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CONCERNING IMAGERY[1]

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An attempt is made to analyze imagery in physiological terms. It is proposed (*a*) that eye movement has an organizing function, (*b*) that 1st-order cell assemblies are the basis of vivid specific imagery, and (*c*) that higher-order assemblies are the basis of less specific imagery and nonrepresentational conceptual processes. Eidetic images, hallucinations, and hypnagogic imagery are compared with the memory image, and certain peculiarities of the memory image are discussed.

This paper concerns the content and mechanisms of imagery. The topic has received only sporadic attention, partly because of the positivistic temper of modern psychology and partly, one may suppose, because of the difficulties of dealing with thought processes in general. I propose to see what sort of analytical treatment can be made of the image and, equally, of its relation to sensation, perception, and thought. The occasion for such treatment is mainly my interest in thought—one can hardly turn round in this area without bumping into the image—but also the recent work on the place of imagery in paired-associate learning (Paivio, in press) and the convincing demonstrations of eidetic imagery made by Haber and his colleagues (Haber & Haber, 1964; Leask, Haber, & Haber[2]). I have also in mind the hallucinatory activity reported in conditions of monotony, perceptual isolation, and loss of sleep (Bexton, Heron, & Scott, 1954; Melvill Jones, cited by Hebb, 1960, p. 741; Malmo & Surwillo, 1960; Morris, Williams, & Lubin, 1960; Mosely, 1953).

The Place of Imagery in Objective Psychology

Let me first dispose of what seems to be a misconception, that reporting imagery, or describing it, is necessarily introspective. The point has been made elsewhere (Hebb, 1966) but I repeat it here for those not addicted to introductory textbooks.

An excellent example to begin with is the phantom limb, which is clearly a case of somesthetic imagery. After an arm or leg has been amputated there is, apparently in every case (Simmel, 1956), a hallucinatory awareness of the part that has been cut off. In some 10–15% of the cases the patient also reports pain, the fingers or toes being curled up with cramp. Is this a report of introspection? The argument might be: The pain is in the right hand, but the patient has no right hand; so the pain is really in his mind; so he is describing his mental processes, which is introspection: "looking inward." But the argument is faulty. We are still dealing with a mechanism of response to the environment, though the mechanism (because a part is missing) is now functioning abnormally.

Figure 1 represents a right hand connected schematically with brain and speech organs, before amputation. When the fingers are burnt or cramped the subject (*S*) says "Ouch" or "My hand hurts." This is a normal mode of

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[2] J. Leask, R. N. Haber, and R. B. Haber. Eidetic imagery in children: II. Longitudinal and experimental results, in preparation.

response to the environment, involving (*a*) sensory input, (*b*) excitation of the central processes of perception and consciousness, and (*c*) motor output determined by the central activity. It is obvious that in such reactivity—when I burn my fingers and say "Ouch"—no question of looking inward arises. My verbal response is no more dependent on introspection than a dog's yelp when his tail is trod on.

The same conclusion holds after an amputation. No excitation can originate in the missing hand, but the same excitation in principle can arise higher in the pathway by spontaneous firing on the neurons at level *X* in Figure 1. If *S* now reports pain in his imaginary-or-imagined hand we are not dealing with any different mechanism, in brain function, than when a normal *S* reports pain. Report of "sensation" from a phantom limb is not introspective report.

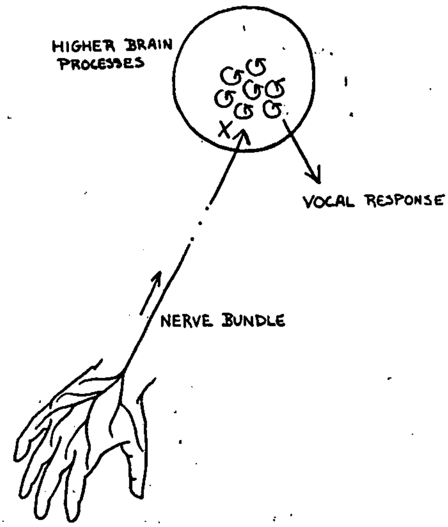

FIG. 1. To illustrate the relation between normal sensation and the phantom limb.

