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CONTRIBUTIONS OF HEBB AND VYGOTSKY TO AN INTEGRATED SCIENCE OF MIND

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Abstract

Hebb and Vygotsky are two of the most influential figures of psychology in the first half of the 20th century. They represent cultural and biological approaches to explaining human development, and thus a number of their ideas remain relevant to current psychology and cognitive neuroscience. In this paper we examine similarities and differences between these two important figures, exploring possibilities for a theoretical synthesis between their two literatures, which have had little contact each other. To pursue these goals the following topics are discussed: 1) Hebb and Vygotsky's lives and training; 2) their innovations in theory building relating to an "objective psychology" and objective science of mind, 3) their developmental approach, 4) their treatment of mediation and neuropsychology and 5) their current relevance and possible integration of their views. We argue that considering the two together improves prospects for a more complete and integrated approach to mind and brain in society.

Keywords

Development; Hebb; Cell-assembly; Integrated science of mind; Luria; Mediation; Mind and mental activity; Neuropsychology; Vygotsky

Two approaches to the development of the human mind have strongly influenced current psychology and cognitive neuroscience. One involves the experimental study of the brain, including how brains are able to support mental activities and representations. Insofar as this approach avoids extreme reductionism, it leans heavily upon the work of Donald O. Hebb (1949). The major idea of this approach is that brains consist of cells, and that in the course of development, assemblies of cells, often called networks, are formed with repeated stimulation (Johnson, 2011). A second approach to development points to the importance of culture in shaping mind and behavior through language, imitation and learning, often called an apprenticeship model (Rogoff, 1990; 2003). This approach is most closely associated with Lev S. Vygotsky. In the Vygotskian view socialization by parents, peers and society through language strongly influences the child's thought and behavior.

Followers of these two schools of thought recognize in an abstract sense that nature and nurture interact at all levels, and that development is at once biological and social. However,

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it is as rare for neuroscience treatments of mind to mention Vygotsky (Gazzaniga, Mangun & Ivry, 2008; Johnson, 2011) as it is common for them to deal with Hebb. The reverse is true of discussions of cultural development (Rogoff, 2003).

The separation of these two approaches is so complete that it is difficult to combine and integrate the two (Sternberg & Grigorenko, 2001; Posner & Rothbart, 2007). Nonetheless, Vygotsky showed his appreciation of the biological approach in his study of medicine and in his neuropsychological work with Alexander Luria. Hebb in turn wrote introductory textbooks (Hebb, 1958; 1966; 1972) that covered the full range of psychology, emphasizing the development of mind and mental activity within a common biological framework. Important to linking the two is the work of Alexander Luria (1973), a student and co-worker of Vygotsky and a founder of the neuropsychology that included Hebb's work. Luria's role in neuropsychology is of central importance, but it is his connecting Vygotsky's theories of the mind to the brain's hardware that is a central focus of our paper.

This paper documents the efforts of Vygotsky and Hebb to lead their followers toward more integrated theory. We begin with a short history of their intellectual life and training, then consider the common elements of their theories and attempts to propose a developmental neuropsychology, and finally consider implications for current efforts at integration.

Lev S Vygotsky Biography and Training

Lev Semionovich Vygotsky was born in Orsha, a small town in Belarus, into a well-educated family of Jewish ancestry, on November 17, 1896, the same year as the birth of Jean Piaget and 8 years before the birth of Hebb. Vygotsky's family moved to the city of Gomel, and after attending the gymnasium, he entered the University of Moscow in 1912. Initially he studied medicine, but then switched to law, philosophy and history. After graduating from the University of Moscow in 1917 (the year of the October Revolution), Vygotsky returned to Gomel, where he taught psychology in a teachers' college, worked with handicapped children and pursued his interest in the psychology of art. In Gomel, he married Rosa Smekhova, and they had two daughters.

Vygotsky was 21 years old when the 1917 Revolution broke out. As Luria (1979) states "... my entire generation was infused with the energy of revolutionary change ..." (p. 17). By training, Vygotsky was a literary critic, whose dissertation was a critical analysis of *Hamlet*. His work at a teachers college also brought him into contact with the problems of children who suffered congenital defects. He recognized the need to help these children develop new ways of adaptation. In the course of this practice, he became interested in academic psychology, but his main work in psychology as a science started in 1924.

