Tolman, E. C. (1932). *Purposive behavior in animals and man*. New York: Appleton-Century.

Tolman, E. C. (1949). There is more than one kind of learning. *Psychological Review, 56*, 144-155.

Tulving, E. (1972). Episodic and semantic memory. In E. Tulving & W. Donaldson (Eds.), *Organization of memory* (pp. 381-403). New York: Academic Press.

Wolkowitz, O. M., Tinkelberg, J. R., & Weingartner, H. (1985). Psychopharmacological perspective of cognitive functions II. Specific pharmacologic agents. *Neuropsychobiology, 14*, 133-156.

Zener, K. (1937). The significance of behavior accompanying conditioned salivary secretion for theories of the conditioned response. *American Journal of Psychology, 50*, 384-403.

Chapter 8

Imagination

Sohee Park
Stephen M. Kosslyn
Harvard University

I am myself a good draughtsman, and have a very lively interest in pictures, statues, architectures and decoration, and a keen sensibility to artistic effects. But I am an extremely poor visualizer, and find myself often unable to reproduce in my mind's eye pictures which I have most carefully examined.

. . . I can seldom call to mind even a single letter of the alphabet in purely retinal terms. I must trace the letter by running my mental eye over its contour in order that the image of it shall have any distinctness at all.

William James (II: 53, 61)

Although the theories in William James's *Principles of Psychology* have had an enormous impact on certain fields within psychology (e.g., the study of emotion), James's ideas about the sensory-perceptual aspects of the mind have been largely neglected. We argue in this chapter that James's approach to the study of imagery is surprisingly contemporary, and attempt to note areas illuminated by James within this field that have yet to receive their due in contemporary research.

Considering the great emphasis on perception and psychophysics at the time of his writing, and also the fact that he studied in Germany where these areas were being investigated with vigor and enthusiasm, it seems unlikely that James was uninterested in sensory-perceptual processes. James devotes one chapter of his *Principles* to sensation, one to imagination, and two to perception. His treatment of these areas is sophisticated and elegant, yet his influence on contemporary work appears to be negligible. This is in contrast to Helmholtz, whose work on vision and audition has influenced us directly and whose hypotheses we attempt to test and refine to this day. Perhaps this relative lack of influence is due to James's being perceived primarily as a synthesizer of ideas rather than as a theoretician. And in fact, his main contribution to the study of imagery lies in his multidisciplinary review of the state of the art in research on imagination at the end of the 19th century. He gave us a panoramic view of the field and introduced us to the fundamental problems of imagery. James went a long way toward structuring the area of inquiry by elucidating the problems that should be addressed.

James, firmly rooted in biology, begins his discussion of imagery with sensory processes and ends with a neurological model. This model has much in common with many current models, a century later. However, unlike his predecessors, the British Empiricists, and some contemporary theorists, his approach encompasses psychological data, philosophical concerns, and neurological constraints. In this chapter we focus on James's contributions to the way we conceptualize, and attempt to build plausible models of, imagery. We only briefly review his ideas about the role of imagery in concept representation and individual differences in imagery. Our aim is not only to evaluate James's ideas but also to uncover fertile ground as yet unplowed.

In the "Imagination" chapter James divides the main issues into three broad areas: conceptual and philosophical foundations, individual differences, and neurological processes that underlie imagination.

CONCEPTUAL AND PHILOSOPHICAL FOUNDATIONS

James's stance on the nature of concepts is essentially that of a traditional empiricist, although there are differences. James discusses the then-current idea that sensations modify the nervous system, and as a result allow mental copies to arise in the mind. Fantasy or imagination arises from the process of reproducing copies of original sensations that were once experienced. He distinguishes "reproductive" from "productive" imagination. Reproductive imagination involves the recall of literal copies whereas productive imagination involves the integration of elements from different original stimuli. James excludes sensory afterimages from the realm of imagination; he is interested in the mental representation of sensory experience. Hence, he focuses on the idea of a mental "copy" and its relation to concepts.

