, and on the already developed categories (Riener, 2019). The information flows continuously in both directions – bottom-up and top-down. While the conceptual system adapts to the information given by the perceptions, the perceptions themselves adapt to our conceptions and knowledge. The constructivist approach to vision was initially formulated by Helmholtz (cited by Rock, 1997): when we recognize different objects, we do not do it directly but use ratiocinations. Perception of one thing depends on the perception of other things ("chain of perceptions", Rock, 1997) According to Rock (1997), vision consist of fast and automatic generation and verification of hypotheses. Based on a very small pieces of input information, we generate hypotheses about what we may see, then we use the perceptual system to verify these hypotheses and eventually, to create new ones. In such a way, vision is analogous to the scientific discovery (Gregory, 1980; Friston et al., 2012)!

The debate on how much the top-down processes influence perceptions receives a lot of attention in our days. There are empirical data and philosophical position supporting the whole continuum of ideas – from the extreme deny of such influence (Firestone, Scholl, 2016), through various ideas how to put both top-down and bottom-up processes in a coherent model (Kuang, 2019), to proposing dominance of the top-down process over the bottom-up ones (Gregory, 1980; Friston et al., 2012)

Constructivism in social cognition

The simulation theories of the social cognition and emotions (Shanton & Goldman, 2010) propose the idea that when people

watch somebody else, their own neural system tries to replicate the other's neuronal system, "to resonate" (Rizzolatti et al., 2001). In this way, they empathize, and thus understand the hidden other's mental states. For example, if somebody in front of us makes a grimace of joy, we do the same grimace and thus our brain understands the mental state of the other person. Of course, it is not necessary the imitations to be full and to involve even the face muscles. No, it is simply enough to be performed in our motor cortex.

The simulation theories have their neurophysiological support. Rizzolatti et al. (2000) discovered the "mirror neurons" in monkey's cortex. The mirror neurons react both when the agent – owner of the neuron – makes a certain movement, and when it watches the same movement. Many speculations emerged after the discovery of the mirror neurons; however, they may serve as a good evidence for the simulation theories. At least, what they assume is theoretically possible to happen in the brain (Gallese & Goldman, 1998).

There are also many behavioral data in support of the simulation theories. People are willing to expect from the others the same things that they know about themselves (Katz and Allport, 1931, cited by Jackson Jr, 2001) – whether the others cheat on exams, whether the others have racial prejudices, etc. The young children before their age of four-five cannot understand at all that the others may have different points of view of the world from their own (Wellman & Bartsch, 1988; Baron-Cohen et al.). Only after the age of four-five, people can understand the concept of mental state, and to realize that the others may have different from their own beliefs.

However, nevertheless that the "egocentric bias" (Epley, Morewedge & Keysar, 2004) is undoubtedly strong pressure for our social knowledge, it is also undoubtable that people can learn and can change themselves! Even the mirror neurons should develop somehow based on the development of the conceptual system. Only after the representations of some movements and goals emerge in our mind, the

respective specific neurons that participate in the abstract representations of these movements and goals could emerge.

Many of the researchers from the field of social science accept absolutely that understanding the other's intentions is based on abstract memorized schemas for typical social situations (Crick & Dodge, 1994; Burks et al., 1999). With other words, our understanding of the mental states of the others is a consequence of ratiocinations. We need to make conclusions about them, having common knowledge for the respective situations (Burks et al., 1999). This view is generalized by the term Theory Theory (Sellars, 1956; Gopnik et al., 1997), or specifically for the mental states Theory of Mind (Malle, 2005; Nichols & Stich, 2003 for a review).

According to the Theory Theory, we create theories about how the mental world of other people works analogically to the way we create theories about how the physical world works. For example, from an early age people have a notion that most of the objects fall. Later, during school, people understand that the Earth is round and when learning the concept of gravitation, they re-conceptualize their knowledge. Later on, the students should learn many equations about gravity for their exam, and thus, re-conceptualize their knowledge again. Much later on, only few people continue to re-conceptualize it and some even create new equations. The same happens with the social knowledge! People create and memorize theories that are not static but continuously change and re-conceptualize.

In this way, the Theory Theory is similar to the constructivist approach to vision. Our knowledge for the mental worlds of the other people depends on the ratiocinations and hypotheses that come from our own memory and knowledge (Gallagher & Frith, 2003). Westra (2019) also argues for the close relationship between the top-down processes on how stereotypes influence our decisions and the "action-prediction hierarchy" proposed by the predictive coding approach to perceptual processes (Barron, Aukstulewicz, Friston, 2020; Friston et al., 2012).