The ordinary memory image can be understood in much the same way. The central processes here may be excited associatively (i.e., the cell assemblies are excited by other assemblies instead of spontaneously firing afferent neurons), but in both cases we are dealing with a short circuiting of a sensory-perceptual-motor pathway. The *S* on holiday, seeing the ocean for the first time, remarks on the size of the breakers; reminded of the scene later he may say, "I can still see those waves." Though there is now no sensory input, the same central process, more or less, is exciting the same motor response—more or less. (What the differences may be we will consider later.) It is the same outward-looking mechanism that is operative, not introspection.

At least, it is not introspection in the sense of a special inward-looking mechanism of self-knowledge. Anyone may define the term to suit himself, and may use it when reports of private events such as endogenous pain and imagery are in question. My point is that such report does not transcend the rules of objective psychology, in which mental processes are examined by inference and not by direct observation. The primary basis of inference is the relation of overt behavior to present and past stimulation, but there is also a basis of inference about oneself from the appearance of the external world: I may, for example, conclude that I am color-blind if surfaces that others call green and red look alike to me. I also make inferences about the functioning of my visual system when I observe positive and negative after-images though my eyes are shut.

It is important to say also, with regard to a report of imagery, that one is not describing the image but the apparent object. This becomes clear if one observes the apparent locus of what one is describing. One does not perceive one's perceptions, nor describe them; one describes the *object* that is perceived, from which one may draw inferences about the nature of the perceptual process. In the case of imagery, one knows that the apparent object does not exist, and so it is natural to think that it must be the image that one perceives and describes, but this is unwarranted. The mechanism of imagery is an aberrant mechanism of exteroception, not a form of looking inward to observe the operations of the mind. So understood, the description of an imagined object has a legitimate place in the data of objective psychology.

WORKING DEFINITIONS

In what follows it will be necessary to distinguish between sensation and perception, without supposing that there is a sharp separation between them. The distinction is based primarily on physiological considerations but the psychological evidence is in agreement. *Sensation* is defined here as the activity of receptors and the resulting activity of the afferent pathway up to and including the cortical sensory area; *perception* as the central (cortico-diencephalic) activity that is directly excited by sensation as defined. For the purposes of this analysis, then, sensation is a linear input to sensory cortex, perception the reentrant or reverberatory activity of cell-assemblies lying in association cortex and related structures.

The term perception itself has two meanings in ordinary usage. Which of the two is intended is usually clear from the context, but when necessary I distinguish *perceiving,* as the process of arriving at a "perception," from a *percept,* the end product, the brain process that *is* the cognition or awareness of the object perceived. Except with very familiar objects, perceiving is not a one-stage, single-shot affair. It usually involves (*a*) a sensory event; (*b*) a motor output, the adjustment of eye, head, or hand to see, hear, or feel better; (*c*) the resulting feedback; (*d*) further motor output, further feedback, and so on. As we will see later, this is not a trivial point but must affect our understanding both of percept and of image.

Physiologically there is a discontinuity in the mode of operation of the afferent pathway to the sensory cortical area and the structures that lie beyond. The afferent transmission is highly reliable, whereas cortico-cortical transmission, the higher activity that includes perception as defined, occurs only in favorable circumstances. An evoked potential in sensory cortex is obtainable in coma or under anesthesia, but any transmission past this point is not sufficient to break up the synchronous EEG activity. Thus "anesthesia," meaning literally a lack of sensation, is a misnomer; we are dealing instead with a failure of transmission at a higher level.

As Teuber (1960) has pointed out, perception cannot be identified with an activity of sensory cortex, so the physiological basis of a distinction between sensation and perception is clear. Sensory systems are organized with fibers in parallel, providing for lateral summation and hence reliability of transmission at each synaptic junction. The divergent course of fibers from sensory cortex onward lacks this feature, and transmission here requires supporting facilitation from the brainstem arousal system, which is absent under anesthesia. The selectivity of response to sensory stimulation even in the normal conscious state strongly indicates that supporting facilitation is also needed from the concurrent cortical activity; except when there is a sharp increase of arousal, due to pain stimulation or certain unfamiliar events, we "notice," perceive, or respond to only those events in the normal environment that are related to what we are thinking about at the moment.

Finally, another relevance of the distinction between sensation and perception from a psychological point of view is the fact that different sensations or sensory patterns can give rise to the same perception, as in the perceptual constancies; and the fact that the same sensory pattern can give rise to quite different perceptions, as in the ambiguous figure (even with fixation of gaze). In this latter case, the only explanation that has been given is that different cell assemblies are excited by the input at different times.

