Donald O. Hebb  
(1904 - 1985)  

Chapter 14

2. B.A. from Dalhousie University with lowest GPA.
3. Went to McGill for his masters and completed it in 1932.
4. Did not think Pavlovian conditioning had much value.

5. In 1934, read Kohler’s *Gestalt Psychology* and Karl Lashley’s work on brain physiology.
6. In 1936, entered PhD program at Harvard under Lashley.
7. In 1942 joined Lashley at the Yerkes Laboratory of Primate Biology, in Florida.

[Image of Donald O. Hebb]
Donald O. Hebb

8. In 1948, accepted an appointment as a professor at McGill University and remained there till retirement.

Behaviorists and Brain

1. Behaviorists like Watson, Thorndike, and Hull argued that brain was merely a complex switchboard, that connected sensory events in certain regions of the brain to motor events.
2. Learning involved changes in neural circuitry so that stimulation now activated areas of the brain other than originally stimulated by sensory events.
3. If a part of the brain and connections between sensory and motor events were to be severed. Learning would be disrupted.

Karl Lashley

1. Born 1890, Davis, West Virginia.
2. Did his PhD in genetics at Johns Hopkins University, and was associated with John Watson.
3. In 1920 became an assistant professor of psychology at the University of Minnesota.
Karl Lashley

4. He became a professor at the University of Chicago (1929-35), Harvard University (1935-55) and finally director of the Yerkes Laboratories of Primate Biology Florida (1942-55.)

Lashley and Brain

1. Lashley's research expressed serious doubts on the idea that brain was a switchboard.
2. He showed that after learning (discrimination), certain brain areas could be destroyed, and yet the animal would relearn the task.

Lashley and Brain

3. The amount of brain destroyed was directly associated with disruption of learning came to be known as the principle of mass action.
4. Lashley (1950) also concluded that cortex functions as a whole. And that if one part of the brain is destroyed another takes over, called principle of equipotentiality.
5. Under Lashley's patronage Hebb developed most of his thinking and ideas.
Wilder Penfield

Hebb worked with Penfield at the Montreal Neurological Institute, and found that recovering patients with substantial loss of frontal cortex (20%), showed no loss in intelligence.

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Hebb’s Conclusions about Brain

1. Brain is not a switchboard. Because destroying parts of the brain did not lead to functional disruption in learning or intelligence.
2. Intelligence comes from experience, and therefore not genetically determined.
3. Childhood experiences (during development of the brain) are more important in determining intelligence than adulthood experiences.

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Restricted Environments

1. If adults have had little experience to develop their perception during early life, then any redemption of perceptual abilities may be remote.
2. When adult blinds regained their sight by cataract removal, they had difficulty discriminating a circle and a triangle (Von Senden, 1932), suggesting lack of early experience compromises perception.
3. With extensive practice these patients did learn to identify objects.
Restricted Environments

4. Similar results were observed in chimpanzees who were raised in darkness for two years. It was only with long exposure that these apes learnt to see again (Riesen, 1947).

5. Not only did the restricted environment work on the visual sense it was found that Scottish Terriers were oblivious to pain if raised in partial isolation during development (Melzack & Thompson, 1956).

Enriched Environments

1. To study the effects of restricted environment, Hebb carried out a number of comparison experiments that would test the animals in enriched environments.

2. So in 1949, he studied two sets of rats, one raised in his laboratory and the other at home by his daughters. Rats raised at home had more opportunities to play in the house, thus did particularly well on a series of detour and maze problems compared to lab animals.

3. Hebb’s experiments were followed by many others to show that rats raised in enriched environments became fast learners, with morphological changes in their brains, compared to those raised in impoverished environments (Rosenzweig et al., 1964).
Conclusions about Brain Plasticity

1. Intelligence, perception, and even emotions are learnt during early development.
2. Infants are born with random interconnections of neural networks. With sensory experience these networks become organized and provide effective interaction with the environment.
3. Effects of an impoverished environment are not permanent? Damage by restricted environment can be undone if conditions change for better. Thus no critical stage for recovery of function.

Neural Networks

1. How do neural networks become organized?
2. Hebb suggested that during perception complex arrays of neurons get stimulated in brain. The pattern of neuronal stimulation forms a cell assembly.
3. Whenever this cell assembly is stimulated we perceive that object.

