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# Perception as a context for conceptual processing and language understanding

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In the research on language understanding, context is defined in terms of words that help to construct the meaning of the target word or passage of text. Here, it is argued that the definition of context in language understanding should be broader in order to incorporate perception as an essential component of meaning. A theory of perceptual symbol systems is provided as a framework for understanding the role of perception in solving the symbol grounding problem for higher-level cognition. Theory posits that symbolic thought acquires its meaning only through reactivation of perceptual experiences of objects or states in the world to which the though refers to. Empirical evidence supporting the theory is also reviewed.

*Key words:* embodied cognition, language, conceptual processing, perceptual simulation

Context could be defined as a background information or whole situation that enables us to understand the meaning of the text. This information might be provided immediately before or after the main piece of text that we tried to understand. Language communication poses a lot of ambiguities that we routinely resolve using contextual information. Ambiguities arise from the fact that many words have different meanings in different contexts. For example, word *root* refers to very different objects when we talk about mathematics (square root), botany (root of a plant) or dentistry (root of the tooth). Although it is clear that context plays a significant role in semantic processing it receives relatively little attention in cognitive science (Barsalou, 1999; 2008).

Standard assumption in cognitive science is that human mind operates as a device for symbol manipulation (Anderson, 1983; Laird, Newell, & Rosenbloom, 1987). Symbols are conceived as abstract entities which represent or stand for some objects, set of objects or state of affair in the world. Manipulation over symbolic content is achieved using rules such as production or IF-THEN rules. Symbols by themselves do not have any relations to the objects they represent. Take for example a word CAR. This three-letter word does not give any indication of how car look like, what is its shape or colour. Therefore, the symbols are completely de-contextualised from their referent objects. It is believed that such context-free representation is useful property for cognitive system because it reduces the computational burden and allows the focus to be made on abstract relations between symbols.

In the general cognitive architectures like ACT or SOAR, knowledge is represented as a set of propositions that relates symbols to other symbols (Anderson, 1983; Laird, Newell, & Rosenbloom, 1987). For instance, concept CAR is related to other concepts such as CAR IS A VEHICLE or CAR IS USED FOR DRIVING which looks much like dictionary. Problem with this approach is that it is not clear how to acquire or learn such a massive repository of definitions. In practical applications, propositions are supplied by the programmer. Recent advances in computational psycholinguistics suggests that word meaning could be derived from statistical information about co-occurrence of words in sentences (Burgess & Lund, 1997; Landauer & Dumais, 1997; Landauer, Foltz, & Laham, 1998). Basic idea is that words that frequently occur together in texts probably share mean-

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ing. By using statistical techniques such as principal component analysis or singular value decomposition over large database of texts, it is possible to derive high-dimensional vector space which represents latent semantic variations present in the input. According to Landauer and Dumais (1997) and Burgess and Lund (1997) such vectors represent the meaning of the words.

Propositional and statistical approaches to meaning, however, ignore the fact that our knowledge is derived from sensory experiences and from interactions with the world. We know what car is because we saw it or we heard it before. By relying on the dictionary definitions or statistical information alone we will never be able to precisely find to which object in the environment words refer to. This is known as a symbol grounding problem which prevents any artificial system to relate with the world in a meaningful way (Glenberg & Robertson, 2000, Harnad, 1990). Furthermore, perceptual representation is much richer source of information or as a Chinese proverb says "picture is worth thousand words". If we tried to describe our knowledge about car using propositions, we would require enormous amount of them to encompass all information present within a single picture. These arguments led Barsalou (1999) to seek for an alternative theoretical perspective where perception plays a central role in higher-level cognition. His theory is described in the next section.

### *Theory of perceptual symbol systems*

According to the theory of perceptual symbol systems (PSS), symbols do not lose contact with perceptual traces related to the objects they represent. Instead, there are bidirectional links between symbolic representation and content of the corresponding perceptual experience. Central assumption of the theory is that as perceptual experience is able to activate symbolic representation, it is also possible that symbolic representation reactive memory traces of past perceptual experience (Barsalou, 1999, 2008). For instance, when we view a car, perceptual experience related to it, activates corresponding category node and we recognise this object as an example of a concept CAR. On the other hand, when we read or hear a word CAR it should reactive the same perceptual traces that were used during perception of the object. Such reactivation is called perceptual simulation and according to the PSS it constitutes crucial process which enables construction of meaning. Perceptual simulation solves the symbol grounding problem by connecting words to the perceptual traces that look like real objects to which words refer. Of course, such perceptual reactivation is not perfect, vivid recreation of the perceptual representation. Perceptual simulation could be considered as a form of mental imagery. However, there are important differences between simulation and imagery. Mental imagery is conscious, effortful process which we engage as needed. On the other hand, simulation is an automatic, involuntary process which is activated whenever we think about certain word or concept. Perceptual simulation should be conceived as an active process which enables great flexibility in conceptual processing. For instance, different simulations could be combined in order to form new more complex simulation. Attention might help to focus simulation on particular property so not all aspects of perceptual experience need to be activated in any moment (Barsalou, Simmons, Barbey, & Wilson, 2003).