THE PATTERN OF ACTIVITY

Both the ordinary memory image and the eidetic image arise from perception. As we will see, this does not mean that the memory image is identical with perception (though eidetic imagery may be), but it does have implications that have not been recognized. The percept of any but the simplest object cannot be regarded as a static pattern of activity isomorphic with the perceived object but must be a sequentially organized or temporal pattern. The same statement, it seems, applies to the memory image.

This has been well established for the image of printed verbal material (Woodworth, 1938, p. 42, citing Binet and Fernald). The *S* with good visual imagery may be asked to form an image of a familiar word of medium length ("establish" or "material" would be suitable). When he has done so, he is asked to read off the letters backward; or if *S* is one who reports that when he has memorized verse he can see the words on the page, he may be asked to recall a particular stanza and then to read the last words of each line going from bottom to top. With the printed word before him, spelling the word backward can be done nearly as quickly as forward, but this is not true of the image and the *S* who tries such a task for the first time is apt to be surprised at what he finds. There is a sequential left-to-right organization of the parts within the apparently unitary presentation, corresponding to the order of presentation in perception as one reads English from left to right and from top to bottom.

Something of the same sort applies with imagery of nonliteral material, though now the order of "seeing" or reporting is less rigid. If the reader will form an image of some familiar object such as a car or a rowboat he will find that its different parts are not clear all at once but successively, as if his gaze in looking at an actual car shifted from fender to trunk to windshield to rear door to windshield, and so on. This freedom in seeing any part at will may make one feel that all is simultaneously given: that the figure of speech of an image, a picture "before the mind's eye," in the old phrase, does not misrepresent the actual situation. But Binet (1903) drew attention to a surprising incompleteness in certain cases of imagery, which suggests a different conception. Let us consider the question more closely.

First, consider the actual mechanics of perceiving a complex visual object that is not completely strange but not so familiar that it can be fully perceived at a glance. Figure 2 represents a slightly off-beat squirrel or chipmunk. The eye movements made in perceiving it must vary, but assume that there are four points of fixation, *A, B, C,* and *D*. After fixating these points, perhaps repeatedly, the object is perceived with clarity: *one* percept is arrived at. But how are the separate visual impressions integrated?

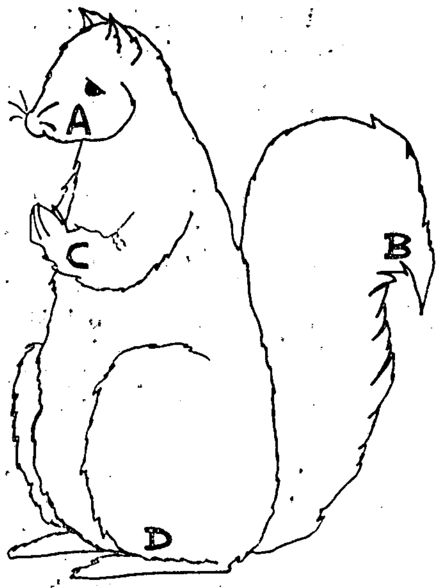

FIG. 2. To illustrate the role of eye movement in perception and imagery. (*A, B, C, D*, fixation points.)

We must take account of the fact that these four part-perceptions are all made in central vision, more or less on top of each other, though they are separated in time by eye movements. Each of the four is an excitation of a small group of cell-assemblies, which I will call for the moment Activity *A*, Activity *B*, and so on. These activities must take place in the same tissues, more or less intertwined. Activity *A* is separated from a following Activity *B* by an eye movement to the right and slightly downward; if Activity *D* occurs next, it is preceded by an eye movement downward and to the left; and so on. These movements are mechanically necessary in scanning the object, but they may have a further role.

In other words, the motor process may have an organizing function in the percept itself and in imagery. The image is a reinstatement of the perceptual activity, but consider the result if all four of the separate part-perceptions were reinstated at the same time. The effect must be the same as if, in perception, one saw four copies of Figure 2 superimposed to make Points *A, B, C,* and *D* coincide, in a mishmash of lines. Instead, Activities *A, B, C,* and *D* must be reinstated one at a time, the transition from one to the next mediated by a motor activity corresponding to the appropriate eye movement.

