**Chapter 7: Imagery and Knowledge Representation**

**Learning Objectives**

* Explain the difference between a propositional representation of knowledge and an image representation.
* Describe the uses and limitations of visual imagery in cognition.
* Contrast rule-governed concepts with object concepts based on family resemblance.
* Describe the neocortical areas that mediate the conceptual representation of artifacts (e.g., tools), natural kinds (e.g., animals), and abstractions (e.g., numbers).
* Discuss how semantic memory is organized and used in answering factual questions.

**Chapter 7: Imagery and Knowledge Representation**

**Brief Summary**

Theories for how knowledge is represented in long-term memory are concerned with identifying the underlying coding for this knowledge. Two distinct types of codes have been proposed: An concrete, perceptual-like imaginal code that is modality specific and an abstract, verbal-like propositional code that is amodal. Pioneering work by Shepard using experiments studying the use of visual imagery to make mental rotation judgments provided initial support for the role of imaginal coding in knowledge representation. Later work by Kosslyn identifying analogous properties in imaginal coding and visual perception led to the functional equivalence hypothesis which claims that visual imagery uses the same mental representation, processes, and neural structures as does visual perception. Growing evidence from cognitive neuroscience emphasizes that knowledge representation is often grounded in the perceptual and motor activity of the brain.

Semantic memory not only permits knowledge representation to occur, but enables categorization of this knowledge and allows the engagement of higher-level forms of cognition. The ability to categorize knowledge is dependent on the development of concepts related to the information encountered through experience. Rule-governed concepts specify the features and relations that define membership in the class on an all-or-none basis. Object concepts have fuzzy boundaries and a gradient of category membership, with some instances being more typical than others. Our mental representation of a concept often centers on our understanding of the most typical member of a category or the prototype. Knowledge of the prototype enables us to classify new instances as belonging to a concept or not. Models of the process used to retrieve information from semantic memory have been proposed to test how semantic memory functions. Semantic network models postulate a hierarchical structure to semantic memory with features of a concept only represented once within the hierarchy. The feature comparison model is based on examining defining and characteristic features of a concept in a two-stage process.

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**Detailed Summary**

1. Semantic memory contains factual and conceptual knowledge represented by means of imaginal and propositional codes. Imaginal codes are concrete and perceptual-like, whereas propositional codes are abstract and verbal-like. Each proposition represents a single, limited assertion about the world that can be judged as true or false. Propositional codes, then, break down knowledge into individual factual components and represent how they all are related to one another. An image behaves in much the same manner as the object it represents. Imagery and perception are functionally equivalent. For example, the time needed to rotate a mental image increases linearly with the angle of rotation, much like the time needed to rotate the object itself. Behavioral and neuroimaging evidence indicate that a dual-coding system is used in human semantic memory.

2. Object concepts refer to natural kinds (biological objects) and artifacts (human-made objects). An object concept categorizes objects and events of significance in the real world. As with any concept, an object concept treats objects that differ as being the same if they fall within its defining boundary. With object concepts, this membership boundary is fuzzy or flexible. Concepts are often organized hierarchically. The hierarchy of subordinate (robin), basic (bird), and superordinate (animal) concepts illustrates this point. Rule-governed concepts, by contrast, are defined by logical relations among a set of defining features. Their membership boundaries are clear-cut and inflexible. For example, the abstract mathematical concept of an integer is well defined.

3. All concepts specify the dimensions along which members differ from one another and order the members in terms of a gradient of membership or typicality. The prototype represents the best example of a given concept. Concepts may also be coherent, in the sense that they relate in a deep, theoretical manner to other concepts or other representations of world knowledge. Concepts may also be organized hierarchically, with the basic level of categorization providing the optimal amount of information about its members. Schemas organize related concepts in meaningful ways. For example, a restaurant script is a kind of schema that organizes everything we know about the routine activities of entering a restaurant, ordering food, paying for the food, and so on.

4. Two of the major models of how we retrieve information from semantic memory were presented. Network theory assumes that knowledge is represented hierarchically and that features connected at a superordinate level are not redundantly represented at lower levels. Retrieving a fact involves working through the various levels of the network and searching the relevant nodes for feature information. Feature comparison theory assumes that each concept includes a list of characteristic and defining features. Retrieving a fact first involves a comparison of overall similarity based on both feature types. If similarity is low, then a second stage of comparison is needed based on defining features only. The feature comparison model handles experimental results better, although it, too, has difficulties in accounting for some findings.

