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S. Kaplan and L. L. Fu (1999) Making Room for Insight and Incrementalism in the Same Brain: The contribution of D. O. Hebb. *Psycoloquy*: 10(076).

MAKING ROOM FOR INSIGHT AND INCREMENTALISM IN THE SAME BRAIN: THE CONTRIBUTION OF D. O. HEBB

Book Review of Orbach on Lashley-Hebb

Stephen Kaplan
Department of Psychology
and Electrical Engineering and Computer Science
University of Michigan
525 E. University
Ann Arbor, MI 48109-1109
USA

Leeann L. Fu
Electrical Engineering and Computer Science
University of Michigan
1301 Beal
Ann Arbor, MI 48109-2122
USA
skap@umich.edu lfu@umich.edu

Abstract

Although their theories were in many respects similar, Orbach identifies two areas of difference between Lashley and Hebb: stimulus generalization and the nature of the learning process. Orbach favors Lashley; we point to reasons for believing that Hebb's position is the stronger one. Convinced that Hebb's theory was derived from Lashley and at the same time inferior to Lashley's, Orbach feels it necessary to explain that Hebb had greater impact because he was the better writer. We propose two additional explanatory factors, namely, that Hebb offered a synthesis of the associative and the cognitive, and that psychology in the decades following the publication of "The Organization of Behavior" was hungry for just such a synthesis.

Keywords

cell assembly, central autonomous process, engram, equipotentiality, Hebb, Hebbian learning, Lashley, localization, memory trace, nativism, reverberatory circuit, Vanuxem Lectures

1. Hebb was not an advocate of the "either-or" perspective. In his APA presidential address, "The American Revolution," Hebb (1960) decried the associative/S-R view that there was nothing more to mind than S's, R's and connections between them. At the same time, he objected to the view that everything was cognitive and that connections played no role in thought. Instead, Hebb suggested two roles for association: to help define what is cognitive by providing an explanatory basis for simple behaviors, and to provide an essential underpinning upon which to build a theory of cognition. This moderate, conciliatory view, as we shall attempt to demonstrate, fit the mood of psychology at the time - and is equally relevant today.

2. Orbach's (1998, 1999) argument in "The Neuropsychological Theories of Lashley and Hebb" supports an "either-or" stance, albeit indirectly. He argues that Hebb's (good) ideas came from Lashley and that where Lashley and Hebb differed, in general, Lashley's position was superior. In particular, from Orbach's perspective, Lashley's "cognitive" framework is correct and the associationist/connectionist one is wrong. Fortunately, Hebb showed us long ago that such an over-simplified approach was neither necessary nor appropriate.

3. We begin our analysis by focusing on stimulus generalization and the nature of the learning process, two areas where Orbach describes Hebb and Lashley as taking different perspectives. We then respond to Orbach's explanation for why Hebb was more influential than Lashley, despite what Orbach sees as Hebb's derivative (and inferior) framework. This part of the analysis deals with aspects of Hebb's contribution that Orbach does not fully appreciate, as well as historical factors which heightened the receptivity to Hebb's book.

4. Before proceeding, we should acknowledge that our perspective is colored by a long history (some 40 years) of applying Hebb's theory to diverse practical issues. Along the way, our group (SESAME, Seminar on Environmentally Sensitive Adaptive Mechanisms) has added new mechanisms to Hebb's remarkably adaptable framework. Many of these mechanisms have made it possible to interface the cognitive capacity of the organism with the demands and uncertainties of the physical (as opposed to social or linguistic) environment (Kaplan, Weaver & French, 1990; Kaplan, Sonntag & Chown, 1991; Chown, Kaplan & Kortenkamp, 1995).

I. STIMULUS GENERALIZATION

5. Orbach acknowledges Hebb's concept of stimulus generalization as a contribution to perceptual theory because it "proposed the startling idea that a simple figure like an outline triangle is not perceived as a whole, innately, as alleged by the Gestaltists." Hebb's cell assembly construct provides a mechanism for realizing this idea via an analysis of the parts (unlike the Gestalt position, which denied this possibility). The resulting percept is holistic and retains the benefits of Gestalt theory.

6. Lashley considered stimulus generalization to be an innate property of the system, arising from a failure to discriminate. While Orbach casts Hebb's conception as a different way to understand stimulus generalization, we feel that Hebb's analysis speaks to a problem of far greater significance. Hebb appropriately called this larger problem "perceptual generalization." Perceptual generalization is the capacity to appropriately place many different stimulus patterns in the same category despite enormous variability between the members of the category. A category conceived in this way is often referred to as a "natural category" (Rosch, 1977) since there is no fixed set of features that is necessary and sufficient for determining membership. Some other means of specification is thus necessary. The ability to form natural categories is not innate; it arises from perceptual learning.