When looking at the actual object each part-perception is accompanied by three motor excitations (assuming these four fixation points) produced by peripheral stimulation. One of them becomes liminal and the result is eye movement followed by another part-perception. If the image is a reinstatement of the perceptual process it should include the eye movements (and in fact usually does); and if we can assume that the motor activity, implicit or overt, plays an active part we have an explanation of the way in which the part-images are integrated sequentially. In short, a part-image does not excite another directly, but excites the motor system, which in turn excites the next part-image. That there is an essential motor component in both perception and imagery was proposed earlier (Hebb, 1949, pp. 34–37) with some informal supporting observations that as far as I can discover are still valid. It is easy to form a clear image of a triangle or a circle when eye movement is made freely (not necessarily following the contours of the imagined figure), harder to do with fixation of gaze while imagining the eye movement, but impossible if one attempts to imagine the figure as being seen with fixation on one point. Though such informal evidence cannot carry great weight, it does agree with the idea that the motor accompaniments of imagery are not adventitious but essential.

Abstraction and Higher-Order Assemblies

One of the classical problems of imagery is the generality of the image. Another is its relation to abstract thought. A hypothetical clarification of such questions emerges from a consideration of the relation of secondary and higher-order assemblies to primary ones. There is a classical view going back to Berkeley that an image must be of a specific object or situation and cannot have generalized reference, but Woodworth (1938, p. 43) cites an early paper by Koffka to the contrary, and it seems that the view is more a consequence of theory (regarding the image as reinstated sensation) than of observation. But how can an image be general, or abstract? Again, Binet (1903, p. 124) reports an opposition between thought and imagery. The image, a representative process, is by definition an element in thought: How can we understand such an opposition?

The present status of the theory of cell assemblies is paradoxical, since it has a way of leading to experiments that both support and disprove it. An impressive confirmation from the phenomena of stabilized images (Pritchard, Heron, & Hebb, 1960) is matched by quite definite evidence, from the same set of experiments, that the theory is unsatisfactory as it stands (Hebb, 1963). Some of the difficulty for the treatment of perception becomes less with the proposal of Good (1965) that an assembly must consist of a number of subassemblies that enter momentarily now into one assembly, now into another. The assembly itself need no longer be thought of as all-or-nothing in its activity. Fading, for example, may be a function of the density of subassemblies active in a given region, and a strong stimulation may excite all the subassemblies that are available for a given assembly while a weaker stimulation excites fewer of them. A subassembly, conceivably, might be as small as one of Lorente de Nó's closed loops consisting of only two or three neurons.

It is, however, another aspect of the theory that concerns us now. This is the varying degree of directness of relation between a sensory stimulus and an assembly activity. The old idea that an image must always be of a specific object was the result of thinking (*a*) that an image is the reinstatement of a sensory-central process, and (*b*) that the central part of the process corresponds exactly to the sensory stimulation. The epochal work of Hubel and Wiesel (epochal certainly for understanding perception) shows that this may be true for some components of the central process but is not true for others. A "simple cell" in the cortex responds to a specific retinal stimulation, its receptive field permitting little variation; but "complex cells" respond to stimulation in any part of their larger receptive fields, upwards of half a degree of visual angle in extent (Hubel & Wiesel, 1968). A subassembly made up of simple cells, or controlled by them, will thus be representative of a very specific sensory event, but one made up of complex cells will incorporate in itself some degree of generalization or abstraction. Assembly activities accordingly may be more or less specific as perceptual or imaginal events.

The superordinate assembly (Hebb, 1949) takes the process of generalization or abstraction further. The primary or first-order assembly is one that is directly excited by sensory stimulation. The second-order assembly is made up of neurons and subassemblies that are excited, farther on in transmission, by a particular group of primary assemblies; the thirdorder made up of those excited by second-order assemblies. The theoretical idea is very similar to what Hubel and Wiesel have demonstrated experimentally for simple, complex, and hypercomplex cells; simple cells being those on which a number of retinal cells converge, complex cells those on which simple cells converge, and hypercomplex those on which complex cells converge. From this it may be concluded that the first-order assembly is predominantly composed of or fired by simple cells.