His first appearance in psychology circles was on January 6, 1924, at the Second All-Russian Psycho-neurological Congress in Leningrad, where one of his presentations was titled "Methods of Reflexological and Psychological Investigation." (Vygotsky, 1994a). This presentation led Kornilov (1930), the newly appointed director of Moscow Institute of Psychology, to invite Vygotsky to join the Institute. In 1924, Vygotsky moved to Moscow and started to work on psychological research and restructuring the Psychology Institute.

This turning point separates two major periods of Vygotsky's life: Vygotsky as a teacher with wide interests in history, literature, philosophy and art and Vygotsky as a scholar, psychological theorist and researcher. The years between 1924 and 1934 (his death) were the period of actualization of Vygotsky's ideas about different branches of psychology, including the development of thought and language, remediation, cognitive processes, and most importantly, the reformulation of psychology in the service of what he hoped would be a new kind of society (Vygotsky, 1994b). He was a supporter of the Russian Revolution and

believed that socialism could improve the life and social conditions of all people (van der Veer & Valsiner, 1991).¹

Vygotsky was almost a self-trained psychologist, influenced by the “Soviet” tradition of psychology as formulated in the works of Sechenov, Pavlov, Bekhterev, and Kornilov on the one hand, and the Russian Formalists such as Victor Shklovsky, Roman Jakobson, and Lev Jakublisky (Kozulin, 1990, ch.1), on the other. The role of Sabina Spielrien and the Moscow psychoanalytic society in advancing Vygotsky’s career in Moscow has been documented by Etkind (1997).

Another important aspect of his approach was the influence of Marxist thinking about humans, social structure and the process of change (Robins, 2001; Gredler and Shields, 2008). This aspect is mostly recognized in his analysis of higher order psychological functions in general and in particular the relationship between thought and speech. However, there were thinkers beside Marx who influenced Vygotsky’s ideas. Among these Spinoza, Hegel and Nietzsche are most important. Spinoza’s work on emotion, Hegel’s ideas of change and Nietzsche’s idea of the role of culture in human nature were all reflected in Vygotsky’s writings (Vygotsky, 1994a, Etkind, 1997; Gredler & Shields, 2008;).

Vygotsky had acquired a nearly encyclopedic knowledge of the social sciences, literature, and the arts (Wertsch, 1987; Kozulin, 1990). He developed an approach to psychology called the cultural-historical approach, which over recent decades has influenced many scholars and researchers. He died of tuberculosis at 37, leaving about 270 unpublished manuscripts and having trained researchers who would become eminent psychologists in the Soviet Union. Despite his early death, he has been ranked as the eighty-third most eminent psychologist of the twentieth century (Haggbloom, Warnick, and Warnick, 2002).

Although a contemporary of Watson, Pavlov, Freud and Piaget, Vygotsky’s work never attained their level of eminence during his lifetime. Part of this was because his work was often criticized and suppressed by the Soviet government’s ban on pedology (the study of child development), making his writings largely inaccessible to the Western world. Despite this, Vygotsky is considered a seminal thinker in psychology, his work has continued to grow in influence since his death and is still being discovered, translated and explored (van der Veer & Valsiner, 1991) Lima, 1995; Ghassemzadeh, 2009; van der Veer & Yasnitsky, 2011).

Much of the recent interest in Vygotsky in the US has been due to research on the influence of culture on the formation of higher level thought processes, but Vygotsky also had a real interest in neurology and neurological bases of behavior. This interest was in part related to the general atmosphere in the medical sciences as influenced by Pavlov and German physiologists. It was also related to Vygotsky’s experience as a teacher of those with learning disabilities and his clinical work with Luria on aphasia and Parkinson’s disease. His ideas about the brain and neurology were not based on any strict experimental and/ or clinical work, and he did not have systematic training in neurology or psychology. But through his close relation with students and colleagues such as Luria and Leontiev, he was able to build a significant body of psychological and neuropsychological knowledge.