This view of how meaning of concepts is represented is very different from traditional view, and it requires rigorous testing before we can consider it as a serious theoretical alternative. Theory of PSS offers a number of testable predictions. It posits that perceptual mechanisms are activated whenever we engage in conceptual processing and therefore traces of perceptual activation should be evident even during conceptual tasks. If this is true, there should be an interaction between perceptual variables and cognitive task which participant tries to solve.

### *Empirical evidence*

In recent years, many investigators reported evidence that supports the PSS theory. In the field of language comprehension, Zwaan and his collaborators conducted numerous experiments which illustrates how important is perception for construction of meaning. In one of the earliest study they used sentences like

*"Ranger saw the eagle on the sky*"

or

"*The ranger saw the eagle in the nest*".

First sentence implies that eagle is flying so its wings are spread. On the other hand, second sentence implies that eagle has wings pulled toward the body. Therefore, these sentences invoke different mental images of the eagle. If these sentences are followed by the real image of the eagle, reaction time to the image will be shorter if the content of the image match with the content of the sentence (Zwaan, Stanfield, & Yaxley, 2002). Similar study showed that the same is true for the implied orientation of the object in the sentence. For instance, in the sentence "He hammered a nail to the wall" implied orientation of the nail is horizontal while in the sentence "He hammered the nail in to the floor" implied orientation of the nail is vertical. Picture recognition after such sentences is faster if the implied orientation of the object in the sentence matches with the orientation of the object in the picture. Furthermore, there was a strong positive correlation between reaction time measure in this task and standard mental rotation task which suggests a tight link between sentence processing and mental imagery (Stanfield & Zwaan, 2001).

With respect to the motion perception, it was shown that listening to the sentence which implies certain type of motion influences following judgment of the direction of motion. For instance, if sentence implies motion toward the observer as in “The player hurled the softball toward you”, participant will be faster in the task of deciding whether the two sequentially presented objects are the same or not if the second object is larger than the first one. In other words, sentence produced perceptual expectation that the second object should be larger due to the fact that it approaches the observer (Zwaan, Madden, Yaxley &Aveyard, 2004). Interestingly, motion perception was completely irrelevant for the object comparison task. Still, it produced its effect via perceptual simulation of the content of the sentence. Richardson, Spivey, Barsalou and McRae (2003) showed that verbs activate spatial representation consistent with the spatial direction of the referent activity. Verbs like pull or push are associated with horizontal dimension due to the fact that most of the pushing or pulling is done in left-right dimension. On the other hand, verbs like lift or sink are associated with vertical dimension. When sentences with these verbs are presented to participants, their response to the simple perceptual task of discriminating shapes (square vs. circle) was impaired if the position of the stimulus coincides with the verb’s spatial scheme.

Further research revealed that perceptual simulation occurred even at the level of the single word and not just at the level of the whole sentence. Zwaan and Yaxley (2003) discovered that relative spatial position of words affects judgments of semantic relatedness based on the usual position of their referent objects. If the participants saw the words

*SKY*

*GROUND*

They will be faster in deciding that both words are semantically related compared to the situation

*GROUND*

*SKY*

Authors conclude that words activate the perceptual simulation of the referent object along with its typical spatial position which interacts with the actual position of the words. In a similar vein, Šetić and Domijan (2007) showed that attention manipulation to the top or the bottom part of the visual field also affects semantic judgments. When attention is moved to the top part of the visual display, participants were faster to verify that seagull is flying animal compared to the response that mouse is not a flying animal. Opposite pattern were observed when the attention is moved to the bottom part of the visual display. Šetić and Domijan (2007) also showed that this effect extends to non-living objects. Furthermore, Estes, Verges and Barsalou (2008) showed that words immediately trigger reorientation of attention towards the spatial position where we usually observe the denoting object.