4. How are cell assemblies formed? Axon of cell A proximal to cell B repeatedly fires to modify morphology and the metabolic patterns of the synapse, making it stronger (Hebbian synapse).
Cell Assemblies

1. Cell assemblies are dynamic, thus continuously leave and join other assemblies.
2. Formation of these assemblies may be based on both internal and external stimulation.
3. When a cell assembly fires in the absence of an object we experience thought.
4. A phase sequence is, “a temporally integrated series of assembly activities” and amounts to a stream of thought.

Kinds of Learning

1. One form of learning involves a slow buildup cell assemblies and phase sequences (early in life) and represents behavioral learning (as in S-R theories, Guthrie etc.). Objects and events in the environment get related at the brain level.
2. The second form of learning is more cognitive (Tolman) in nature. Adult learning often characterized by insight and creativity, and involves rearrangement of phase sequences.

Arousal Theory

1. Hebb working under Lashley studied fear in monkeys, and developed his arousal theory involving the functioning of the reticular activation system (RAS).
2. RAS processes sleep, attention, arousal and emotional behavior. Emotion (fear) inducing stimulus has a cue and an arousal function.
3. Cue function of the stimulus provides sensory information, and the arousal function activates the RAS.
Arousal Theory

4. Hebb believed that if the arousal function of the stimulus was optimal, cue function will have its full effect. Too low, the animal is sleepy or drowsy, too high and information relayed to the cortex results in confusion, response conflict and irrelevant behavior.

Arousal Theory

5. Clearly, performance is also dependent on cue and arousal functions of the stimulus. Low arousal (sleep) lead to poor performance and, high levels deteriorate concentration (Hebb & Donderi, 1987).

Arousal Theory

6. When arousal level is too high, decreasing it is reinforcing, and when too low, increasing it is reinforcing. Unlike Hull who equates drive reduction with reinforcement, Hebb’s theory (see Mowrer) equates reinforcement with either an increase or decrease in drive, depending on circumstances (Hergenhahn & Olson, 2005).
Nature of Fear: Observations
1. While working at Yerkes, Hebb studied fear in chimpanzees and observed:
2. Chimps showed no sign of fear until they were about four months old.
3. Did not fear completely familiar or unfamiliar objects. It was only when familiar objects were shown in unfamiliar ways that fear was generated.

Nature of Fear: Conclusions
1. Hebb argued, that fear in monkeys occurred because of disruption of learnt phase sequences about objects or individuals (monkeys or humans).
2. He also concluded that since fear was spontaneous in these animals it was not due to learned conditioned responses.

Sensory Deprivation
Hebb and colleagues (Heron, 1957) carried out experiments to investigate, if restriction of sensory experience during adulthood results in similar problems observed in adults who have been raised under restricted perceptual conditions all their life.
Sensory Deprivation: Results

1. College students were given $20.00 a day to lay in bed where they were deprived of sensory and motor activity. Food and water was given on demand along with use of the washroom.

Sensory Deprivation: Results

2. Most participants could stand such conditions for 2-3 days (6 days longest) only, and suffered a variety of mental and personality problems. These included:
3. Incoherent thinking, having difficulty solving simple problems, and hallucinations.
4. Some reported hallucinations included: procession of squirrels carrying sacks, prehistoric animals walking in the jungle, eyeglasses dancing down the street.

Sensory Deprivation: Conclusions

1. Hebb concluded sensory stimulation is important during and after development.
2. If sensory stimulation is blocked it results in disruption of psychological and mental function.
3. Like any other need (hunger, thirst, sleep) sensory stimulation is also a need and has to be fulfilled for the individual to function optimally.
It has been known for quite some time that we have two kinds of memories (James, 1890; Muller & Pilzacker, 1900). One is called short-term (or working memory) and the other long-term memory.

It was Hebb who provided physiological and anatomical proofs of these two kinds of memories. He called them transient and permanent memories.

The two memories can be schematically seen below:

- **Transient Memory**
  - Ongoing activity in cell assemblies & phase sequences
  - Short-term Memory

- **Permanent Memory**
  - Structural changes in the synapses
  - Long-term Memory

Sensory experience causes reverberating neural activity in transient memory that lasts 10 seconds.

The idea that short-term memory somehow translates into long-term memory is called consolidation.
Blocking Transient Memory

If rehearsal (reverberating neural activity) is blocked, transient memory is impaired. Brown (1958) Peterson and Peterson (1959) used this technique to measure the duration (18 sec.) of short-term memory.

Blocking Permanent Memory

1. If the process of consolidation is somehow blocked, permanent memory also gets impaired.
2. After learning to climb and avoid an electric grid, rats were given electric shock after various times. Immediate shock disrupted consolidation and long-term memory (Duncan, 1949).