Constructivist emotions

More than a century after his work, William James (1884, 1890) is one of the most influential researchers of emotions. According to him, the emotions are direct response of our body to the stimuli around us. Note, not the stimuli themselves, but the bodily response to them. The stimuli could be either external (configurations of sounds, colors, contours...) or internal (imaginings, abstract ideas...), but in both cases, the stimuli cause a physical response in the body of the observer, i.e. a reaction. The emotions, according to James, are the subjective feeling of that reaction. Thus, there are some basic emotions, building blocks for the more complex ones, and these basic emotions should have their unique physiological correlate – a “neuronal signature”.

The simulation theories, described in the previous section, deal not only with the question how we understand the other's intentions, but also with other's emotions. According to them, the only thing we should do when we need to understand somebody, is to imitate his actions and his context. If we can do this successfully enough, our own neural system will fall in the same state and then we could interpret the respective neuronal signature.

However, the emotional system may fall in illusions in the same way the visual one does! Zillmann & Bryant (1974) ask half of the participants in their experiment to bike for a few minutes, whereas the other half should work on a rebus sitting in their chairs. Normally, the first group becomes much more aroused for about six minutes after the exercises. However, just after the second minute, the people with bicycles lost their psychological feeling of the arousal. With other words, their blood pressure and pulse had been increased but they did not sense this consciously. During this period (between the second and the sixth minute), the researchers provoke aggressively all the participants and measure their reactions. People from the bicycle group respond much more aggressively to the provocation. This could not be due to the psychological feeling because it has been equal in both groups. This could be only due to the residual unconscious arousal. However, biking is not related to the

aggressive behavior, thus, the researchers interpret this result as an emotional illusion! People had unconsciously interpreted wrongly the state of their own body. They had attributed their increased pulse and blood pressure to the provocation, even though it was due to the biking.

Many similar experiments had been performed and the results are converging: sometimes people tend to attribute wrong reasons to their emotions. In order for such emotional illusion to happen, three conditions are necessary – people should be physically aroused; they should not define the right reason for this arousal; and a certain contextual stimulus in their environment should be potentially interpreted as a source of emotion (Reisenzein & Gättinger, 1982).

Constructive approach to vision emerged after studying the perceptual illusions. In a similar way, emotional illusions have provoked completely different view on the human emotional system. Recently, there are evidences that it is difficult to distinguish emotions from cognition (Pessoa, 2008; Niedenthal & Wood, 2019), thus it is not surprising that the constructive theories from other domains of cognition could be found in emotion studies too.

Schachter (1964) proposes two-steps model of emotions. On the first step, the stimulus causes a bodily response – nothing novel until now. However, according to Schachter, this bodily response is not differentiated; it is not a neural response of a certain emotions. The emotions emerge on the second step of the Schachter's model, on which the cognitive system interprets the physical state of the body in the context of the current situation. With other words, the emotions are an act of attribution of a reason for the bodily state.

The temporary attributive theories of emotions stress on the cognitive component and assume that the same stimulus may produce different emotions in different contexts, and vice versa – different stimuli may produce one and the same emotion (or at least, one and the same verbal label that people use for their emotions). The Conceptual Act Theory (Barret et al., 2015) proposes four basic hypoth-

eses: (1) The emotions are concepts; categories like the other categories we have. (2) The emotions are constructs, meaning that we create them on the basis of both the changes in our bodies and the conceptual system we have. (3) The psychological primitives related to the emotions may differ phenomenologically from that of the other cognitive processes, but they are not something principally different. (4) Being constructs, the emotions have characteristics that the physical states alone do not.

Summarizing, the emotions are products of our memorized conceptual system. They are acts of interpretation of the bodily state in the light of the current context. It seems naturally to assume that maybe the same cognitive mechanisms lie at the basis of perception, understanding the other's minds, and emotions. These are processes of continuous generation of hypotheses, bottom-up projection of these hypotheses, and their verification.

Constructive high-level thinking

It seems more natural to assume that conscious thinking and high-level reasoning depend on what people know after proposing that perceptions, emotions, and social knowledge are based on bottom-up processes and depend deeply on our memory and conceptual system.