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**Topical Outline**

Imagery and Abstract Representation

* Knowledge representations in long-term memory may take one of two forms: A modality-specific imaginal code or a symbolic, verbal-like propositional code.

Visual Imagery

* + The study of visual imagery was pioneered by Shepard and his colleagues using a series of experiments on the mental rotation of three-dimensional objects.
  + Mental rotation requires participants to judge whether a pair of objects are identical, but presented at two different viewing angles, or different. In order to perform the mental rotation task, participants must mentally rotate one of the objects to determine if it can match the orientation angle of the second object.
  + Shepard and his colleagues found a linear relationship between rotation angle and decision time in that participants required systematically more time to evaluate the objects as the same as the angle of rotation difference between them increased.

Analog Properties

* Kosslyn and his colleagues performed a series of experiments demonstrating that scanning mental images shares many of the properties of visual perception.

Imagery Versus Perception

* + The functional equivalence hypothesis claims that visual imagery uses the same mental representations, processes, and neural structures as does visual perception.
  + Neuroimaging and event-related potential studies indicate that mental imagery tasks use brain areas known to be active during visual tasks.

Mental Maps

* People integrate their knowledge of the world with their experience of environments to construct spatial mental models. These mental models are often distorted by individuals’ beliefs about how the world is organized.

Propositions

* + A proposition is coded as a relation and a set of arguments specifying an assertion that may be true or false
  + Latent Semantic Analysis (LSA) is a mathematical procedure that allows one to compare two texts in terms of the similarity of their propositional content and to answer questions about a text.

Conclusion

* Both propositional and imaginal codes are regarded as essential to our understanding of how knowledge is represented in the brain.
* Recent research has raised questions about the psychological validity of amodal, propositional codes.
* Growing evidence from cognitive neuroscience emphasizes that the conceptual knowledge of semantic memory is often grounded in the perceptual and motor activity of the brain.

Representing Concepts

* Semantic memory allows us to categorize the world and engage in high-level forms of cognition.

Rule-Governed Concepts

* Rule-governed concepts specify the features and relations that define membership in the class on an all-or-none basis.

Object Concepts

* Object concepts refer to natural kinds (biological objects) and artifacts (human-made objects) that are often organized hierarchically in subordinate, basic, and superordinate categories.
* Object concepts have fuzzy boundaries and a gradient of category membership, with some instances being more typical than others.

Prototypes

* The prototype is the most typical member of a category and serves as an important mental representation of the concept.
* Object concepts adhere to a family resemblance structure in which a category is defined by a large number of features that are applied to some-but not all-instances.

Concepts as Theories

* Object concepts are consistent with people’s background knowledge and folk theories.
* Regions in the temporal lobe are associated with specific semantic categories.

Using Semantic Memory

* Models of retrieval processes have been proposed and tested to understand how people use semantic memory.

Semantic Network Models

* The subordinate, basic, and superordinate levels of concepts and their associated features can be organized into a hierarchical structure called a semantic network model.
* The cognitive economy assumption claims that the features of a concept are represented only once at either the subordinate, basic, or superordinate level of the hierarchy.

The Feature Comparison Model

* The feature comparison model accounts for typicality effects and the category size effect by postulating a two-stage process of checking, first, defining and characteristic features, and second, defining features only.

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**Key Terms**

imaginal code

propositional code

functional equivalence hypothesis

latent semantic analysis (LSA)

rule-governed concepts

object concepts

prototype

family resemblance structure

typicality effect

folk theories

semantic network model

cognitive economy assumption

synset

feature comparison model

category size effect

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**Discussion Questions**

Discussion Question #1

Explain how mental imagery is related to knowledge representation. Is it possible to represent knowledge without using mental imagery or are mental images necessary to the process of representing knowledge?

Discussion Question #2

Think of an example of how mental rotation would be used to perform a task in everyday life and identify the key elements of the task that require the use of mental rotation. Discuss how performance in this task would be different without the use of mental rotation.

Discussion Question #3

Suppose you are the manager of a technology help line that assists callers with issues that arise when using a new cell phone. Based on your experience, you find that one of the obstacles to helping callers is the large gap in knowledge of technology between the callers and the technology experts that work on the help line. Often, callers report that they have trouble troubleshooting their technology issues because they can’t understand the jargon used by the experts. Describe how you could communicate this issue about jargon to your technology experts using the hierarchical model of knowledge representation in terms of subordinate, basic, and superordinate categories.

Discussion Question #4

Describe the characteristics of the prototypical college student. What are some examples of college students that are low in prototypicality?

Discussion Question #5

List as many similarities and differences as you can between mental imagery and perception. Based on this list, explain how mental imagery can aid as well as hinder perception.