7. Dreyfus (1972), in a thoughtful analysis of the challenge of perceptual generalization, suggests that rather than common traits, there may be a "complicated network of overlapping similarities" capable of assimilating ever new variations. The ill-defined boundaries of the resulting categories can be usefully conceptualized in terms of the concept of family resemblance (Rosch, 1977). With family resemblance, each of the category members overlap in features with some but not all other members of the category. Thus, some category members may have no features in common. Lashley's notion of generalization as a failure of discrimination cannot account for the ability to handle categories that are based on family resemblance. When there is a possibility that two members of a category may have no features in common, failure to discriminate would mean that for these two members to belong to the same category, that category would have to include everything.

8. Because excitation of a subset of associated features can cause an entire cell assembly to become active, Hebb's cell assembly provides a mechanism for handling family resemblance. It is important to recognize that the significance of this concept is not restricted to the process of categorization; if any useful role is to be played by information stored in memory, there must be a way to access it that is not dependent on a recurrence of the identical situation. Thus perceptual generalization (and the related ideas of natural categories and family resemblance) is not merely a nice addition, but an essential component of information processing in higher organisms.

II. THE NATURE OF THE LEARNING PROCESS

9. Lashley's (and Orbach's) reservations about associative learning represent a classic example of the "either-or" perspective. There are two key components of their arguments: (a) learning can occur in a single trial; and (b) the improvement in performance with practice (as in a rat's learning a maze or solving a jumping stand problem) is most appropriately construed as the outcome of a hypothesis-

testing process. Until the organism pays attention to (and hence generates hypotheses about) the appropriate portion of the stimulus configuration, no learning occurs. When insight does occur, it is all or none. (This is the noncontinuity side of what has been called the continuity-noncontinuity debate.)

10. An alternative view of learning might look something like this: (a) When two events occur close in time, some strengthening of the connection between the corresponding neural elements occurs. (b) The rate of learning is highly sensitive to increases in the level of arousal following the two events; arousal is seen as influencing the intensity of the consolidation process. (c) Reinforcement is one means of increasing arousal. (d) Hypothesis testing may occur in the learning process; incremental learning will occur whether or not hypothesis testing takes place. (e) Some stimuli are more potent than others; which stimulus is sampled will vary from trial to trial. The less potent the critical stimulus (or the harder it is to detect from the organism's vantage point), the slower the learning.

11. These statements are mutually compatible. They are also compatible with Hebb's theory (from which they were for the most part derived). While there are many examples, two studies may provide a useful illustration. Both studies looked at one-trial paired associate learning in which there was no instruction to learn. In the first study (Kleinsmith & Kaplan, 1963), both "arousing" and "non-arousing" words were paired with single digit numbers. Arousal was measured using skin resistance recording. The "high arousal pairs" (i.e., those to which the participant had the highest arousal) showed one-trial learning. This was purely a long term memory effect, demonstrated at either 45 min., 1 day, or 1 week after training. Memory for this material immediately after training was poor (presumably due to a fatigue effect resulting from intense consolidation). By contrast, "low arousal items" showed strong short term recall, but memory faded rapidly with minimal recall at the longer retention intervals. (The second study [Kleinsmith & Kaplan, 1964] was identical in procedure and results but used nonsense syllables rather than high and low arousal words.) There is little doubt that with repeated presentations the low arousal items would show greater strength of long term memory. The fact that some learning occurs in one trial does not mean that this is the case for all (or even most) learning.

12. Comparably, the innumerable studies (as reviewed in Melton, 1950; Goldstein, Krantz & Rains, 1965; Goodrich, Ross & Wagner, 1960) that have demonstrated a continuity effect do not substantiate that organisms never use hypotheses. Framing this issue as an "either-or" proposition may have been beneficial as far as the experimenters' adrenaline was concerned. It seems unlikely that it was beneficial if the goal is a broad theory of learning that can encompass both cognitive and non-cognitive factors. (Note to future theorists: when such a theory is attempted, attention should be paid to Hebb's analysis of early vs. late learning. Early learning tends to be slow and incremental. It provides the necessary basis for later learning, which is more likely to be fast and insightful.)