However, this point of view is not accepted from all researchers! Gigerenzer and his research team study the so-called "heuristics" in human thinking (Brighton & Gigerenzer, 2015). They argue that even if a lot of the relevant information is available, sometimes it is better purposefully to ignore large part of it and to make decisions based on small portion of it only. The purpose of this is to make better decision, not to save time or efforts! Often the models that consider a lot of information describe the data better but predict novel situations worse than the models that try to capture only the main trends. Gigerenzer assumes that people are equipped with many innate heuristics, which they use when they reason and make decisions (Gigerenzer, 2020).

Daniel Kahneman и Amos Tversky (Tversky & Kahneman, 1974, 1981) also assume that much of our thinking is based on prin-

ciples that are not necessarily learned during the education about the right normative way of judgment and decision-making.

Obviously, language is one of the most vivid differences between the cognitive systems of humans and the other species. A lot (and possibly all) of our conceptual system depends on the language we use. However, it is not easy to find out how people acquire the language. According to Chomsky (1997), it is logically impossible to unambiguously map the set of the language labels that the children hear to the set of their subjective experiences. Thus, Chomsky concludes that something should be innate, the so-called "universal grammar". The foundations of the language and in turn, of almost all the cognitive processes, are fixed, structural, biological directives (Olson et al., 1991).

Although many researchers doubt that all high-level processes of thinking, judgment, and decision-making are fully based on our knowledge, the common view is similar to that. The high-level processes are mainly processes of deliverable, slow, conscious analyzing. During these processes, we continuously project our schemas onto the environment, generate hypotheses, and try to verify them. This is similar to the scientific discovery. The constructivist approach to cognition assumes that most of the other cognitive processes, even perceptions and emotions, operate in the same manner.

RELATIONS AT THE CORE OF HUMAN THINKING

Many researchers assume that human's ability to manipulate complex structures of relations lies at the core of human cognition (Hofstadter, 2001; Kokinov & French, 2003; Day & Gentner, 2007; Petkov et al., 2011; Halford et al., 2010). Penn et al. (2008), Penn & Povinelli (2012) argue that there is a discrete difference between the cognitive systems of humans and animals, namely relational thinking. People can easily deal not only with objects, their properties, and the relations between the objects, but also with relations between relations!

Analogy making is probably the most beautiful demonstration of human relational thinking. Analogy making lies at the core of creativity (Dunbar, 1997; Hofstadter et al., 1995; Markman & Wood, 2009), intelligence (Gentner, 2010), learning of logical statements (Halford, 1993), understanding of causality (Walker & Gopnik, 2014), and even scientific discovery (Nersessian, 1988). Analogy making is a perfect demonstration of one of the basic properties of human cognition (Hofstadter, 2001) – our ability to map the new information to the old one and to adjust them both until they fit consistently.

Having in mind the great importance of relational thinking for almost all human cognitive abilities, we may reasonably hypothesize that the constructivist bottom-up processes are by nature processes of relational transfer. Probably most of the primitives come from the different perceptual systems but how we will combine and interpret them in a structural way depends mainly on the relations we have in our memory. The rest of this section provides support for this hypothesis in the domains of vision, social cognition, emotions, and high-level thinking.

One of the most influential researchers in the field of vision, James Gibson (1979) introduces the concept of “affordances”. The affordances of the objects reflect the way we, people, can interact with them. For example, the affordance of an apple is to be eaten, the affordance of the kettle is to grab its handle; the affordance of a flat stone is to sit on it. In all of these cases, it is about relations between people and objects. Gibson himself, does not support the constructive view of vision, however, he admits the necessity for some relations to come initially from somewhere outside of the perceptions. Maybe the relations come from the design of our bodies, maybe they are learned, however the affordances do not exist objectively in the objects; they are human’s attribute. Hummel (2000) justifies logically that no one finite set of visual primitives is enough to construct all possible forms that people can learn. Relational combination of the primitives is a necessary condition for an effective visual system.

Day and Gentner (2007) perform series of psychological experiments testing people’s understanding of various social situations. For example, one of the stories was about a man, who bought plain tickets to Rio de Janeiro immediately after he heard about his uncle’s death. However, it remained unclear from the story whether he is going to travel to the place of death to honor his uncle, or vice versa, he is running away from this place. The participants interpreted the story depending on the relations involved in another story, presented to them before that. Similar results report Shahbazyan et al. (2014). The research on stereotypes also convergently point to the conclusion that the stereotypes are defined by their internal relational structure (Wittenbrink et al., 1997). Something more, people tend to transfer the relational structure of their stereotypes to completely unrelated situations, even when watching animated movies (Wittenbrink et al., 1997)!

