DIANE PECHER
ROLF A. ZWAAN

GROUNDING COGNITION

THE ROLE OF PERCEPTION AND ACTION IN MEMORY, LANGUAGE AND THINKING

CAMBRIDGE

This page intentionally left blank

Grounding Cognition

One of the key questions in cognitive psychology is how people represent knowledge about concepts such as football or love. Recently, some researchers have proposed that concepts are represented in human memory by the sensorimotor systems that underlie interaction with the outside world. These theories represent a recent development in cognitive science to view cognition no longer in terms of abstract information processing, but in terms of perception and action. In other words, cognition is grounded in embodied experiences. Studies show that sensory perception and motor actions support human understanding of words and object concepts. Moreover, even understanding of abstract and emotion concepts can be shown to rely on more concrete, embodied experiences. Finally, language itself can be shown to be grounded in sensorimotor processes. This book brings together theoretical arguments and empirical evidence from several key researchers in this field to support this framework.

Diane Pecher is assistant professor at the Erasmus University Rotterdam (The Netherlands). She received a Ph.D. from the University of Amsterdam in 1999. Her dissertation *Dynamics of Semantic Memory* was supervised by Jeroen G. W. Raaijmakers. Her research is funded by a grant from the Netherlands Organization of Scientific Research (NWO).

Rolf A. Zwaan is Professor of Psychology at Florida State University. He received his Ph.D. from Utrecht University, The Netherlands, in 1992 and is the author of more than 60 scientific publications. His journal publications include articles in *Psychological Science*, *Cognition*, and *Psychological Bulletin*. His research is funded by grants from the National Institutes of Health.

Grounding Cognition

The Role of Perception and Action in Memory, Language, and Thinking

Edited by

DIANE PECHER
Erasmus University Rotterdam

ROLF A. ZWAAN
Florida State University

CAMBRIDGE
UNIVERSITY PRESS

CAMBRIDGE UNIVERSITY PRESS
Cambridge, New York, Melbourne, Madrid, Cape Town, Singapore, São Paulo

Cambridge University Press
The Edinburgh Building, Cambridge CB2 2RU, UK

Published in the United States of America by Cambridge University Press, New York

www.cambridge.org
Information on this title: www.cambridge.org/9780521834643

First published in print format

ISBN-13 978-0-511-08214-6 eBook (NetLibrary)
ISBN-10 0-511-08214-2 eBook (NetLibrary)