III. HEBB'S ACHIEVEMENTS IN CONTEXT OF THE TIMES

13. As Bruce (1996) pointed out, Hebb and Lashley had many opportunities for exchanging ideas during their years at Yerkes Laboratories. As many of us know, the development of one's ideas can benefit greatly from extended discussion with one's students and former students. This is particularly true in the case of highly capable and insightful students. There is every reason to believe that Hebb fit that description; it hardly seems appropriate to assume that all insight flowed in one direction. Moreover, anthropologists studying insight and innovation find far more support for Zeitgeist-based explanations than for the popular view that focuses on the uniqueness of the individual's contribution (Brady & Isaac, 1975).

14. Orbach's argument that Hebb's success can be attributed to his excellence as a writer fails to recognize both what Hebb did achieve and the tenor of the time. As Hebb pointed out in the "Instructor's Manual for the Textbook Of Psychology" (1958), "Our problem is to retain the great benefits of Gestalt theory while avoiding those aspects that are liabilities." He felt that the pattern of many introductory texts of the time, thoroughly behaviorist except for the perception chapter, was totally unacceptable. One could ask whether Hebb achieved his goal. When George Katona, one of the Gestaltists transplanted from Germany to the US before World War II, spoke in a graduate course I was taking in 1957, I asked him whether he felt Hebb had adequately dealt with the Gestalt phenomena. He responded "Hebb is one of the best Gestaltists."

15. To understand another of Hebb's achievements, it is necessary to appreciate the Zeitgeist at the time the "The Organization of Behavior" was published. Spence's (1949) review of the current status of learning in Steven's "Handbook Of Experimental Psychology" and Melton's (1950) chapter on learning in the first volume of "Annual Review Of Psychology" were remarkably similar. Both saw learning as a great battleground between Behaviorism and Gestalt represented by Tolman as well as Lashley). Both were convinced that Behaviorism was winning. In subsequent years, however, the fortunes of Behaviorism declined steadily. Harlow's (1949) work with monkeys epitomized the multitude of challenges that Behaviorism faced. In response to Harlow's findings, Spence was quoted as saying that rats and people were similar and that monkeys were a totally different kind of animal! By 1958, at a conference held at Northwestern University for the graduate students of prominent learning theorists, one of the attendees said that while he hoped Freud was not right, he felt that his own research with rats had no bearing on the understanding of human behavior. Behaviorism was losing its attractiveness; its narrowness had become burdensome. There was a yearning for a broader conception of behavior.

16. At the same time, however, an associative approach to understanding behavior was still attractive. Voss (1969) pointed out that psychology had long favored some sort of associationism, although what was to be associated had varied considerably over the years. A striking illustration of the desire to deal with broader issues from within an associative framework was the attempt by MacCorquodale and Meehl (1954) to translate Tolman's cognitive map theory into associative terms. But was it possible to broaden the scope of the theoretical framework and still preserve associationism? Hebb demonstrated that it was, and his 1949 book received a warm welcome. (Hebb once told me he was quite surprised by its reception. He commented that he would not have written it quite the way he did had he known how well it would be received.)

17. The importance of Hebb's achievement for psychology was enormous. Attneave (1962), an early and powerful force in the cognitive revolution, reflected this clearly in his overview of work on perception in Koch's "Psychology: The Study Of A Science": "Many psychologists who still feel some identification with the behaviorist movement are - in terms of their own behavior - steering back into the main stream of American psychology, the broad associationism that is perhaps best represented, over several generations, in the thinking of William James, R. S. Woodworth, and D. O. Hebb" (p. 649).

18. Thus it could be argued that Hebb achieved far more than he intended. His central construct, the cell assembly, has the following properties: (a) it accounts for perceptual generalization; (b) it makes possible the collecting together of many experiences into a coherent, simplified pattern; (c) it offers a credible description of how the information can be acquired and stored by the organism, and (d) it provides a useful account of how the appropriate mental structures can be accessed from the environment as well as internally.

19. These are, as it turns out, the properties essential to creating an internal representation, the basic cognitive unit that fueled the cognitive revolution. Hebb's cell assembly not only manages to achieve all this, but to achieve it without the loss of the vast research base on the role and usefulness of associations and associative learning.