James begins his discussion of how images and concepts are related with Hume's atomistic view. Hume believed that ideas are copies of the original stimuli and that all ideas originate from sensations. Sensory "impressions" and ideas were thought to differ only in their strength; an image was conceived of as just a weak impression. Hume argued that because a strong impression must have a determinate quantity and quality, so too must its weaker copy. However, James points out that surely Hume himself must

have been able to image his own works (books) "without seeing distinctly every word and letter upon the pages which floated before his mind's eye" (II: 46). In other words, James noted that images do not have to be exact copies of the sensory impressions. James then considers Huxley's modification of Hume's position. Huxley argued that our memories are sketches and not exact copies, and complex images are "generic" rather than specific; he equated vague images with abstract ideas. That is, complex images were thought to be prototypical rather than specific. James, however, disagrees with Huxley's position that abstract ideas are the same as vague images: Whether one has a blurred picture in memory (hence, vague) or a sharp one, the image must be a symbol if it is to stand for a whole class of individuals (see Fodor, 1975; Kosslyn, 1983).

In recent years, the idea of prototypes has had a major influence on theories of concept representation. It has been suggested that internal representations of prototypes play an important role in our thought processes and that mental images can serve as such representations (for a review, see Smith & Medin, 1981). However, it is now generally acknowledged that images—like pictures—are "under description"; they must be interpreted in order to have meaning. A picture of a man walking up a hill, for example, could be taken by a Martian as a picture of a man sliding downhill backwards. (Wittgenstein, 1953, pointed out that this ambiguity is unlikely actually to occur for a person, and underlined the importance of our innate mental predispositions to interpret pictures as depicting one thing over all of the other logical possibilities.) The image must be conceptualized in the context of a system of interpretation, which is a view very similar to the one developed by James. As James suggested, it now is clear that not all concepts can be represented by quasi-perceptual images, but images do appear to play a role in at least some forms of thought (cf. Fodor, 1975; Kosslyn, 1983; Shepard & Cooper, 1982).

INDIVIDUAL DIFFERENCES

James then turns to a rather lengthy treatment of individual differences in imagination. He acknowledges that there are great individual differences in imagination abilities (indeed, as quoted at the outset, he professes not to have very vivid visual images himself). James spends the bulk of this section considering lengthy quotes from Galton (1883), which describe Galton's "Breakfast Table Questionnaire" (the grandfather of all imagery questionnaires). Galton began by giving this questionnaire to his friends, who were professionals and eminent men of science. This questionnaire asked the informants to consider how they described what they had eaten for breakfast that morning; this questionnaire had three parts. The first part addressed the "illumination" of the image; was it clear or dim? The second part addressed the "definition" of the images on the breakfast table; were all objects well-defined simultaneously? The third part addressed colors of the images. From the responses, Galton concluded that intellectual men do not use visual imagery because it is antagonistic to abstract thinking. Galton then went on to expand his sample to other sorts of people, and eventually inferred that imagery is used more by "lower" human beings (i.e., lower class men, women, and children) than by intellectual men. From these results, Galton hypothesized that imagery is an inferior and primitive form of mental activity. James's chapter gives some weight to these speculations.

The notion that imagery is an inferior form of thought was not systematically explored until the 1950s, for a number of reasons. First, very little research on imagery was done at all for almost 50 years. The rise of behaviorism in America had as one hallmark a strong anti-introspectionist ideology. As was demonstrated in the 1970s and 1980s, methodologies could be developed for the scientific study of imagery that do not require active introspection; however, there was no impetus to develop them prior to the 1950s. Until then, behaviorism dominated the content of research in academic psychology, and the focus was on input/output relations, not on the internal events that mediated them.

It is curious that during the behaviorist era clinicians studying the effects of brain damage continued to report cases that demonstrated the existence of mental function, including imagery, but these were not incorporated into mainstream psychology. Indeed, even today many, and perhaps most, experimental psychologists are unaware of this body of data. James placed great emphasis on neuropsychological data, and for good reason, as we shall argue shortly.

Modern research on individual differences in mental imagery entered a new phase with Roe's (1951) study of leading scientists. The results of her questionnaire study contradicted Galton's claim that eminent men of science have poor imagery. She found that scientists in different fields use different types of imagery. For example, biologists and experimental physicists reported using visual imagery, whereas theoretical physicists, psychologists, and anthropologists seemed to prefer "verbal" imagery.

The relationship between intelligence and imagery ability has not yet been systematically investigated beyond Galton's speculations. However, if intelligence is defined as performance on an IQ test, then there will be a relation in part if only because certain subsets of the Wechsler Adult Intelligence Tests require some imagery abilities (e.g., the block design task). There are also reports of sex differences in spatial reasoning abilities. Systematic uses of imagery tasks in this context may prove to be useful. Indeed, a research team in our lab has presented 50 adults with an intelligence test and imagery tasks that selectively assessed mental rotation ability, image scanning ability, image generation ability, and image retention ability. The correlations between scores on the intelligence test and scores on the

imagery tasks were very low. This is only preliminary research, and needs to be extended further. If these results are robust over a variety of different types of subject populations, then it simply may be that imagery and other forms of intelligence are independent. If so, then Galton's result could reflect small sample size or nonrandom sampling.