ISBN-13 978-0-521-83464-3 hardback
ISBN-10 0-521-83464-3 hardback

Contents

List of Contributors

Lawrence W. Barsalou, Emory University, Atlanta, Georgia, USA

Raymond Becker, University of Wisconsin, Madison, Wisconsin, USA

Anna M. Borghi, University of Bologna, Bologna, Italy

Laura A. Carlson, University of Notre Dame, Notre Dame, Indiana, USA

Ying Feng, Indiana University, Bloomington, Indiana, USA

Raymond W. Gibbs, Jr., University of California, Santa Cruz, California, USA

Arthur M. Glenberg, University of Wisconsin, Madison, Wisconsin, USA

Robert L. Goldstone, Indiana University, Bloomington, Indiana, USA

Monica Gonzalez-Marquez, Cornell University, Ithaca, New York, USA

David Havas, University of Wisconsin, Madison, Wisconsin, USA

Ryan Kenny, University of Notre Dame, Notre Dame, Indiana, USA

Ronald W. Langacker, University of California, San Diego, California, USA

Brian MacWhinney, Carnegie Mellon University, Pittsburgh, Pennsylvania, USA

Carol J. Madden, Florida State University, Tallahassee, Florida, USA

Diane Pecher, Erasmus University Rotterdam, Rotterdam, The Netherlands

Jesse J. Prinz, University of North Carolina, Chapel Hill, North Carolina, USA

Daniel C. Richardson, Stanford University, Stanford, California, USA

Mike Rinck, Technical University of Dresden, Dresden, Germany

Brian J. Rogosky, Indiana University, Bloomington, Indiana, USA

Michael J. Spivey, Cornell University, Ithaca, New York, USA

Katja Wiemer-Hastings, Northern Illinois University, DeKalb, Illinois, USA

Rolf A. Zwaan, Florida State University, Tallahassee, Florida, USA

1

Introduction to *Grounding Cognition*

The Role of Perception and Action in Memory, Language, and Thinking

Diane Pecher and Rolf A. Zwaan

Fifty years of research in cognitive science have demonstrated that the study of cognition is essential for a scientific understanding of human behavior. A growing number of researchers in the field are proposing that mental processes such as remembering, thinking, and understanding language are based on the physical interactions that people have with their environment. Rather than viewing the body as a support system for a mind that needs to be fueled and transported, they view the mind as a support system that facilitates the functioning of the body. By shifting the basis for mental behavior toward the body, these researchers assume that mental processes are supported by the same processes that are used for physical interactions, that is, for perception and action. Cognitive structures develop from perception and action.

To fully understand why this idea is so exciting, we need to look at the history of cognitive science. One of the major ideas propelling the cognitive revolution was the computer metaphor, in which cognitive processes are likened to software computations (Turing, 1950). Just like software can run on different hardware systems, so can cognitive processes run independently from the hardware in which they happened to be implemented, the human brain and body. Furthermore, just as computer programs, the human mind was thought to manipulate abstract symbols in a rule-based manner. These symbols were abstract because they were not derived from interactions with the environment by way of sensory organs and effectors.

Traditional cognitive theories assume that the meaning of a concept consists of the links between the abstract symbol for that concept and the abstract symbols for other concepts or for semantic features. However, this view has fundamental problems, as has been demonstrated in an increasing number of contributions to the literature (e.g., Barsalou, 1999; Glenberg, 1997; Pulvermüller, 1999). Two of these problems are the transduction problem (Barsalou, 1999) and the grounding problem (Harnad, 1990). The transduction problem is the problem of how perceptual experiences are translated into the arbitrary symbols that are used to represent concepts. In traditional artificial intelligence (AI) research, this problem was solved by way of divine intervention on the part of the programmer. Brooks (1987) provides this example. The following two complex propositions are true of a chair [CAN[SIT-ON, PERSON, CHAIR]], [CAN[STAND-ON, PERSON, CHAIR]], but it would be a gross oversimplification to state that these propositions provide an exhaustive description of chairs. For example, some chairs have back support, others do not, some chairs have wooden frames, others have metal frames, some chairs can be folded, and others cannot. In order for AI programs to work, programmers abstract concrete entities, actions, and events to atomic concepts such as PERSON, CHAIR, and SIT. These are the concepts the computer works with. It can therefore be argued that traditional AI programs do not display intelligence, because they do not address the transduction problem in a theoretically meaningful way (Brooks, 1987; Pfeifer & Scheier, 1999).

The grounding problem is the problem of how the symbols are mapped back onto the real world. Many models of conceptual memory assume that the meaning of a symbol is captured in its relations to other symbols (e.g., semantic network models). However, without any reference to the outside world such symbols are essentially meaningless. Therefore, it seems more fruitful to consider cognition to be grounded in the human body and its interaction with the environment, and thus in perception and action. Rather than being merely input and output devices, perception and action are considered central to higher cognition. Some recent experiments have shown that perceptual and motor representations play a role in higher cognitive processes such as understanding language and retrieving information from memory (Glenberg & Kaschak, 2002; Pecher, Zeelenberg, & Barsalou, 2003; Solomon & Barsalou, 2001; Spivey, Tyler, Richardson, & Young, 2000; Stanfield & Zwaan, 2001; Zwaan, Stanfield, & Yaxley, 2002). Many of these and other experiments are described in the contributions to this volume.

As yet, there is no unified embodied theory of cognition. In an insightful review of the literature, Wilson (2002) identified six rather diverse claims about embodied cognition: (1) cognition is situated; (2) cognition is time-pressured; (3) we off-load cognitive work onto the environment; (4) the environment is part of the cognitive system; (5) cognition is for action; (6) offline cognition is body based. She argues that the sixth claim is the best documented and the most powerful of these claims. According to this claim, sensorimotor functions that evolved for action and perception have been co-opted for use during offline cognition. Offline cognition occurs when sensorimotor functions are decoupled from the immediate environment and subserve what we might call "displaced thought processes," i.e., thoughts about situations and events in other times and places. Most of the research presented in this volume can be viewed as addressing this sixth claim about embodied cognition (except for Borghi's chapter, which also addresses the fifth claim). The eleven chapters that follow are clustered around five topics: (1) The interaction between cognition and spatial and action processes, (2) understanding emotional and abstract concepts, (3) the grounding of grammar in embodied experiences, (4) examining the role of sensorimotor processes and representation in language comprehension, and (5) mental representations.