An artificial example to make this specific: Let us say an infant has already developed assemblies for lines of different slope in his visual field. He is now exposed visually to a triangular object fastened to the side of his crib, so he sees it over and over again from a particular angle. Looking at it excites three primary assemblies, corresponding to the three sides. As these are excited together, a secondary assembly gradually develops, whose activity is perception of the object as a whole—but in that orientation only. If now he has a triangular block to play with, and sees it again and again from various angles he will develop several secondary assemblies, for the perception of the triangle in its different orientations. Finally, taking this to its logical conclusion, when these various secondary assemblies are active together or in close sequence, a tertiary assembly is developed, whose activity is perception of the triangle as a triangle, regardless of its orientation.

How realistic is this proposal of complex processes developing further complex processes, in brain function? A heavy demand is made on the brain in the large number of neurons needed for what seems a simple perception. Two comments are in order. As Lashley (1950) observed, the same neuron may enter into different organizations, and many more "ideas" (considered as temporary organizations of neuron groups) are possible than the total number of neurons in the brain; an ideational element may be a phase in a constant flow of changed groupings of neurons. The second point is that there *are* limits on the process of elaboration. A secondary assembly may be the limit of capacity of the rat brain as far as triangles are concerned, for all the complexity of that small brain. The tertiary assembly, it seems, calls for a bigger brain. The rat is doubtfully capable of perceiving a triangle as a whole, even when it has a fixed orientation, and is *not* capable of recognizing a triangle when it is rotated from the position in which he was trained to respond to it. The young chimpanzee, however, or the 2-year-old child, recognizes the rotated figure easily (Gellerman, 1933).

Another example: The baby repeatedly exposed to the sight of mother's hand in a number of positions would develop subassembly and assembly activities corresponding to perceptions of parts of the hand, and then the whole hand, as seen in these varied orientations. As the hand is seen in motion, these assemblies would be made active in close sequence. Their combined effects, at a higher level in transmission, would be the basis for forming a higher-order assembly whose activity would be the perception of a hand irrespective of posture.

Although with present knowledge such proposals must be made in very general terms, they are not unreasonably complex in the light of the anatomical and physiological evidence that is available, and they do offer an approach to the otherwise mysterious abstractions and generalizations of thought. Human thought consists of abstraction piled on abstraction, of generalizations themselves based on generalizations, and if we are to accept the notion that thought is an activity of the brain we must explore the speculative possibilities of how this may occur.

The actual perception of an object, following this line of thought, involves both primary and higher-order assemblies. The object is perceived both as a specific thing in a specific place with specific properties, and as generalized and abstracted from—but not all of this simultaneously. In imagery, only part of this activity may be reinstated. First-order assemblies, directly excited by sensation, must be an essential feature of perception, but need not be active when the excitation comes from other cortical processes. A memory image, that is, may consist only of second- and higher-order assemblies, without the first-order ones that would give it the completeness and vividness of perception.

Eidetic Imagery

We are now in a position to consider a hypothesis of the nature of eidetic imagery. The eidetic image has been regarded with skepticism, I think, because as described it seems to have incompatible characteristics of both afterimage and memory image. Its occurrence only after stimulation, its transience, and its vividness in detail make it seem like an afterimage; but its apparent independence of eye movement, its failure to move as the eyes move and the possibility of "looking at" its different parts, to see them with equal clarity, means that it cannot be an afterimage. To the skeptic it sounds like an image that has got stuck to the viewing surface, which is unlikely to say the least. Part of the difficulty of understanding disappears if we first assume, with Allport (1928), that the eidetic image is in the same class with the memory image, and if we then recognize that eye movement has a positive integrating role in memory images. Now the scanning of the viewing surface becomes intelligible: As the eidetiker changes fixation from one point to another the motor activity helps to reinstate the corresponding part-percept.

It remains then to account for the detailed vividness of the eidetic image and my hypothesis proposes in short that the eidetic image includes the activity of first-order cell assemblies that are characteristic of perception but absent from the memory image. The idea finds support in the observation of Leask, Haber, and Haber (see Footnote 2) that the eidetic image may be strictly monocular when formed with one eye open, disappearing when that eye is closed and the other opened. It was proposed above that the first-order assembly is composed of (or controlled by) first-order cells most of which have monocular function (Hubel & Wiesel, 1968).