Self-reports of great scientists also dampen the generality of Galton's claims. For example, Kekulé's moment of insight into the structure of the benzene molecule reportedly came to him in an image. Kekulé was dozing off, and "saw" a chain of snakes floating. Suddenly, the head of the chain joined the tail of the last snake and formed a ring (Koestler, 1964), inspiring Kekulé to hypothesize that benzene is a ring. Einstein also reported the use of imagery in his thinking, and describes an "imagery simulation" of what a beam of light would look like if one could chase after it and match its speed; Einstein later claimed that this image was one root of his theory of relativity (see Schlipp, 1949; Shepard & Cooper, 1982, discuss many similar examples).

Recently two studies conducted by Kosslyn, Seger, Pani, and Hillger (in press) investigated the ways in which people report using imagery in everyday life. In the first study, the subjects kept a diary for a week, reporting images at the end of the day; in the second study, a detailed questionnaire was given to a group of new subjects, which was filled out hourly or immediately after an image was noted. The results from both studies were extremely similar, lending credibility to the reports. The most surprising result was that most of the images that subjects reported were not formed with an obvious immediate purpose, but often seemed a form of daydream—not unlike some of the anecdotal reports from scientists in their moments of discovery. Not many people reported imagery that was intentionally used for problem solving. It is possible, however, that there are individual differences in the uses of imagery, and that some people tend to use imagery for specific ends more than do other people. This notion is entirely consistent with James's views, particularly if we consider differences in preferred modality of imagery.

James's interest in individual difference is developed further in his discussion of imagination types. Following Binet (1886/1907), he divides people into modality-specific types. For example, those who rely primarily on visual imagery are the visual types, whereas those who are very good at imagining sounds are the auditory types. There are also motor types and tactile types. Although there has been some work along these lines in recent times, it has not flowered. For example, Leibovitz, London, Cooper, and Tart (1972) asked subjects to rate the type of imagery evoked by a series of words, and were able to group the respondents according to the modality that predominated. Marsella and Quijano (1974) attempted to find cross-cultural differences in imagery types based on the hypothesis that different cultures stress different sensory modalities. They found no evidence for the hypothesis. After reviewing the literature on individual differences in imagery, White, Sheehan, and Ashton (1977) concluded that more people have and use visual imagery than other types, with the next most common form being auditory imagery. Overall, research in this area has been exploratory and descriptive; unfortunately, there has not been a coherent theoretical framework for approaching individual differences in modality dominance.

Paivio and Ernest (1971) developed one of the few theory-based approaches to studying individual differences in imagery. Paivio's "Dual Code Theory" led them to postulate two distinct ways of representing information in memory: imaginally or verbally. Paivio and Ernest developed the "Individual Differences Questionnaire" (IDQ), which assessed the representational proclivities of a person. This questionnaire produced evidence that some people prefer specific modes of thought, and these preferences predict performance in other tasks (such as speed of identifying briefly presented stimuli).

The most widely used imagery questionnaire in recent times seems to be the VVIQ (Vividness of Visual Imagery Quotient), developed by Marks (1973). Marks found that people who report more vivid images show fewer eye movements when recalling pictures, and Finke (1980) summarizes a variety of behavioral correlations with VVIQ score. These results are interesting, but some of them have proven difficult to replicate. Part of the problem may be that "vividness" is not a simple construct; it could reflect a number of different processing components, some of which may be more relevant for a given task than others. Thus, vividness may be a composite measure, and depending on which components have contributed most in a given sample, the measure will or will not predict performance on other tasks.

Kosslyn, Brunn, Cave, and Wallach (1984) analyzed the underlying processing used in imagery, and provided evidence that people differ in the efficacy of the individual processes. Kosslyn et al. recruited 50 subjects from an advertisement in the local newspaper, ensuring that a varied sample was tested. These people participated in 6 hours of testing, allowing the collection of 13 measures of imagery performance. The first important result was that there were not generally high correlations among the scores for the different imagery tasks; rather, there was a range of correlations, from −.44 to .79. Thus, imagery is not a single ability; if it were, then each person should have performed comparably on all of the tasks. For each measure, a model of the underlying processing subsystems was developed, and the similarity of each pair of tasks was computed using the number of shared processing subsystems posited in the models (the actual method of computing intertask similarity was more complicated than this, but this description serves to convey the gist of what was done). The second result of interest was that the similarities of the models predicted the observed intertask correlations. The correlation between the predicted similarities and actual correlations was $r = .56$. Another version of this theory of imagery was subsequently developed to be consistent with facts about the neurophysiology and neuroanatomy of the visual system; this version was then used to generate new estimates of intertask similarity, and these estimates proved slightly better, correlating $r = .63$ (Kosslyn, Van Kleeck, & Kirby, in press).