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**Questions for Thought**

In what daily activities do you use imaginal mental representations to represent familiar concepts? Can you describe activities that are more likely to draw on propositional mental representations?

How does a judge define the legal concept of manslaughter or third-degree murder to a jury? What are the defining features of this rule-governed concept? How would the concept differ if prototype and fuzzy boundary were instead used in law?

What is the first word that comes to mind when you think of the concept of “cold”? Now, using your response as a stimulus, what concept do you think of next? Continue this chain of associations through several steps. How do these words relate to one another when positioned in a semantic network that shows links that are labeled with the nature of the relationship (e.g., “Is an example of” or “Has the property of” or “Is opposite in meaning to” or “Is similar in meaning to”)?

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**Web Resources**

[**Instructions for the Mental Rotation Experiment**](http://psych.hanover.edu/JavaTest/CLE/Cognition/Cognition/mentalrotation_instructions.html)

An interactive demonstration of the mental rotation task.

[**Imagery: Imagery Value vs. Meaningfulness**](http://courses.missouristate.edu/TimothyBender/mem/mydemos.html#recent)

Click on “Recent Demonstrations” and scroll down the page to “Imagery: Imagery value vs. meaningfulness” for an interactive demonstration of Paivio, Smith, and Yuille’s (1968) study on memory recall for words based on meaningfulness vs. the imagery value of the words.

[**Latent Semantic Analysis**](http://lsa.colorado.edu/)

An interactive demonstration of latent semantic analysis.

[**Prototypes**](https://coglab.cengage.com/labs/prototypes.shtml)

An interactive demonstration of Posner and Keele’s (1968) classic study on prototypes.

[**Link Word**](https://coglab.cengage.com/labs/link_word.shtml)

An interactive demonstration of the link word mnemonic that uses visual imagery to enhance memory.

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**SAGE Journal Articles**

Dijkerman, H.C., Ietswaart, M., Johnston, M., & MacWalter, R.S. (2004). [Does motor imagery training improve hand function in chronic stroke patients? A pilot study.](http://cre.sagepub.com/cgi/reprint/18/5/538?ijkey=4MaAZ0a8jcMM6&keytype=ref&siteid=spcre) Clinical Rehabilitation, 18, 538-549.

1. In their paper, the authors report that training using motor imagery can improve the physical movement of individuals recovering from strokes. However, the authors found no evidence for a link between attentional control, perceived control, and motor imagery. Based on these results, do you think there is evidence for a functional equivalence for motor imagery and motor movements?
2. What are some other examples of motor tasks where performance might be improved through the use of motor imagery?
3. The authors used two tasks in their study of stroke patients: a motor imagery task and a visual imagery task. A description of these tasks is provided in the appendix to the article. Identify the characteristics that differ between these tasks in terms of the elements that must be imaged.

Lewis, J.W. (2006). [Cortical networks related to human use of tools.](http://nro.sagepub.com/cgi/reprint/12/3/211?ijkey=AzrTZmsqyI6kU&keytype=ref&siteid=spnro) The Neuroscientist, 12, 211-231.

1. In his discussion of tool use, the author introduces the concept of a “body schema.” According to the author, what type of knowledge is represented by a body schema?
2. After a thorough review of the research examining the brain areas activated during tool use, the author concludes that there is a “left hemisphere lateralization bias” associated with tool use. Interestingly, the left hemisphere also contains specialized structures, such as Broca’s area and Wernicke’s area, devoted to language function. In what ways are tool use and language similar? Dissimilar?
3. The author discusses two types of movement disorders: ideomotor apraxia and ideational apraxia. What are the distinguishing characteristics of these forms of apraxia? What is the difference between apraxia and aphasia?

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**Recommended Readings**

Ashby, F. G., & Maddox, W. T. (2005). Human category learning. *Annual Review of Psychology*, 56, 149-178.

Baron-Cohen, S. (1995). *Mindblindness: An essay on autism and theory of mind*. Cambridge, MA: MIT Press.

Medin, D. L., Lynch, E. B., & Soloman, K. O. (2000). Are there kinds of concepts? Ann*ual Review of Psychology*, 51, 121-147.

Markman, A. B. (1999). K*nowledge representation*. Mahwah, NJ: Erlbaum.

Martin, A. (2007). The representation of object concepts in the brain. *Annual Review of Psychology*, 58, 25-45.

McCarthy, R. A. (Ed.). (1995). *Semantic knowledge and semantic representations*. East Sussex, England: Erlbaum.