Obviously, some stimuli cause immediate emotions in people. For example, when somebody sees a bear, he feels a fear. Although emotional illusions happen sometimes, in most of the cases people correctly interpret the reasons for their bodily states. However, why, for example, people do not fear bears in the zoo? Gallagher (2012) criticizes the simulation theories arguing that the separate components of a certain situation are not enough for understanding the others’ intentions and emotions. Instead, it is necessary to create a whole story, a coherent, structured story that involves in a noncontroversial manner the goals, the actions, and the emotions of the others in the respective context. Russell (2003) points out that people do not register a mess of flashes of light, sounds, etc., when they scan the environment. Instead, people always look for a relationally structured understanding of the whole situation. De Bruin et al. (2014) continues further on and argues that not only the emotional situations are relational structures but also that the emotions themselves are complex items involving relational structures.

Finally, the high-level conceptual system is probably a structure involving many relations. Many of the categories are defined by the de-

gree of coherence of its relational structures (Kurtz & Gentner, 2001). With other words, often we put objects in the same category not because of similarities of their visual or spatial properties but because of similarities of their relational structures. For example, the dogs and the dolphins are both in the category of mammals because of similarity of the functionality of their organisms. The ad-hoc categories (Barsalou, 1983; Goldstone, 1996), for example, the category of the typical personality traits of the people working in the financial sphere, are from the same type.

Searching for relational structures and grouping different elements because of similarity of their relational structures, are probably basic mechanisms of all cognitive processes. Perceptual systems are able to detect various signals – changes in color, some lines and edges, sounds, etc., but the cognitive system immediately attempts to project relational knowledge on them, in order to group, to abstract, and in turn to interpret these stimulations in a coherent, structured manner.

COMPUTER SIMULATIONS WITH A MODEL FOR ANALOGY-MAKING

The cognitive architecture DUAL (Kokinov, 1994b, c) is a computer program for simulating various cognitive processes. It was initially developed by Boicho Kokinov together with another computer program, AMBR (Kokinov, 1994a), which explicit task was to make analogies between remote domains. Further on, additional mechanisms were upgraded to DUAL (Petkov & Shahbazyan, 2007). The architecture includes various details; a lot of models have been developed on it; some of the added mechanisms were further on rejected because of contradicting empirical or logical evidences; some others were added. A relatively coherent description of the current details of the architecture could be found in Petkov, Petrova (2019).

Two are the most important characteristics of DUAL: it combines associative organization of the memory with powerful mechanisms for searching and mapping of complex relational structures.

The knowledge in DUAL is organized in a two-dimensional semantic network of agents, combining the abstractness dimension with the part-whole one. There is no explicit distinction between semantic and episodic memory, as well as between how the concepts and situations are represented in a nested manner. Some of the agents are explicitly labeled as relations. All agents have a hybrid nature – they combine symbolic and connectionist part. From the symbolic point of view, every agent stands for something, but even very small pieces of knowledge should be represented with large coalitions of agents. From the connectionist point of view, each agent has dynamically changed activation level, which represents the relevance of the respective agent to the current context. The two aspects are interrelated – the symbolic operations have ‘price’ that should be paid with activation. Thus, the most relevant agents work faster; the less relevant one – slower.

There is a special marker-passing mechanism in DUAL that is responsible for finding similarities between agents. For example, it may happen that the agent representing ‘lion’ emits marker, which spreads through the class-hierarchy. If the agent ‘flower’ also is active enough to emit marker, the two markers may cross in the concept ‘living thing’. Consequently, a hypothesis for correspondence between the two marker-origins will emerge. This hypothesis is an agent, representing the knowledge that it is something in common between lions and flowers – they both are living thing.

There are many additional mechanisms in DUAL for enlarging the hypotheses for correspondences, involving the structural constraints that if two relations are mapped, then their arguments should be also mapped and so on.