In an article entitled “L. S. Vygotsky and the problem of functional localization”, Luria (2002) argues that Vygotsky’s research of the late 1920’s into the development of higher mental functions, the changes occurring in these functions under abnormal conditions, and

¹For the readers interested in learning more about Vygotsky’s life, his daughter’s memoirs (1995a, 1995b), Yaroshevsky’s (1989) detailed account of his life and ideas, Luria’s (1979) chapter on his formulation of Soviet psychology, and Kozulin’s (1990) biography of ideas are interesting and informative.

their disintegration in the presence of cerebral injury laid the foundation for a new area of science, neuropsychology. Vygotsky's last work, published posthumously, "Psychology and the Localization of Mental Functions", was a program for investigating the functional organization of the human brain as the organ of consciousness (Luria, 2002, p. 23). Akhutina (2003) also considers this work as a "neuropsychological testament". Luria (2002) believed that "Vygotsky's ideas radically changed our view of the nature and structure of mental processes" (p.19). Mental functions assumed to be fixed and immutable by many psychologists were transformed by Vygotsky into complex and mobile functional systems that change during development and learning.

Vygotsky's major introduction into the United States was through the work of two American scholars, Eugenia Hanfmann and Gertrude Vakar, who provided an abridged version of the original *Thought and Language* in 1962 with an introduction by Jerome Bruner. But it was the Kasanin-Hanfmann (Vygotsky) Test of the individual's ability to use abstract concepts that brought his name into the textbooks of testing and educational psychology. This was the main reason that Vygotsky was originally considered mostly as an educational psychologist in the United States and many European countries, with his work in the area of neuropsychology little recognized before the publication of his collected works in 1997-1999.

Donald O Hebb Biography and Training

Donald O Hebb was born on July 23, 1904 in the town of Chester, Nova Scotia in Canada. He was raised by his physician parents and educated at Dalhousie, earning the B.A. degree in English (1925). He started to teach in public schools and had an ambition to be a novel writer. He did not succeed in novel writing, however, and spent one year harvesting on a farm in Alberta, and then laboring in Quebec. His reading of Sigmund Freud at this time led Hebb to become a psychologist. He was accepted as a part-time graduate student at McGill University and earned his M.A. in psychology there in 1932.

While recovering from a tubercular infection of the hip in 1931, Hebb studied Sherrington's *The Integrative Action of the Nervous System* (1906) and Pavlov's *Conditioned Reflexes*, which had been translated into English in 1927. Influenced by these two prominent researchers, his theoretical master's thesis was titled *Conditioned and Unconditioned Reflexes and Inhibition*, which he regarded as a "prelude" to the Hebb synapse.

During 1933-1934, Hebb wrote an unpublished booklet entitled *Scientific Method in Psychology: A Theory of Epistemology Based on Objective Psychology*, in which many ideas of the *Organization of Behavior* (1949) and *Essay on Mind* (1980) were first proposed. Becoming increasingly interested in physiological psychology, Hebb decided to leave Montreal, because most of the McGill faculty were engaged in testing and educational psychology. Based on Babkin's (a former student of Pavlov who later joined the Physiology Department of McGill) suggestion, he applied to work with Karl Lashley at the University of Chicago. Lashley accepted him as a Ph.D. student, but had meanwhile decided to join the Harvard University's Psychology Department. Hebb also moved to Harvard, and in 1936 he submitted a thesis on the vision of rats reared in darkness for the Ph.D.

Later, Hebb applied for a job under Wilder Penfield, the famous neurosurgeon and founder of the Montreal Neurological Institute (MNI), who was looking for someone to study the psychological effects of brain operations. From 1937 to 1939 he worked with patients and published papers concerning the functions of the frontal lobes. Hebb left the MNI in 1939 and found a permanent position at Queen's University in Kingston, Ontario. After 1939 he did not study patients again until 1947, when he returned to McGill. Hebb collaborated with Penfield through his (Hebb's) students and colleagues, including Mortimer Mishkin, H.

Enger Rosvold, and Brenda Milner. Milner followed up Hebb's ideas on the frontal lobes, and extended them to explore the effects of temporal lobe and hippocampal lesions, most famously with patient H.M.

Hebb's thinking about the frontal lobes and their role in intelligence inspired his quest for a theory of the brain and intelligent behavior. For this purpose he started to work on rats as an animal model amenable to study with the lesion method. At Queen's University, Hebb and his student Kenneth Williams designed a variable path maze called the Hebb-Williams maze, which has since been used in numerous studies of learning in animals (Milner, 1993, p. 126). To determine the effects of early experience on learning, Hebb used this and other tests to examine the function of rats blinded at different ages. He also compared rats reared as pets at home and rats reared in laboratory settings. These studies showed that enriched experience during development resulted in improved maze learning in adulthood.