20. The subtitle of Orbach's book is "Contemporary Perspectives Fifty Years after Hebb's Organization of Behavior." Making a contemporary assessment is particularly difficult with Hebb's document. During the decade after its publication, when it was so well received and appeared on so many psychologists' bookshelves, it was far more appreciated than incorporated. It justified research by psychologists with an associative bent in areas once off limits, but its substantive impact on their research agenda was less evident. In later decades Hebb's masterpiece has fallen out of favor many times. One of the most remarkable characteristics of this work is its durability. In recent years, Hebb's contribution slipped into the background again. Or so it seemed until Tang et al. (1999) brought it once more to the forefront. Their work, "Genetic enhancement of learning and memory in mice," provides a stunning confirmation of the centrality of the basic associative mechanism throughout the brain and across many different kinds of learning. Once again Hebb's seminal work (and the associative perspective it helped bring into the modern era) is at the forefront of research and theory about the workings of the mind.

REFERENCES

Attneave, F. (1962) Perception and related areas. In S. Koch (Ed.) Psychology: A study of a science, Volume 4. (pp. 619-659). New York: McGraw-Hill.

Brady, I.A. & Isaac, B.L. (1975) A reader in cultural change. Vol. I: Theories. Cambridge, MA: Schenkman.

Bruce, D. (1996) Lashley, Hebb, connections, and criticisms. Canadian Psychology, 37, 3, 129-136.

Chown, E. Kaplan, S. & Kortenkamp, K. (1995) Prototypes, location, and associative networks (PLAN): Towards a unified theory of cognitive mapping. Cognitive Science, 19, 1-51.

Dreyfus, H. L. (1972) What computers can't do: A critique of artificial reason. New York: Harper and Row.

Goldstein, H., Krantz, D.L. & Rains, J.D. (1965) Continuity vs. noncontinuity learning. In H. Goldstein, D.L. Krantz & J.D. Rains (Eds.) Controversial issues in learning (pp. 345-348). New York: Appleton-Century- Crofts.

Goodrich, K.P., Ross, L.E., & Wagner, A.R. (1960) An examination of selected aspects of the continuity and non-continuity positions in discrimination learning. Psychological Records, 11, 105-117.

Harlow, H.F. (1949) The formation of learning sets. Psychological Review, 56, 51-65.

Hebb, D.O. (1949) The organization of behavior. New York: Wiley.

Hebb, D.O. (1958) Instructor's Manual for Textbook of Psychology. Philadelphia: Saunders.

Hebb, D.O. (1960) The American revolution. American Psychologist, 15, 735-745.

Kaplan, S., Sonntag, M. & Chown, E. (1991) Tracing Recurrent Activity in Cognitive Elements (TRACE): A model of temporal dynamics in a cell assembly. Connection Science, 3, 179-206.

Kaplan, S., Weaver, M. & French, R. M. (1990) Active symbols and internal models: Towards a cognitive connectionism. AI and Society, 4, 51-71.

Kleinsmith, L.J. & Kaplan, S. (1963) Paired associate learning as a function of arousal and interpolated interval. Journal of Experimental Psychology, 65, 190-193.

Kleinsmith, L.J. & Kaplan, S. (1964) The interaction of arousal and recall interval in nonsense syllable paired-associate learning. Journal of Experimental Psychology, 67, 124-126.

MacCorquodale, K. & Meehl, P.E. (1954) Edward C. Tolman. In W.K. Estes, et al. Modern Learning theory: A critical analysis of five examples (pp. 177- 266). New York: Appleton-Century-Crofts.

Melton, A.W. (1950) Learning. Annual Review of Psychology, 1, 9-30.

Orbach, J. (1999) Precis of: The Neuropsychological Theories of Lashley and Hebb. PSYCOLOQUY 10(23). ftp://ftp.princeton.edu/pub/harnad/Psycoloquy/1999.volume.10/ psyc.99.10.029.lashley-hebb.1.orbachhttp://www.cogsci.soton.ac.uk/cgi/psyc/newpsy?10.029

Orbach, J. (1998) (Ed.) The neuropsychological theories of Lashley and Hebb. University Press of America.

Spence, K.W. (1951) Theoretical interpretations of learning. In S.S. Stevens (Ed.) Handbook of experimental psychology (pp. 690-729). New York: Wiley.

Rosch, E. (1977) Principles of categorization. In E. Rosch & B. Lloyd (Eds.) Cognition and categorization (pp.27-48). Hillsdale, NJ: Erlbaum.

Tang, Y-P, Shimizu, E., Dube, G.R., Rampon, C., Kerchner, G.A., Zhuo, M. Liu, G. & Tsien, J.Z. (1999, 2 Sept) Genetic enhancement of learning and memory in mice. Nature, 401, 63-69

Voss, J.F. (1969) Associative learning and thought. In J. F. Voss (Ed.) Approaches to thought. Columbus, OH: Merrill.