It is crucial for the embodied framework to demonstrate that cognition is grounded in bodily interactions with the environment. The way people represent and understand the world around them is directly linked to perception and action. Thus, it needs to be shown that sensorimotor patterns are activated when concepts are accessed. In her chapter, Anna Borghi investigates the idea that concepts are for action. During interaction with the environment, people need to be able to quickly perform actions on objects. In an extensive review of the available evidence, Borghi shows that motor information is activated automatically by direct visual input but also by the activation of concepts via words and by goals. This evidence provides strong support for the idea that concepts should be thought of as a set of sensorimotor patterns that allow the organism to interact with the physical world, rather than as a collection of abstract symbols.

Laura Carlson and Ryan Kenny review results from a series of experiments that show how the perception of space and the understanding of spatial terms is grounded in physical action. These experiments investigated how terms such as "above" or "below" are understood in the context of space around a specific object. The results showed that the way people usually interact with these objects affects how the space around these objects is perceived. The results also showed that prior exposure to a specific interaction with the object biased the perception of space around the object towards that function.

As is shown in a number of studies and the first two chapters, there is evidence that perception and action play a crucial role in the representations of objects. Critics of the embodied view have argued that it might be a problem to extend this finding to abstract concepts such as "truth" or "political power," which do not refer directly to concrete objects people interact with physically. The representation of abstract concepts in terms of sensorimotor processes poses a challenge to the embodied view. There have been two proposals for mechanisms by which people represent abstract concepts. The first proposal comes from cognitive linguistics and states that abstract concepts are understood via metaphors. For example, "time" might be understood by metaphorical mapping on "movement in space." Evidence for such metaphorical mapping comes from expressions such as "time flies." The second proposal argues that both concrete and abstract concepts are representations of situations, and that the difference between them is merely one of focus.

In his chapter, Ray Gibbs discusses how people's bodily actions are used to support the use of language and abstract thought. His first claim is that language developed from perception and action. By metaphorical extension, words that originally referred to concrete objects and actions acquired new and more abstract meanings. His second point is that understanding of abstract concepts is grounded in patterns of bodily experiences called image schemas (Lakoff, 1987). These image schemas are sensorimotor structures that organize experiences. He discusses results from psychological experiments that support this notion.

Jesse Prinz presents an analysis of how moral concepts ("good" and "bad") are understood. Whether something is good or bad cannot be perceived directly, which leads to the question of how moral judgments can be grounded in perception. Prinz argues that moral concepts are grounded in emotions such as anger and disgust. He further argues that emotions are perceptions of one's own bodily state. This way, moral concepts are grounded in perception.

Art Glenberg, David Havas, Raymond Becker, and Mike Rinck argue that part of understanding language about emotions is to put the body in the corresponding state. They present two experiments in which they use the Strack, Martin, and Stepper (1988) procedure to manipulate mood. In this procedure participants hold a pen in their mouth. If they hold the pen with their teeth, their mouth is forced into a smile. If they hold the pen with their lips a partial frown is forced. They show that judgments of emotional sentences are facilitated if the mood of the sentence is congruent with the mood induced by the pen manipulation.

A different solution to the problem of abstract concepts is provided by Larry Barsalou and Katja Wiemer-Hastings. In their chapter, they suggest that accessing the situation in which a concept occurs is an important factor in understanding and representing both concrete and abstract concepts. Concrete and abstract concepts might differ in the focus of attention. Concrete concepts depend mainly on objects in the situation whereas abstract concepts depend mainly on events and introspections. Another difference is that the representations of abstract concepts are more complex than those for concrete concepts. Barsalou and Wiemer-Hastings discuss an exploratory study, which provides initial evidence for this view.