Neither the theory of Kosslyn et al. (1984) nor that of Kosslyn, Van Kleek, and Kirby (in press) were developed with individual differences in mind; both theories were attempts to devise accounts of basic imagery phenomena that were precise and complete enough to be implemented in a computer simulation model. The attempt, then, to integrate the study of individual differences into the more general study of cognition is exactly along the lines adopted by James. James was not so much interested in individual differences for their own sake, but as a means of gaining insight into the nature of the faculty. This tradition is alive and well.

Most work on individual differences in imagery has focused on visual imagery, including that which attempts to develop the underlying bases of individual differences in information processing. James, however, was interested in modality differences in imagery (partly, it would seem, because of the disparity in the quality of his own auditory and visual imagery). It seems that the time is ripe for renewed attention to the issue of modality-specific processing, especially within an information-processing context. The interaction between different modes of imagery has been reported sporadically, but most of these studies are largely exploratory. For example, Wolpin and Weinstein (1983) studied the effect of olfactory stimulation on visual imagery. They asked people to form visual images with a consistent odor or an inconsistent odor. In the "consistent" condition subjects reported that their visual images became clearer and more vivid. In the "inconsistent" condition, the subjects reported that their visual images became less clear and vivid. (However, only female subjects were tested, which limits the generality of any conclusions one could draw from the study.)

Individual differences in imagery and creativity, another topic that interested James, has not been studied systematically, but there are occasional reports. Luria's (1968) famous synesthesic mnemonist was reportedly able to utilize images in all senses, and often had cross-sensory imagery; he could "feel" the color red, "see" the sound of the flute, "hear" roundness and so on. One may imagine that with such an unusual mind, full of imagery, he was rather artistic or creative. Unfortunately, his vast memory apparently was also a burden on his intellectual functioning. He could never concentrate or attend to one thing at a time. On the other hand, Mozart, who seems to have been endowed with exceptional auditory imagery, reportedly utilized this tool in his moments of creation. He wrote in his letters that when he composed a symphony, he could "hear" all parts in his head simultaneously (Holmes, 1878). Thus, this too is a potentially rich area of research that has yet to be mined.

At present, then, we have more anecdotal accounts than solid data on many facets of individual differences in imagery. If James were alive today, our bet is that he would steer a graduate student or two in this direction, and we see no reason why his modern-day surrogates should not do the same.

NEURAL UNDERPINNINGS

Finally, James considers the possible neural mechanisms that underlie imagery. This is where he tackles the fundamental issues, addressing questions such as: Where does sensation end and imagery begin? What is the nature of imagery? How do we form images? Where is the seat of imagination in the brain? To address these issues he advocates a "backflow" model in which "currents" flow backwards in perceptual pathways in the brain. This idea is very much alive today, and has important implications for the so-called "imagery debate." These ideas are so relevant and central to contemporary concerns that we will focus on them for the remainder of this chapter.

Neuropsychological case studies of imagery have become increasingly popular in recent years (e.g., see Farah, 1984, for a review), almost 100 years after James discussed Charcot's patient (Mr. X) in his chapter on imagination. It was very natural for James to refer to brain functions when discussing cognitive functions, yet mainstream cognitive psychologists have only recently begun to do this without squeamishness.

To orient the reader to James's perspective, we will briefly review his discussion of Mr. X. This patient was a highly educated, multilingual businessman who reportedly had wonderful visual imagery (but inferior auditory memory) prior to his "confusional attack." After the attack, everything seemed foreign and new to him. He could see all things distinctively, but his memory for form and color was gone. For example, he could not recall his wife's or children's faces, and when he saw them they seemed unfamiliar to him. He knew that his wife had black hair, but he did not know what the color black looked like. Moreover, he forgot his own face. When he returned to a well-visited city, it seemed totally new to him. His ability to recognize objects gradually returned, and he came to feel at home again in familiar cities. However, when asked to imagine a well-know landmark in town, he reportedly could not imagine it at all although he knew that it was there. His drawing ability also suffered. His drawings had become very childish, apparently as a result of his inability to imagine what things look like. When he was asked to draw an arcade, he knew it was described as having semi-circular arches, but he could not image what semi-circular things look like! (It is not clear whether he could copy well.) With such loss of visual imagery, he attempted to compensate by relying more on auditory imagery, even though his auditory memory had been clearly inferior to his visual memory prior to his attack. He apparently reported that he began to dream only in words.