Hebb also showed that the effects of brain damage on the development of intelligence depended on the age when the damage occurred (Hebb, 1942; Brown & Milner, 2003, p. 1015). Hebb's stress on the importance of experience for brain development was similar to Vygotsky's position and is also present currently in the study of brain plasticity. But as Milner (1993) indicates, the concept was too advanced for its time; in 1940 most psychologists defined intelligence as a primarily innate characteristic (p. 126).

After leaving Queens in 1942, Hebb joined the Yerkes Laboratories of Primate Biology as a research fellow where he completed the manuscript of a book, eventually published under the title of *The Organization of Behavior* (1949). In this book he proposed and outlined a new way of looking at brain and behavior. In 1947, he came back to McGill as a professor of psychology, serving as chairman of the department (1948-1959), Vice-Dean for Biological Sciences (1964- 1966), and finally Chancellor of the University (1970-1974).

Hebb died on 20 August, 1985. He was survived by two daughters; both by his second marriage (see Brown and Milner, 2003). Hebb has been ranked as the nineteenth most eminent psychologist of the twentieth century (Haggbloom, Warnick, & Warnick, 2002), but as Brown and Milner (2003) have indicated, a greater awareness of what we owe to Hebb should increase this ranking substantially (p. 1918).

In addition to *The Organization of Behavior*, Hebb wrote the *Textbook of Psychology* and *Essay on Mind*. His *Textbook of Psychology* (1958, 1966, 1972) may be regarded as one the most influential textbooks of 1960's and 1970's. It is a very well-written book, concise and organized. Despite its brevity, it covered most of the topics in psychology and as Hebb argued in the preface to its first edition (1958), provided a critical understanding of psychology. The Hebb synapse, cell assembly and phase sequence are compatible with modern views of human brain function from both cellular and neuroimaging studies. Of particular interest is the importance Hebb placed on genetic and experiential influences on development. It has been argued that Hebb's constructs provide a reasonable basis for the integration of topics in psychology, including individual differences, clinical, developmental and social aspects of the field (Posner & Rothbart, 2007).

In the next section, we consider how Hebb and Vygotsky were both trying to build a theory different from or even opposed to the mainstream trends of the psychology of their time. Despite similar goals, however, Hebb and Vygotsky's social and political milieus were totally different. While Hebb grew in more or less stable political and social conditions, Vygotsky experienced enormous political, social and economic change, and felt himself as a part of the revolution. There was also a vast difference in their training. Hebb was a well-educated psychologist who had the opportunity to work directly under famous psychologists

such as Lashley and others. Vygotsky, on the other hand, was mostly a self-trained psychologist with knowledge in many areas of the humanities and social sciences.

Building A New Psychology

A major concern of Vygotsky was reformulating psychology in accord with the strong emphasis on its societal aspects related to the 1917 Revolution. Rejecting the dominant positions of the time, Vygotsky's position was that neither the subjective or mentalistic psychology of Chelpanov (the founder of the Moscow Institute of Psychology) nor the oversimplified psychology of reflex or reaction (Bekhterev and Kornilov's views) would lead to a satisfactory model of human psychology. Vygotsky argued that previously psychology had studied mind without behavior, but now it studied behavior without mind. In both cases, "mind" and "behavior" were understood as two distinct and separate phenomena. Vygotsky's new psychology was designed to overcome the conceptual isolation of behavior, mind, and consciousness (Vygotsky, 1997). In his view a general psychology would combine objective approaches to mind and behavior with appropriate philosophical approaches.

Psychology for Vygotsky had a core that could bring many different ideas and concepts together. In *Thought and Language*, one of the best representatives of his works, one can find constructs and explanations from psychology, history, linguistics, philosophy, anthropology and other disciplines woven together to present a multi-disciplinary approach to mind (Wertsch, 1987, p. 932). His analysis of mind and cognitive processes was built on the study of the inter-relation of thought and language. The unit of analysis for him was word meaning, which undergoes many changes in different stages of development. By unit he means a product of analysis that retains all the basic properties of the whole and cannot be further divided without losing them. He believed that such a unit can be found in the internal aspect of the word, word meaning, which contains all the elements needed for verbal thought. Vygotsky concludes that "psychology, which aims at a study of complex holistic systems, must replace the method of analysis into elements with the method of analysis into units" (Vygotsky, 1986, p. 5).