An area that at first sight does not seem to provide fertile ground for an embodied approach is language. After all, language is typically thought of as consisting of systematically organized strings of auditory and visual symbols, which are arbitrarily related to their referents and meaning. On this view, language processing by definition is the manipulation of abstract, amodal, and arbitrary symbols. However, careful analyses by cognitive linguists such as Langacker (1987, 1991), Lakoff (1987), Talmy (2002a, 2002b), Givón (1992), and Goldberg (1995) have begun to uncover the sensorimotor foundations of grammar. Continuing this line of research, Ron Langacker in his chapter shows how simple perceptual processes such as visual scanning are essential to the meaning of sentences such as "A scar extends from his ankle to his knee," or "A scar extends from his knee to his ankle," and also underlie the meaning of more abstract sentences such as "The rainy season starts in December and runs through March."

Along similar lines, Brian MacWhinney views grammar as a set of cues for perspective taking. He argues that perspective taking is based upon our interactions with the world, but can be expanded to situations that are distant in time or space. He then goes on to show that the perspective theory provides a coherent account for a variety of linguistic phenomena, such as deixis, syntactic ambiguity, and pronominal reference.

Rolf Zwaan and Carol Madden discuss a set of empirical data collected in their lab, pointing to the conclusion that visual representations are routinely activated when people understand words and sentences. They present a theory of sentence comprehension according to which meaning is construed by activating and integrating sensorimotor representations in mental simulations of the described situation.

Michael Spivey, Daniel Richardson, and Monica Gonzalez-Marquez likewise argue that language and sensorimotor processes can smoothly interface. They review a series of experiments from their lab that provide strong support for this general thesis and for more specific predictions derived from theories of meaning in cognitive linguistics, for example predictions regarding the role of image schemata in language comprehension.

Finally, Rob Goldstone, Ying Feng, and Brian Rogosky describe ABSURDIST, a computational model, which translates between two conceptual systems, for example between two people trying to talk about the same concepts. They show that both internal relations between concepts and external grounding contribute to alignments between systems. They argue that internally and externally based sources of meaning are mutually reinforcing.

The collection of ideas in this book and the empirical support obtained for them present an exciting new approach to the study of cognition. The number of researchers who are investigating the role of the body in cognition is growing, and we hope that this book will contribute to that development.

ACKNOWLEDGMENTS

We would like to thank the following individuals who have provided excellent "inside" and "outside" reviews of the chapters in this volume: Larry Barsalou, Anna Borghi, Gordon Bower, Laura Carlson, Andy Clark, Seana Coulson, Kenny Coventry, Delphine Dahan, Stefan Frank, Ray Gibbs, Art

Glenberg, Sam Glucksberg, Mike Kaschak, Fred Keijzer, Ron Langacker, Carol Madden, Mike Masson, Teenie Matlock, Ted Sanders, Micheal Spivey, Brian MacWhinney, Margaret Wilson, and René Zeelenberg. We would also like to thank Kiki Zanoli for her help with preparing the index.

Part of this chapter was written while Rolf Zwaan was a Fellow at the Hanse Institute for Advanced Study in Delmenhorst, Germany. Rolf Zwaan's research is also supported by grant MH-63972 from the National Institutes of Health.

References

Barsalou, L. W. (1999). Perceptual symbol systems. *Behavioral & Brain Sciences 22*, 577–660.

Brooks, R. A. (1987). Intelligence without representation. *Artificial Intelligence 47*, 139–159.

Glenberg, A. M. (1997). What memory is for. *Behavioral and Brain Sciences 20*, 1–55.

Glenberg, A. M., & Kaschak, M. P. (2002). Grounding language in action. *Psychonomic Bulletin & Review 9*, 558–565.

Givón, T. (1992). The grammar of referential coherence as mental processing instructions. *Linguistics 30*, 5–55.

Goldberg, A. (1995). *Constructions: A Construction Grammar Approach to Argument Structure*. Chicago: University of Chicago Press.

Harnad, S. (1990). The symbol grounding problem. *Physica D 42*, 335–346.

Lakoff, G. (1987). *Women, Fire, and Dangerous Things: What Categories reveal about the Mind*. Chicago: University of Chicago Press.