Amnesia

1. It is believed that the hippocampus (limbic system) in the brain leads to consolidation of long-term memories. A surgical operation led patient HM to lose his hippocampi, and he suffered from anterograde amnesia, the inability to consolidate new memories after the operation.
2. When past events or memories cannot be recalled after traumatic experience retrograde amnesia occurs.
Tower of Hanoi

1. In procedural tasks like the tower of Hanoi, HM shows improvement over time, yet remains unaware that such learning has taken place.
2. Neuroscientists suggest that there are two different brain centers consolidate procedural memories (basal ganglia) and declarative memories (limbic system).

Minimum moves for four rings to move from tower A to C are 15. \(2^n-1\), where \(n\) = rings.

Hebb’s influence on Neuroscientific Research

James Olds

2. Olds with Peter Milner discovered reinforcement centers in the rat brain.
Reinforcement Centers

1. Olds and Milner (1954) working in Hebb's lab serendipitously discovered reinforcement (pleasure?) centers in the brain.

2. Weak electrical stimulation of these centers brought these animals (rats) back to the same place, where they were initially stimulated. Thus stimulation of these centers seemed reinforcing.

3. Olds and Milner (1954) trained rats to press a lever in an operant chamber which would give a mild electrical shock. The rats reinforced (self-stimulated) themselves by pressing bar for a long time.

4. The phenomena Olds and Milner (1954) discovered is related to activational and motivational properties of reinforcement.

Reinforcement from Direct Stimulation

Reinforcement by direct stimulation has some unusual characteristics and operate differently from primary reinforcers such as food or water (Hergenhahn & Olson, 2005).

1. No deprivation needed before training.
2. Satiation does not work.
3. Takes priority over other drives.
4. There is rapid extinction.
5. Most schedules of reinforcement do not work.
Role of Dopamine in Reinforcement

1. Recent research concerning reinforcement centers is focused on nucleus accumbens.
2. If stimulating electrodes in nucleus accumbens releases dopamine, the effect is reinforcing. If however, dopamine is not released, the effect is not reinforcing.
3. Thus many researchers believe that dopamine has an activational and motivational affect on reinforcement.

Role of Dopamine in Reinforcement

4. The motivational and hedonic effects of dopamine thus can be separated. Rats were trained to lever-press on continuous reinforcement. Dopamine was depleted. Rats continued to press lever for food, suggesting reinforcing properties of food were not diminished with dopamine depletion.
5. Similarly euphoric effects of drugs were not diminished when dopamine was blocked.

Non-associative Learning

1. Eric Kandel (1960s) experimented with invertebrates like aplysia and observed elementary learning.
2. If the siphon in the aplysia is weakly stimulated, the gill withdraws reflexively. If stimulation continues gill response habituates.
Habituation

3. Kandel reported that habituation of gill response was caused by a reduction in neurotransmitter release from the sensory neuron.

![Hypothetical Sensory Neuron Response](image)

Sensitization

4. After gill response habituates with repeated stimulation of the siphon, stimulation of tail leads to an exaggerated gill response (sensitization).

Long Term Potentiation (LTP)

1. As the neural mechanisms of non-associative learning in aplysia were worked out by Kandel, Bliss & Lømo (1966, 1973) showed comparable cellular mechanisms in the mammalian hippocampus that resembled a variety of learning forms all the way from classical conditioning to long-term memory (LTM).
LTP Experiment

2. Bliss and Lømo (1973) discovered long-term potentiation (LTP) in the hippocampus which is heightened neuronal activity that spreads in the dentate gyrus after sensory stimulation of the perforant path.

LTP and LTM

3. LTP is an associative form of learning that resembles long-term memory.
4. They both need synthesis of new proteins, and both can last for many months.
6. Like LTP, long-term depression (LTD) has also been observed in the hippocampus. LTD is a weak response in the hippocampus made to weak electrical stimulation.

Neuroplasticity

1. For many years it was believed that adult mammalian brain had relatively fixed and stable synaptic connections. These connections only changed with neuronal death or atrophy (Hergenhahn & Olson, 2004).
2. However it is now understood that even in the adult brain plastic changes in synapses continually occur.
Experience & Dendrites

1. Enriched environment leads to changes in brain weight, increased levels of neurotransmitters, and other morphological changes in the brain.
2. Two of these morphological changes in the brain are the length of dendrites and numbers of receptor sites on these dendrites.