In contemporary terms, it seems that Mr. X probably suffered in part from visual associative agnosia (Damasio, 1986), which may have reflected damage to the visual memories themselves or to the means of accessing them. James emphasizes here that the problem was in visual processing, affecting both perception and imagery, and that there are other imagery systems that can partially compensate for the loss of these visual abilities. The idea that imagery and perception share common mechanisms has gained considerable empirical support in recent years (e.g., see Farah, 1988; Finke, 1980; Finke & Shepard, 1986; Shepard & Cooper, 1982, for reviews). However, the idea of compensation across sensory modalities has, to our knowledge, not been studied. Indeed, the role of imagery in drawing is not often examined and is only poorly understood.

Although the idea that imagery and perception share some processes has a long and venerable history, exactly what is shared has never been clear. James's interest lay in the neural pathways that may be shared by imagery and perceptual processes. He took Bain's position that imagery processes occupy the "very same parts" in the brain in the same manner as sensory processes, and analyzed this claim cautiously. What did Bain mean by the "same parts"? Did he mean only the parts inside the brain or also the same peripheral parts? This question is important in addressing the issue of where sensation ends and imagery begins.

At the time, it was commonly believed that imagery is a milder, diluted type of sensation. James uses Bain (1855/1977) to illustrate this viewpoint; to Bain persistence of sensation after the withdrawal of external stimuli suggested continuation of the "same currents," but weaker. Bain then considered "impressions" evoked by mental causes alone and concluded that this "renewed feeling" occupies the very same parts in the same manner as the original impression. James argues that all "currents" tend to run forward (i.e., from sensory organs to brain to motor system) during normal perceptual activity. His question is whether these currents run backwards during imagination processes, and if so, how far. If, James points out, Bain means to include the peripheral parts of the perceptual systems in the imagery systems, then these parts must be somehow excited during the imagination process. James asks, can peripheral sense organs be excited from above during imagination?

James's evidence that currents do run backwards was drawn from personal accounts by Meyer (1843, quoted in James 1890), and by Féré (quoted in James, 1890). Meyer's "experiments" are subjective introspections. For example, he imagined a silver stirrup and after he had "looked" in his mind's eye for a while, he opened his eyes and was able to see an afterimage for a long time. The existence of such a negative afterimage is taken to support James's view. Furthermore, James points out, when external stimulation is very weak it is hard to discriminate images from sensations (Perky, 1910; Segal & Fusella, 1970). More recently, Finke and Schmidt (1977, 1978) demonstrated that orientation-specific color aftereffects (the "McCollough effect") could, under some circumstances, be obtained with imagery. Hence, the borderline between imagination and perception is not clear cut. However, because these sorts of phenomena occur only under unusual circumstances, James concludes that peripheral sense organs are not ordinarily involved in imagery processes; the backflow typically stops before the sensory organs are reached.

Even if the same sense organs (or "low level processes," to use contemporary terminology) are not involved in imagery and perception, the question of whether the two abilities make use of the same types of representations remains. The idea of a top-down activation of perceptual representations has been put forward by Hebb (1968), Shepard & Cooper (1982), and Finke (1980), among others. Farah (1988) reviews the neuropsychological literature and presents a strong case for the use of shared representations. Her evidence includes electrophysiological and cerebral blood flow data collected during imagery tasks, in addition to reports of common effects of brain damage on imagery and visual perception. During visual imagery tasks, normal subjects show activation of the occipital lobe, posterior superior parietal, and posterior inferior temporal areas. These areas show similar activation during normal visual perceptual tasks. In short, there is now good evidence that parts of the brain involved in visual perception are also used in visual imagery.

The next question James considered was, assuming that imagery and like-modality perception share common mechanisms, then how do we discriminate images from sensations under ordinary circumstances? Although James lacked the vocabulary, both literally and conceptually, to state his theory unambiguously, he seems to have been trying to say something like the following: In both perception and imagery there is "current" running bottom-up and top-down (our terms), but the relative intensities are different. In perception, the world is driving most (but not all) of the activity, where as in imagery the activity arises in higher brain centers and currents flow back to the parts of the brain involved in sensory processing (but not to the sense organs themselves). Thus, the way we typically tell which is which is by the "resistance" set up from the backflow relative to the bottom-up currents—by the relative intensities of the two kinds of processing. During perception there is little resistance from backflow.