Langacker, R. L. (1987). *Foundations of Cognitive Grammar, Vol. 1, Theoretical Prerequisites*. Stanford, CA: Stanford University Press.

Langacker, R. L. (1991). *Foundations of Cognitive Grammar, Vol. 2, Descriptive Application*. Stanford, CA: Stanford University Press.

Pecher, D., Zeelenberg, R., & Barsalou, L. W. (2003). Verifying conceptual properties in different modalities produces switching costs. *Psychological Science 14*, 119–124.

Pfeifer, R., & Scheier, C. (1999). *Understanding Intelligence*. Cambridge, MA: Cambridge University Press.

Pulvermüller, F. (1999). Words in the brain's language. *Behavioral & Brain Sciences 22*, 253–336.

Solomon, K. O., & Barsalou, L. W. (2001). Representing properties locally. *Cognitive Psychology 43*, 129–169.

Spivey, M., Tyler, M., Richardson, D., & Young, E. (2000). Eye movements during comprehension of spoken scene descriptions. *Proceedings of the 22nd Annual Conference of the Cognitive Science Society* (pp. 487–492). Mahwah, NJ: Erlbaum.

Stanfield, R. A., & Zwaan, R. A. (2001). The effect of implied orientation derived from verbal context on picture recognition. *Psychological Science 12*, 153–156.

Strack, F., Martin, L. L., & Stepper, S. (1988). Inhibiting and facilitating condition of facial expressions: A non-obtrusive test of the facial feedback hypothesis. *Journal of Personality & Social Psychology 54*, 768–777.

Talmy, L. (2000a). *Toward a Cognitive Semantics, Vol. I: Concept Structuring Systems,* Cambridge, MA: MIT Press.

Talmy, L. (2000b). *Toward a Cognitive Semantics, Vol. II: Typology and Process in Concept Structuring*. Cambridge, MA: MIT Press.

Turing, A. (1950). Computing machinery and intelligence. *Mind 59*, 433–460.

Wilson, M. (2002). Six views of embodied cognition. *Psychonomic Bulletin & Review 9*, 625–636.

Zwaan, R. A., Stanfield, R. A., & Yaxley, R. H. (2002). Language comprehenders mentally represent the shapes of objects. *Psychological Science 13*, 168–171.

2

Object Concepts and Action

Anna M. Borghi

Successful interaction with objects in the environment is the precondition for our survival and for the success of our attempts to improve life by using artifacts and technologies to transform our environment. Our ability to interact appropriately with objects depends on the capacity, fundamental for human beings, for categorizing objects and storing information about them, thus forming concepts, and on the capacity to associate concepts with names. Concepts serve as a kind of "mental glue" that "ties our past experiences to our present interactions with the world" (Murphy, 2002). These concepts are the cognitive and mental aspects of categories (Barsalou, Simmons, Barbey, & Wilson, 2003).

The generally accepted view sees concepts as being made of propositional symbols related arbitrarily to their referents. This implies that there exists a process by which sensorimotor experience is translated into amodal symbols. By proposing that concepts are, rather, grounded in sensorimotor activity, many authors have shown the limitations of this view (Barsalou, 1999; Harnad, 1990; Thelen & Smith, 1994). According to Barsalou (1999), concepts are perceptual symbols – i.e., recordings of the neural activation that arises during perception – arranged as distributed systems or "simulators." Once we have a simulator it is possible to activate simulations, which consist in the reenactment of a part of the content of the simulator.

This view presupposes a close relationship among perception, action, and cognition. Many recent theories argue against the existence of a separation between perception and action, instead favoring rather a view that incorporates motor aspects in perception (Berthoz, 1997). In theories that posit perception and action as separate spheres (Sternberg, 1969; Pylyshyn, 1999), it is not possible to envision action systems as having effects on perception, because the assumption is that the perceptual process takes place in the same way, independent from the kind of response involved – manual, by saccade, etc. (Ward, 2002). The primary limitation of this view is that it is not adaptive. It is difficult to imagine the evolution of the human perceptual system as something other than an ongoing process of finding appropriate responses to the environment. Perception cannot be simply the recording of sensorial messages. It must be influenced and filtered by action.