Hebb was also concerned with creating a new theory in psychology. In the middle decades of 20th century, the dominant trend of psychology in North America was behaviorism and Hebb had been raised in this atmosphere. He was inspired by the works of Thorndike, Watson and Skinner on the one hand, and Sherrington and Pavlov on the other. But over the course of his career, he moved away from behaviorism as well as reflex theory and argued that thoughts are processes requiring explanation that goes beyond stimulus-response (S-R) formulations. As a graduate student he started to work in the Pavlovian paradigm. This interest was reflected in his theoretical M.A. thesis entitled "Conditioned and Unconditioned Reflexes and Inhibition". Later his involvement in physiological psychology went beyond Pavlovian methodology and experimentation.

Hebb's main concern was to provide a scientific explanation for higher mental processes such as perception, thinking, and voluntary behavior. In the last chapter of his *Textbook of Psychology*, Hebb provided a clear idea about his perspective on objective psychology. He related behavioristic ideas of his time to an implicit assumption that the nervous system is a set of paths running from receptor to effector, or one-way streets, "no back connections, no feedback within the system, no loop circuits in which an excitation could maintain itself without sensory stimulation (Hebb, 1972, p. 277). Hebb was looking for a neurological and/or neurophysiological theory that could explain such connections and loop circuits. His theory of cell-assemblies and phase sequences provided those capacities.

An Objective Science of the Mind

Vygotsky and Hebb were both concerned with creating an objective science of the mind. The two showed similarities in that Vygotsky was influenced by the Russian tradition of reflexology emphasizing the requirement for science, including psychology, of adopting objective methods of investigation. This had clear resonance with Hebb's physiological psychology. However, Vygotsky's analysis of the most complex forms of thought that were uniquely the subject of psychology went further to include the study of historical, social and cultural factors as explanations of behavior.

Vygotsky argued that the higher mental functions originate in the social history of man. In forming society and using tools, men created new, indirect relationships to the external world, which they had formerly accommodated themselves to and which they now controlled through tool use. The formation of language during the development provided man not only with a new way of communication but also with a new tool for regulating one's own mental processes. Based on this approach, Vygotsky analyzed the role of speech in the development of higher cortical functions. This analysis provided him with a methodology that he considered as an objective method in the study of psychology (Luria, 2002).

Objective psychology for Hebb was behavioristic in the sense that it was based on public or objective evidence, as contrasted with introspection or other subjective methods (1972, p. 306). What people do can be observed by others, and agreement concerning the facts is possible at least in principle. Hebb included all behavior that permitted a reliable inference that something is happening in the mind. For him speech, including reports of subjective experience, is a form of behavior. Behavior can tell us what is going on in the mind only when we take account of the circumstances in which it occurs (1972, pp. 13-15).

A Developmental Science of the Mind

One of the most important contributions of Hebb and Vygotsky to psychology was their emphasis on development. Most of the textbooks of developmental psychology have considered Vygotsky's theory to be a very important contribution to the field (e.g. Miller, 2009), and Wertsch and Tulviste (1996) have discussed the relevance of his theory to contemporary developmental psychology.

Although less well known, a developmental approach is also evident in Hebb's thinking and research. As discussed previously, Hebb's rat studies showed that enriched experience during development resulted in improvements in adulthood, and he concluded "there is a lasting effect of infant experience on the problem-solving ability of the adult rat" (Hebb, 1947, 9. 307). These ideas formed the basis of developmental plasticity, one of the most powerful concepts in developmental psychology. This idea has led to 'early start' programs to enrich the experiences of underprivileged children in reading, writing and mathematical abilities, and in music, sports and art. It also led to studies on the effects of environmental stimulation on neural development that continue today. Hebb also showed, as had Vygotsky, the differing effects of brain damage when it occurred at different periods of development.

Hebb and Vygotsky both discussed behavior in interaction with a complex real environment. But environment for Vygotsky included cultural-historical influences concept, which shape the development of the child's thought. Hebb's explanation of the environment was not historical in the usual sense, although it includes a strong element of development and experience. Both of them used the term mediation to explain the more complicated patterns of behavior and thought.

Mediational Processes

The behaviorism dominant at the time Hebb and Vygotsky wrote attempted to relate stimulus to response, but with only a few exceptions left the intervening organism as a black box or as involving only hypothetical intervening variables (Hull, 1943). Hebb and Vygotsky both used the term mediation to refer to processes that intervene between stimulus and response. Vygotsky with his idea of cultural tools and Hebb with the cell assembly both sought to articulate the intervening processes. While at the time their methods seemed quite different, in our era cultural tools like language can be examined in terms of their neural networks and thereby linked to Hebbian concepts. It seems likely that Vygotsky would have strongly endorsed this view.