This sort of theorizing is important for two reasons. First the question of how we distinguish imagery from perception has been neglected in contemporary research. This question is fundamental; if we cannot answer it, we do not really understand the way in which perception and imagery share common processes. Second, and more subtle, the notion of "backflow" has some important implications for the "imagery debate." Before we can discuss these implications, a very brief review is necessary: The debate about imagery began in 1973, with the publication of Zenon Pylyshyn's paper "What the Mind's Eye Tells the Mind's Brain: A Critique of Mental Imagery." This debate was not about the existence or qualities of the experience of "having a mental image." Rather, the debate focused on the way mental images are internally represented, and whether this type of representation is distinct from the "propositional representations" used in language processing. Pylyshyn argued that the pictorial properties of imagery evident to introspection are simply epiphenomenal. That is, just as the heat given off by a lightbulb has no role in allowing one to read, the pictorial properties of imagery putatively have nothing to do with how information is represented or processed. Kosslyn and Pomerantz (1977) summarized and attempted to refute each of Pylyshyn's arguments. Kosslyn and Pomerantz (1977) also summarized the evidence for distinct, non-linguistic imagery representations; for each class of data they compared and contrasted "propositional" and "imagery" account, and argued that the imagery accounts often were more compelling.

Pylyshyn (1981) then put forward an essentially methodological critique, arguing that the experimental results taken to support the claim that images have pictorial properties were flawed. He posited that "task demands" led subjects (often unconsciously) to interpret imagery instructions to require them to mimic what they believed would occur in the analogous perceptual situation. Pinker, Choate, and Finke (1984) and Jolicoeur and Kosslyn (1985) directly addressed this claim, and provided evidence that task demands were not at the root of one imagery result, namely the increased time required to scan increased distance over imagined objects.

There were numerous exchanges in this debate, but it proved largely inconclusive. For the most part, people who initially were convinced that imagery is a distinct form of internal representation stayed convinced, and people who thought imagery representations are in fact like those used in language, continued to think so. This state of affairs is rather depressing from the point of view of cognitive science as science. We need theories that are unambiguous and precise enough to make clear predictions, and we need methodologies that allow disputes to be settled to the satisfaction of all parties. The failure to resolve the debate implies either that the alternative positions were not stated clearly enough to be discriminated empirically, and/or that the appropriate methodology was not available.

James's ideas about imagery have some interesting implications for the debate about the nature of imagery representations if we consider them in a little greater depth. Specifically, what would it mean for "current" to "backflow" during imagery? Recent neuroanatomical studies have revealed that the primate visual system consists of many distinct areas, with the best estimate to date being about 30 (Van Essen, personal communication). These areas are organized roughly hierarchically, with each one projecting fibers to specific other areas. At least so far, every area that projects fibers to another area also receives fibers from that area. And more than that, the sizes of the tracks running in each direction are roughly equivalent—implying that much information is in fact flowing backwards.

A critical insight comes when one asks what the early visual areas are like, that is, those near the end of the "backwards" flow. It turns out that these areas are almost all topographically organized; the cells are arranged to preserve the spatial layout of a stimulus. In a particularly compelling demonstration of this, Tootell, Silverman, Switkes, and DeValois (1982) trained a monkey to look at a pattern and then injected it with a radioactive tracer (2DG); this tracer was taken up into the brain in proportion to how much a given part of the brain was activated. After the animal had looked at the pattern, its brain was (essentially) "developed," allowing one to see which parts had been especially active while the monkey was seeing the pattern. Dramatically, the pattern itself could be seen to be laid out on the primary visual cortex! The pattern was slightly distorted because the foveal areas have proportionally greater representation in the cortex, but its spatial structure was clearly evident.

The primary visual cortex is just one (of some 10 or so) topographically organized area in the brain. Of particular interest is an area called V4, which not only is topographically organized but has cells whose activity is modified by attention and expectation (e.g., Moran & Desimone, 1985). It seems plausible that during imagery a spatial pattern of activation is invoked in this area.