Fingerprints of the perceptual simulation are also revealed in conceptual processing. Here, the focus is not on the sentence or word processing but on revealing the underlying structure of categories that comprise our knowledge. Conceptual structure is tested in a property verification task where the participants are required to check whether presented property belongs to the category (Solomon & Barsalou, 2004). Pecher, Zeelenberg and Barsalou (2003) revealed that there is a switching cost in property verification task when the property is in different modality across successive trials. For instance, it is easier to check that LEMON is SOUR if this task was preceded by the task to verify that STRAWBERRY is SWEET compared to the situation when the same task (LEMON is SOUR) is preceded by the AIRPLANE is LOUD. In the first case, both verifications are made within the same modality of taste and there is no time difference in completing these verifications. In the second case, participants need to change the modality from audition to taste in order to complete the task and this modality switch takes time which incurs longer verification time.

It is interesting to note that the perceptual simulation is not restricted to the standard perceptual attributes such as colour, orientation, motion but it extends its influence to the emotions and motor planning. Meier and Robinson (2004) showed that words for positive and negative emotional states are differentially processed depending on the colour of the words or their spatial position. Positive words are processed faster when they are presented in white colour relative to the presentation in black colour. Also, they are processed faster when they are presented in the upper part of the visual field. On the other hand, negative words are processed faster when they are presented in the black colour or when they are presented in lower part of the visual field. Therefore, white colour and upper space are associated in the human mind with the positive emotions while black colour and lower space are associated with negative emotions. In a similar vein, Glenberg, Havas, Becker and Rinck (2005) showed that participants judged the sensibility of sentences with positive emotional content faster when they are in a positive mood while they judge faster sentences with negative emotional content when they are in a negative mood. Mood was induced with the simple procedure of facial mimicry. Participants were asked to hold pen in the mouth. One group was required to hold pen with their lips which induce negative mood due to the activation of facial muscles similar to the expression of negative mood. Another group was required to hold the pen with their teeth which induced positive mood. Comprehending sentences had also effect on the motor planning and programming. When the sentence implied movement toward the observer (“Open the drawer.”), participants were faster to execute the pull movement with their hand. On the other hand, if the sentence implied movement away from the observer (“Close the drawer.”), participants were faster to execute push movement (Glenberg & Kaschak, 2002). This is known as the action-sentence compatibility effect and has been replicated in numerous studies. All these effects are not compatible with propositional or statistical conception of the meaning.

Recent research in neuroscience also supports the claims of PSS theory (Martin, 2001; 2007). Chao and Martin (1999) used functional brain imaging to show that brain area for colour naming is close to the area for colour perception. When participants perform property verification task, brain areas specialized for processing perceptual attributes also become active. Patients with lesions in visual areas tend to develop deficits in naming objects that heavily relies on visual attributes such as animals. Based on these findings, Pulvermuller (1999, 2001) proposed a theory of functional word web which is similar to the PSS theory. He suggests that words or concepts activated a distributed network of areas including sensory areas which encode perceptual representations of referent objects.

### *Conclusion*

Research in perception revealed abundant evidence for contextual interactions either within single perceptual attribute or between different attributes. For instance, in lightness perception, gray surface lying on the dark background will look lighter that the same gray surface on the white background. This is well-known simultaneous lightness contrast which is attributed to the interactions between luminance information arriving from neighbouring locations in the visual field. There are also interactions between perceptual attributes such as the fact that lighter surface will appear closer in depth which suggests that lightness changes the construction of depth representation. On the other hand, research in cognitive psychology, especially those related to the study of conceptual processing and language understanding tried to ignore perception as a rich source of information and as a context within which conceptual understanding is achieved. Advent of the PSS theory and accumulating empirical evidence supporting it, point to the fact that traditional assumptions about knowledge representation should be re-evaluated.

However, what will be the status of the PSS theory within cognitive science is still a matter of debate. Markman and Dietrich (2000) argued that PSS provide an interesting addition to the traditional view of knowledge representation. On the other hand, Barsalou (2008) claims that PSS provide radically different view and that traditional assumption should be abandoned. Further theoretical and empirical work is needed to assess this issue. On the theoretical ground, it should be noted that PSS is just a verbal theory and it lacks mathematical and computational rigor which is needed in order to compare it with much more developed theories such as ACT or SOAR. On the empirical ground, evidence for PSS is accumulating within a limited domain of word and sentence processing. It still needs to be seen whether similar effects could be found in other domains such as thinking, reasoning, decision making and so on. Whatever the answers to these challenges will be, theory of PSS offers many opportunities for fruitful collaboration between research in perception and cognition.

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