A growing body of research emphasizes the interconnections between the "low-level" or sensorimotor processes and the "high-level" or cognitive processes. It has been proposed that cognition is embodied, i.e., that it depends on the experiences that result from possessing a body with given physical characteristics and a particular sensorimotor system. This view of cognition is clearly in opposition to the classical cognitivist view according to which the mind is a device for manipulating arbitrary symbols.

The aim of this chapter is to provide indications that may serve as tools for evaluating the claims that concepts are grounded in sensorimotor experiences and that "knowledge is for acting" (Wilson, 2002). I will argue that object concepts support direct interaction with objects and that when concepts refer to objects through words, they activate action information.

This idea is compatible with two possibilities. Concepts can be conceived of directly as patterns of potential action (Glenberg, 1997) or as being made of "perceptual symbols" from which it is possible to quickly extract data that serve to inform action (Barsalou, 1999). If concepts directly evoke actions, they allow us to respond quickly to environmental stimuli. However, particular situations and goals may make it necessary to interact with objects in different ways, in which case we have to read concepts as clues to interaction and not simply as blueprints that tell us how to act (Duncker, 1945).

I will argue that both claims are true. Concepts automatically activate motor information for simple interaction with their referents, particularly with manipulable objects. However, when it comes to performing complex goal-oriented actions with complex objects, we may access more general perceptual and situational information and utilize it more flexibly.

OBJECT CONCEPTS AND INTERACTION WITH OBJECTS

Imagine you are using a computer. The concept "computer" supports the current interaction with the current computer. For example, before pressing each key on the keyboard, you access motor images that tell you where the different keys are.

In this perspective, the function of a concept consists of activating online simulations that support interaction with objects. Such simulations may also occur when there is no specific task requirement. Furthermore, this online use of concepts doesn't necessarily imply the mediation of awareness. One could be unaware of the position of the keys on the keyboard. Access to previous experience, however, allows us to understand that the keys have to be pressed instead of pinched. The unconscious mediation of conceptual knowledge makes it possible for us to extract information from the object so that we are able to interact with it successfully. The actions suggested by a particular object are known as affordances (Gibson, 1979). In this section, I will first discuss the ways in which concepts help us combine affordances with previous experience of objects. I will then discuss evidence demonstrating that concepts support action.

Affordances and Interaction with Objects

The affordance an individual derives from an object is neither objective nor subjective. "It is equally a fact of the environment and a fact of behavior" (Gibson, 1979, p. 129). Depending on the constraints of one's body, on the perceptual characteristics of the object in question, and on the situation at hand, we derive different affordances from objects. Perception is filtered and influenced by action, so affordances are interactive. An object blocking our way might afford the action of stopping, but not if the object is very low in relationship to our body.

Also, affordances are variable. As we use an object, its affordances may change. Before we use tools, we conceive of them as separate objects, with their own affordances. As we use them they can change from being mere objects, and may become extensions of our body (Hirose, 2001). There is evidence that peripersonal space is dynamic and can be extended and contracted through the use of a tool (Farne & Ladavas, 2000).

One might ask why we need conceptual knowledge if affordances support us in interacting successfully with objects. This question is crucial. When do concepts come into play? According to Gibson, and in the ecological tradition, affordances are based on intrinsic perceptual properties of objects. These properties are registered directly by the perceptual system without the mediation of object recognition or semantic knowledge. "You do not have to classify and label things in order to perceive what they afford" (Gibson, 1979, p. 134). In this view, the environment is thought to contain all the information the motor system needs to interact with objects, surfaces, substances, and other living entities. The behavioral possibilities afforded by objects are entirely specified by the pattern of stimulation that the object produces in the perceiver.

There are, however, some problems with this theory. Consider the different affordances derived from a rock blocking our way, and those derived from a bicycle. In the case of the rock, we quickly derive the affordance of stopping or of removing the obstacle. In the case of the bicycle, the handle may afford the action of grasping it, the seat of sitting upon it, etc. Thus, we may need to access conceptual information in order to know to which affordances to react.

In fact, the ability to use an object appropriately implies a capacity for combining the affordances it provides with our previous experience of that