Now, consider the implications of this line of reasoning. If imagery is in fact a consequence of higher cortical centers activating lower ones, then a pictorial representation may in fact be present during imagery. That is, during imagery there may be a representation that is "depictive" in the formal sense developed by Kosslyn (1980), with each part of the representation corresponding to part of the object and with the distances between parts of the representation functioning to preserve the distances between parts on the actual object (when the foveal magnification factor is taken into account). If so, then the debate would be settled once and for all: Imagery would correspond to a distinct form of internal representation, different from that used in language.

There is in fact suggestive evidence that the topographically organized regions of the occipital lobe are activated during imagery (for a review, see Farah, 1988). If it can be shown that patterns of metabolic activity vary systematically with the type of image one is forming—illustrating that the activity is not epiphenomenal—the debate can finally be settled. It is not often that a debate in cognitive psychology comes to fruition, and this possibility underlines why James was interested in how the brain functions; mental activity is, after all, nothing more (or less) than brain function. Thus, following James, it may be useful for cognitive psychologists to consider in greater depth the ways in which their putative processes may actually be carried out in the brain.

CONCLUSIONS

James's chapter on imagery is in large part a synthesis of what was known and speculated at that time. However, in typical James style he did more than simply regurgitate what others thought. James organized the material in such a way as to reveal the underlying issues, and his thinking led him to offer interesting speculations about those issues. Given James's track record in other areas, we should take these speculations very seriously. It would be a real pity if come the next commemorative volume on James at least some of these issues had not been studied in depth.

REFERENCES

Bain, A. (1855/1977). The senses and the intellect. In D. N. Robinson (Ed.), *Significant contributions to the history of psychology: 1750–1920*. Washington, DC: University Publishers of America.

Binet, A. (1886/1907). *The psychology of reasoning*. Chicago: Open Court.

Damasio, A. R. (1986). Disorders of complex visual processing: agnosias, achromatopsia, Balint's syndrome, and related difficulties of orientation and construction. In M. M. Mesulam (Ed.), *Principles of behavioral neurology* (pp. 259–288). Philadelphia, PA: F. A. Davis.

Farah, M. J. (1984). The neurological basis of mental imagery: A componential analysis. In S. Pinker (Ed.), *Visual cognition* (pp. 245–272). Cambridge, MA: MIT Press.

Farah, M. J. (1988). Is visual imagery really visual? Overlooked evidence from neuropsychology. *Psychological Review, 95*, 307–317.

Finke, R. A. (1980). Levels of equivalence in imagery and perception. *Psychological Review, 87*, 113–132.

Finke, R. A., & Schmidt, M. J. (1977). Orientation-specific color after-effects following imagination. *Journal of Experimental Psychology: Human Perception and Performance, 3*, 599–606.

Finke, R. A., & Schmidt, M. J. (1978). The quantative measure of pattern representation in images using orientation-specific color aftereffects. *Perception and Psychophysics, 23*, 515–520.

Finke, R. A., & Shepard, R. N. (1986). Visual functions of mental imagery. In K. R. Boff, L. Kaufman, & J. P. Thomas (Eds.), *Handbook of perception and human performance* (pp. 37-1–37-55). New York: Wiley-Interscience.

Fodor, J. A. (1975). *The language of thought*. New York: Crowell.

Galton, F. (1883). *Inquiries into human faculty and its development*. London: Macmillan. (New York: AMS Press, 1973)

Hebb, D. O. (1968). Concerning imagery. *Psychological Review, 75*, 466–479.

Holmes, E. (1878). *The life of Mozart including his correspondence*. London: Novello, Ewer.

James, W. (1890). *The principles of psychology* (Vols. 1–2) New York: Holt.

Jolicoeur, P., & Kosslyn, S. M. (1985). Is time to scan visual images due to demand characteristics? *Memory & Cognition, 13*, 320–332.

Koestler, A. (1964). *The act of creation*. New York: Macmillan.

Kosslyn, S. M. (1983). *Ghosts in the mind's machine*. New York: W. W. Norton.

Kosslyn, S. M. (1980). *Image and mind*. Cambridge, MA: Harvard University Press.

Kosslyn, S. M., Brunn, J. L., Cave, K. R., & Wallach, R. W. (1984). Individual differences in visual imagery: A computational analysis. *Cognition, 18*, 195–243.

Kosslyn, S. M., & Pomerantz, J. R. (1977). Imagery, propositions and the form of internal representations. *Cognitive Psychology, 9*, 52–76.

Kosslyn, S. M., Seger, C., Pani, J. R., & Hillger, L. A. (in press). When is imagery used in everyday life? A diary study. *Journal of Mental Imagery*.