The transfer mechanism is responsible for creation of another type of hypotheses. If the poorly represented target situation happens to map to a certain memorized situation, then the relations from the memorized situation that do not have correspondences will be transferred as anticipations. The anticipations represent the hypothetical knowledge that the relevant

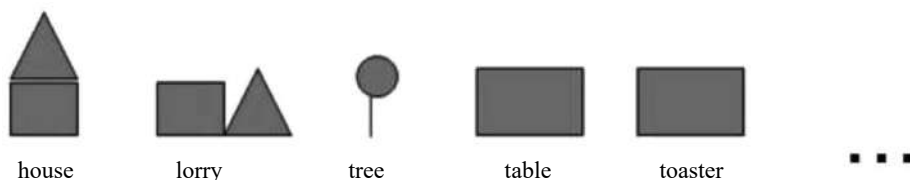


FIGURE 1. THE DOMAIN OF THE RECMap MODEL

relations from the similar past situation may be presented in the current situation as well.

Finally, a special attentional mechanism checks sequentially the anticipations in order of their activation. In this way, the initial poor representation of a certain situation grows, led by a process of active search.

Putting all these mechanisms together, the hypothesis that the constructivist processes in human cognition are grounded in top-down transfer of relations was tested with various simulations. For example, the RecMap model for active vision, grounded on DUAL architecture (Petkov & Shahbazyan, 2007), tries to simulate various empirical data known about human vision.

The domain of RecMap consists of geometrical configurations of lines, ovals, etc. with mnemonic names (Figure 1)

However, on the input of the model only the primitives (the lines and the ovals) are represented to the model, without any relations between them. It is a task of the model to find the relevant relations. The activation spreads from the primitives to their concepts and further on the class hierarchy, some memorized primitives become active, some initial mappings happen, and some anticipations about certain relations emerge. Sequentially, the attention mechanism verifies some of them, rejects other and dynamically, the model enriches the representation and recognizes the respective object. For example, the initial representations of a 'house' and a 'lorry' are completely the same – they both consist of seven three horizontal, two vertical, and two sloped lines. It is a task of the model to hypothesize that both house and lorry can be represented, to create anticipatory relations between the triangle and the square, and just after verify-

ing one of them, to recognize the object. RecMap was able to recognize holistically (first the whole, then the parts) sometimes. It could resolve ambiguous objects depending on context (for example, the table and toaster have exactly the same representation but when a situation with two squares one above the other was presented, the model recognized the upper one as a toaster, the bottom one as a table – this is the usual location of these objects). Even though the model works in a very limited domain, it demonstrated the power of the main idea of the constructivist approach.

CONCLUSIONS

One example of the constructivist approach is presented. According to it, most of the human cognition is a process of generation and verification of hypotheses. Human's memory system continuously generates relational structures and projects them into the primitives, coming from the perceptions. The result is a consistent structured interpretation of the incoming signals that fits to beliefs, goals, and knowledge. In addition, a computation model that realizes these ideas was described. It is based on powerful mechanisms for creating, mapping, and active searching of relational structures.

In addition, a new approach on the role and the consequences of the constructive processes is presented. It is argued that the manifestations of the top-down, constructive processes could be found dominantly in the relational thinking. It is summarized that this could be thought as a common feature among various cognitive processes, nevertheless that phenomenologically, the various cognitive domains seem so different from each other.

This approach differs from the other theories that try to fit the top-down and the bottom-up processes in a single model. The main distinctive feature of this approach is not so much on what amount of each type of processes is included, nor on the exact formula of their interaction, but on the processes that each of the direction of the information flow controls.

The proposed simulations with the cognitive architecture DUAL had disadvantages, as any other computational model. However, they demonstrate at least that potentially this approach could be valid. Their main advantage is that they test the proposed hypothesis for eventual contradictions and the success of the simulations is a reason for looking for further empirical and computational evidence or contradictions.

Logically, important questions arise from this point of view. Although the constructivist paradigm can explain many of the typical phenomena of human cognition, it is unclear how exactly the mechanisms for learning (i.e. adapting knowledge to the incoming information) and the mechanisms for constructing the world (i.e. understanding the incoming information in the light of memorized knowledge) may work together. Analogy making proposes theoretical solution – both the incoming and the memorized information change until they fit consistently. However, some relational knowledge still should be given to us in the beginning. Something should be innate. The different domains in cognitive science could propose different options for a predefined relational knowledge. For example, the embodied view of perceptions claims that knowledge could be presented in our bodies. The simulation theories of social cognition and emotions assume that it is possible for human to use their own neural system to resonate the mental states of the others and thus to understand them. Finally, some researchers argue that even in the domain of high-level reasoning and decision making probably we use innate, predefined heuristics.

It would still be highly speculatively to define the exact boundary between the innate and the acquired phenomena of the cognition.

However, future studies in this direction could potentially highlight important characteristics of human cognitive system.

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