Since the eidetic image occurs only for a brief period following stimulation, one thinks first of the hypothesis as meaning that there is some after-discharge in the first-order assemblies. But this would imply the continued activity of all of them at the same time, whereas—as we have seen—the activity must be sequential and motor-linked. The hypothesis instead must be that the eidetiker has first-order visual assemblies which for some reason remain more excitable, for a brief period following stimulation, than those of other *S*s. It is possible, as Siipola and Hayden (1965) and Freides and Hayden (1966) have suggested, that the difference may be due to some slight brain damage. Other perceptual anomalies suggest, in turn, that one effect of brain damage may be to impair the action of inhibitory neurons in the cortex: neurons whose function is to "turn off" one perceptual (or imaginal) process when it is replaced by another (Hebb, 1960, p. 743). This inhibitory function, however—assuming it exists—is not entirely absent in the *S*s of Leask et al., in view of the ease with which the eidetic imagery could be prevented or disrupted.

The disruptive effect of new stimulation (as *S* looks away from the viewing surface) is intelligible if the subassembly components of the first-order assemblies are now excited in new patterns. Leask et al. also report that "thinking of something else" interferes with the formation of the image, and that the same effect results from verbalization in the attempt to memorize the picture's content. The theoretical implication is that higher-order assembly activity tends to interfere with some lower-order activity, if not by direct inhibition then possibly because the higher-order assembly utilizes some of the components of the lower-order one and thus breaks up its organization.

The central fact in this area is Haber's brilliant experimental analysis of eidetic imagery. The present speculation does nothing to extend his results, though it may help to reduce skepticism (for example, in showing how *S*'s eye movement may actively help in retrieving detail). Instead, his work serves here to provide solid experimental data whose import extends to a wider field in which trustworthy data are sparse indeed.

HALLUCINATION, HYPNAGOGIC IMAGE, AND MEMORY IMAGE

I wish therefore to conclude by taking account of hallucination and hypnagogic imagery, and relating them and the memory image to thought (or, properly, to other forms of thought).

The term hallucination is used here to include any spontaneous imagery that might be taken for a perception, even if *S* knows that he is not perceiving. A phantom leg, for example, is so convincing that the patient may not realize that the leg has been amputated; at this point it meets the criterion of hallucination in the narrower sense, since the patient is deceived, but it continues to have the same convincing character after the patient is informed of his loss and can see the stump of the limb. The nature of the process has not changed; if it was hallucination before, it is hallucination now. Similarly, the imagery of some *S*s in perceptual isolation (Bexton, Heron, & Scott, 1954) was such that they would have thought they were looking at moving pictures if they had not known they were wearing the occluding goggles. This must be hallucination also.

It was proposed above that the memory image lacks vivid detail because it is aroused centrally instead of sensorily. Hallucinations have a central origin also, but their vividness is not inconsistent with the above conclusion. If the cause of hallucinations is spontaneous firing by cortical neurons, the spontaneous firing may occur in first-order as well as in higher-order assemblies. In its vividness, and in its implication of activity by first-order assemblies, the hallucination is like the eidetic image though it is at the opposite pole in its relation to sensory stimulation, since it seems to depend on a *failure* of sensation. In normal waking hours there is a constant modulating influence of sensory input upon cortical activities, helping both to excite cortical neurons and to determine the organization of their firing. When this influence is defective for any reason—pathological processes, or habituation resulting from monotony or "sensory deprivation"—there is still cortical activity. Neurons fire spontaneously if not excited from without. The activity may be unorganized, and in the isolation experiments *S*s in fact were in a lethargic state much of the time, unable even to daydream effectively. But when by chance the spontaneous cortical firing falls into a "meaningful" pattern—when the active neurons include enough of those constituting a cell assembly to make the assembly active and so excite other assemblies in an organized pattern—*S* may find himself with bizarre thoughts or, if first-order assemblies are among those activated, with vivid detailed imagery.

The hypnagogic image, like the eidetic image and unlike hallucination, is an aftereffect of stimulation but there may be a gap of hours, instead of seconds, between stimulation and the appearance of the imaginal activity. It is characteristic of the period before sleep, but on rare occasions may happen at other times. K. S. Lashley once said that after long hours at the microscope watching paramecia he found himself, as he left the laboratory, walking waist-deep through a flowing tide of paramecia (somewhat larger than life-size!) For myself, true hypnagogic imagery is of the same kind though it occurs only before sleep, and is quite different from the ordinary slight distortions of visual imagery at the onset of dreaming and sleep. It depends on prolonged experience of an unaccustomed kind. A day in the woods or a day-long car trip after a sedentary winter sometimes has an extraordinarily vivid aftereffect. As I go to bed and shut my eyes—but not till then, though it may be hours since the conclusion of the special visual stimulation—a path through the bush or a winding highway begins to flow past me and continues to do so till sleep intervenes. The scenes have a convincing realism, except in one respect. Fine detail is missing. I see bushes with leaves on them, for example, but the individual leaf or bush becomes amorphous as soon as I try to see that one clearly, at the same time that its surroundings in peripheral vision remain fully evident. The phenomenon must be very much like the eidetic image, except in its time properties and its lack of fine detail.