Relearning after Brain Injury

1. For many years it was believed that adult mammalian brain had relatively fixed and stable synaptic connections. These connections only changed with neuronal death or atrophy.
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Complex Mechanisms

1. For many years it was believed that adult mammalian brain had relatively fixed and stable synaptic connections. These connections only changed with neuronal death or atrophy.
2. However it is now understood that even in the adult brain plastic changes in synapses do occur.
Roger Sperry

2. Masters in psychology (1937), PhD in zoology (1941) from the University of Chicago.
3. Sperry then did post-doctoral research with Karl Lashley at Harvard University.

Roger Sperry

4. He began work at the Yerkes (1942-46), started teaching University of Chicago (1946-52).
5. Became Section Chief of Neurological Diseases and Blindness at NIH (1952-54).
6. Professor at Caltech. Performed experiments with Gazzaniga.

Roger Sperry

7. Received Nobel Prize in 1981.
8. Died Apr. 17, 1994
Hemispheric Connections

1. Function of corpus callosum was poorly understood before Sperry. He showed that two brain hemispheres could accomplish different if disconnected.
2. In a series of experiments Sperry showed cats could learn a discrimination task with one eye (other eye patched), successfully perform the same task with the other eye later during testing.
3. Cutting the optic chiasm or corpus callosum made no difference to transfer of training.

Separate Hemispheres

4. However, when both optic chiasm and corpus callosum were disconnected no transfer of learning took place during testing.

Differential Learning

5. This kind of surgical separation of the hemispheres showed that animals could be differentially trained for learning tasks. Cats could be taught to approach one door with a cross with one hemisphere, and avoid the door with a circle, with the other.
Left Brain-Right Brain Differences

1. Neuroscientists have known about the language areas since the early 19th century (Dax, 1836; Broca, 1861; Wernicke, 1874).
2. Clinical studies have shown loss of left hemisphere is usually associated with language deficits and a comparable loss of the right brain with attention and perception malfunctions.

Left Brain: Language

3. Tests of brain asymmetry in normal individuals carried out by Kimura (1967) using dichotic listening, suggested that when sounds like ‘ga’ and ‘ba’ were simultaneously presented to the left and right ears... subjects reported hearing ‘ba’ which meant left brain dominance.

Left Brain: Language

4. Similar experiments using visual stimuli have shown left hemisphere association with language, e.g., normal subjects were unable to report seeing the word “cow” if it was presented to the right hemisphere.
5. Research on hemispheric differences has resulted into a lot of speculation. Where some believe that there are hemispheric dichotomies (Dichotomania) others think that differences are merely that of degree.

<table>
<thead>
<tr>
<th>Left Hemisphere*</th>
<th>Right Hemisphere</th>
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<tbody>
<tr>
<td>Intellect</td>
<td>Intuition</td>
</tr>
<tr>
<td>Convergent</td>
<td>Divergent</td>
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<tr>
<td>Realistic</td>
<td>Impulsive</td>
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<tr>
<td>Intellectual</td>
<td>Sensuous</td>
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<tr>
<td>Discrete</td>
<td>Continuous</td>
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<td>Directed</td>
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<td>Rational</td>
<td>Intuitive</td>
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<tr>
<td>Historical</td>
<td>Timeless</td>
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<tr>
<td>Analytic</td>
<td>Holistic</td>
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*Bogen, 1977

6. Gazzaniga (Sperry’s student) and LeDoux (1978) suggest that brain hemispheres may have different response skills but they perceive, learn and process information in the same manner.

New Connectionism

1. Neuroscientists have known about the language areas since the early 19th century (Dax, 1836; Broca, 1861; Wernicke, 1874).
2. Clinical studies have shown loss of left hemisphere is usually associated with language deficits and a comparable loss of the right brain with attention and perception malfunctions.
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### Evaluation

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<th>Criticisms</th>
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<tr>
<td>Hebb's greatest contribution is his idea that higher cognitive functions can be studied using single neurons and synapses.</td>
<td>What Hebb had to say about associations that take place in the brain during learning, were already put forth by Pavlov.</td>
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<tr>
<td>Therefore Hebb had important influence on the study of learning and motivation.</td>
<td>Did not change his theory in the light of new research in neurosciences.</td>
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<td>His theory is simple and elegant.</td>
<td>Hebbian synapse is excitatory in nature. Brain is largely inhibitory in nature.</td>
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### Questions

34. Discuss Lashley's concepts of mass action and equipotentiality?
35. Discuss switchboard conception of the brain. What was Hebb's opposition to such a conception and what did he offer as an alternative?