Kosslyn, S. M., Van Kleeck, M., & Kirby, K. N. (in press). Towards a neurologically plausible theory of individual differences in mental imagery. In D. Marks, P. Hampson, & J. T. E. Richards (Eds.), *Advances in imagery research*. London: Roetledge-Paul.

Leibovitz, M. P., London, P., Cooper, L. M., & Tart, J. T. (1972). Dominance in mental imagery. *Educational and Psychological Measurement, 32*, 679–703.

Luria, A. R. (1968). *The mind of a mnemonist*. Cambridge, MA: Harvard University Press.

Marks, D. F. (1973). Visual imagery differences and eye movements in the recall of pictures. *Perception and Psychophysics, 14*, 407–412.

Marsella, A. J., & Quijano, W. Y. (1974). A comparison of vividness of mental imagery across different sensory modalities in Filipinos and Caucasian Americans. *Journal of Cross Cultural Psychology, 5*, 451–464.

Moran, J., & Desimone, R. (1985). Selective attention gates visual processing in the extrastriate cortex. *Science, 229*, 782–784.

Paivio, A., & Ernest, C. H. (1971). Imagery ability and visual perception of verbal and nonverbal stimuli. *Perception and Psychophysics, 10*, 429–432.

Perky, C. W. (1910). An experimental study of imagination. *American Journal of Psychology, 21*, 422–425.

Pinker, S., Choate, P. A., & Finke, R. A. (1984). Mental extrapolation in patterns constructed from memory. *Memory & Cognition, 12*, 207–218.

Pylyshyn, Z. W. (1973). What the mind's eye tells the mind's brain. A critique of mental imagery. *Psychological Bulletin, 80*, 1–24.

Pylyshyn, Z. W. (1981). The imagery debate: Analogue media versus tacit knowledge. *Psychological Review, 87*, 16–45.

Roe, A. (1951). A study of imagery in research scientists. *Journal of Personality, 19*, 459–470.

Schlipp, P. A. (Ed.). (1940). *Albert Einstein: Philosopher-scientist*. La Salle, IL: Open Court.

Segal, S. J., & Fusella, V. (1970). Influence of imaged pictures and sounds on detection of visual and auditory signals. *Journal of Experimental Psychology, 83*, 458–464.

Shepard, R. N., & Cooper, L. A. (1982). *Mental images and their transformations*. Cambridge, MA: MIT Press.

Smith, E. E., & Medin, D. (1981). *Categories and concepts*. Cambridge, MA: Harvard University Press.

Tootell, R. B. H., Silverman, M. S., Switkes, E., & DeValois, R. L. (1982). Deoxyglucose analysis of retinotopic organization in primate striate cortex. *Science, 218*, 902–904.

White, K., Sheehan, P. W., & Ashton, R. (1977). Imagery assessment: A survey of self report measures. *Journal of Mental Imagery, 1*, 145–170.

Wittgenstein, L. (1953). *Philosophical investigations* (G. E. M. Anscombe, Trans.). Oxford: Blackwell.

Wolpin, M., & Weinstein, C. (1983). Visual imagery and olfactory stimulation. *Journal of Mental Imagery, 7*, 63–74.

Chapter 9

A Look Back at William James's Theory of Perception

Irvin Rock

University of California, Berkeley

I cannot remember what my thoughts were when I first read William James's *Principles of Psychology* as a young student except that I admired the beautiful prose. On rereading it carefully now, however, I came away enormously impressed with James's grasp of the field of perception and with the feeling that we have not made the great strides in our knowledge about this field that might have been expected over a span of 100 years, particularly on a broad theoretical level. Others may disagree with this judgment. However, there have been some important discoveries and there has been some substantial progress in some areas.

What I propose to do in this chapter is first to review what James's theory of perception was, to comment about his theory in the light of present-day thinking, to discuss what we know now about perception that he did not, and finally to discuss one important idea James had about perceptual constancy that may well be right but which has been overlooked. I will end by asking the question about how much progress we have made in this field of inquiry in the 100 years since James's *Principles* appeared.

JAMES'S THEORY OF PERCEPTION SUMMARIZED

Let us begin with a summary of James's theory of perception. To avoid distortion of his views, we will allow him to speak for himself as much as possible. We begin with definitions of sensation and perception:

"*A pure sensation is an abstraction*" (II: 3) and "in popular speech, and in Psychology also" the words sensation and perception "run into each other" (II: 1). Sensation . . . "*differs from Perception only in the extreme simplicity of its object or content*" (II: 2). "The nearer the object cognized