The memory image does not share the peculiarities of these other forms of imagery, but it may still be more peculiar than is generally recognized. We have already seen that it lacks detail, due apparently to an inefficiency of associative mechanisms of arousal. We must now observe that the memory image is typically incomplete in gross respects as well. It frequently lacks even major parts of the object or scene that is imagined—though if one looks for them they show up at once and so, unless the question is made explicit, one may have the impression that the whole was present all along. Binet's 14-year-old daughter had the advantage of not being psychologically trained and not realizing how improbable her reports would sound. Asked to consider the laundress, she reported seeing only the lady's head; if she saw anything else it was very imperfect and did not include the laundress's clothing or what she was doing. For a crystalline lens, she saw not the lens but the eye of her pet dog, with little of the head or the rest of the animal; and for a handle-bar, all the front part of her bicycle but missing the seat and the rear wheel (Binet, 1903, p. 126.) To think of the memory image as the reinstatements of a single unified perceptual process makes such reports fantastic, but they are not all fantastic when the image is regarded as a serial reconstruction that may terminate before the whole perceptual process has been reinstated.

Incomplete imagery has a special relevance for ideas of the "self" (a mixture of fantasy and realism discussed elsewhere: Hebb, 1960). It is comprehensible of course that one can, with deliberate intention, imagine what one would look like from another point in the room—that is, one can have imagery of oneself as seen from an external point—but a less complete imagery may occur unintended and without recognition. Memory of floating in water commonly includes some visual imagery of water lapping about a face (if one recalls floating face up) or of wet hair about the back of the head (if face down). A long time ago I could introspect with ease and did so freely. Becoming aware that there were theoretical difficulties about introspection, I began to look at the process critically. Eventually I discovered to my astonishment that it included some imagery of a pair of eyes with the upper part of the face (*my* eyes and face) somehow embedded in the back of a head (*my* head) looking forward into the sort of gray cavern Ryle (1949) has talked about. Unfortunately this seemed so ridiculous that I rapidly lost my ability to introspect and now can no longer report on the imagery in detail. But such fantasy in one form or another may be a source of the common conviction that one's mental processes are open to inspection. The imagery is fleeting and unobtrusive and not likely to be reported even to oneself, being so inconsistent with one's ideas of what imagery is and how it works, but it may nonetheless be a significant determinant of thought.

The theoretical analysis earlier in this paper, in terms of lower- and higher-order assemblies, implies a continuum from the very vivid imagery of hallucination through the less vivid memory image to the completely abstract conceptual activity that has nothing representational about it. (This includes of course auditory—especially verbal—imagery as well as somesthetic imagery, and it must be wrong to make a dichotomy between visual imagery and thought, or to identify abstract ideas with verbal processes.) The ordinary course of thought involves an interaction of sensory input with the central processes—one looks at the problem situation directly, if it is available, makes sketches, talks to oneself—and the activity of the lower-order assemblies, in imagery, may have the same "semi-sensory" function of modulating the concurrent activity of higher-order assemblies. The relative efficacy of concrete nouns (names of imaginable objects as stimulus-words in paired-associate learning (cf. e.g., Paivio, 1969), together with the fact that pictures of such objects are still better, suggests something of the sort.

Once it has had its effect on higher activity the image may cease; it would be reportable only when it is persistent, tending to interrupt the ongoing thought process, or reinstated later without reinstatement of the whole thought process of which it was part. In this way it is possible to understand how bizarre imagery, of the kind involved in my introspection, might occur without being recognized, or how visual imagery might form an essential part of the cognitive map (Tolman, 1948) of a man driving a car through familiar territory, even for the man who believes that visual imagery plays no part in his planning. The difference between those who have little imagery and those who have much may be not a difference of the mechanism of thinking, but a difference in the retrievability of the image.

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