Vygotsky distinguished two forms of behavior: the elementary or natural form, which presupposes a direct relation to the environment, and the mediated or cultural form, which requires an additional link between stimulus and response (Vygotsky, 1966). According to Vygotsky, human higher mental functions must be viewed as products of mediated activity. The role of mediator is played by psychological tools and means of inter-personal communication. Like material tools, psychological tools are “artificial” formations. Both are social in nature, but whereas material tools are aimed at the control over processes in nature, psychological tools are used to master natural forms of individual behavior and cognition. Psychological tools have mostly a semantic nature, and are internally oriented, transforming the natural human ability and skills into higher mental functions (Kozulin, 1986, p. xxv).

Based on Vygotsky’s formulation, higher mental functions rely on mediation by signs and the sign system, the most important of which is speech. Signs here are special types of stimuli functioning as “psychological tools” relating the environment to the human processing system. The whole Vygotskian developmental psychology is the explanation and formulation of this relationship, in which the elementary forms of behavior through mediation come to support the development of higher mental functions. A simplified description of Vygotsky’s mediational approach is pictured in Figure 1.

The response (R) is not a direct reaction to the stimulus (S), but it is affected by a mediator (X). In this new process, the direct impulse to react is inhibited, and completion of the operation by indirect means is incorporated (Vygotsky, 1978, p. 40). The sign as a psychological tool made it possible for Vygotsky to transform the two-part scheme for the analysis of behavior into a three-part scheme, introducing the “psychological tool” or “sign system” as an intervening link as shown in Figure 2.

The inclusion of the sign system in this formula gives characteristics to behavior that are absent in the S-R formula. Through the sign system (e.g., speech) such functions as voluntary attention, logical memory, abstract reasoning, thinking, planning and decision making are formed. Since speech is a tool and/or mechanism that functions in a social context and according to social rules and determinants, the whole process of higher mental activities is thus social in nature (Karpov and Haywood, 1998; Ghassemzadeh, 2005; Wertsch, 2007).

The psychological system of Vygotsky was also influenced by his semiotic analysis of signs and symbols as aspects of meaning, paying particular attention to semantic mediators. Simple to complex semantic systems such as works of literature were seen to mediate natural impulses into higher mental processes (Kozulin, 1990, pp. 114-115).

Hebb also reviewed critically the hypothesized S-R connection via the mammalian cortex, as perhaps Thorndike would have suggested. He referred to conditioned-avoidance experiments. A buzzer is presented for 10 seconds, followed by a shock from the grid if the

rat does not jump off of it. At the beginning of the experiment the animal jumps as soon as he hears the buzzer; but later we can observe 7, 8 or 9 seconds delay before the jump. Hebb believes that this delay is in conflict with the S-R formula. The delay, which is based on inhibition (a term Vygotsky also adapted from Pavlov), is controlled by a mediating process—a combination of cell-assemblies. Mediating processes according to Hebb may be defined as an activity of the brain which can hold the excitation produced by a sensory event after this event has ceased. The stimulus, in this way, can have its effect at some later time. To “mediate” in this sense indicates a connecting link, the simplest function of which is to connect S with R. A mediating process can also be activated by other mediating processes as well as by sensory events.

When a number of mediating processes interact in this way the result is thinking. Hebb defines a mediating process as the unit or elementary component of thought. As behavioral evidence, Hebb gives an example in which a schoolboy has been asked to add two and eight. First the teacher says “add” and later says “two, eight”. But in order to produce the answer ten, these two instructions should be combined. The first instruction must be held in the mind of the schoolboy until it can operate on two and eight. In Hebb’s theory, a reverberatory path is required to hold information as long as five seconds (Figure 3).

Like Vygotsky, Hebb also refers to two main classes of behavior, one of them reflexive or sense-dominated, which corresponds to elementary or natural mental functions according to Vygotsky, and the other, which involves a much more complex process at the level of the association cortex in the cerebrum (Hebb, 1972, p.80) -- which corresponds to higher mental functions in Vygotsky’s classification. One of the most important distinctions Hebb proposed about human behavior was between non-cognitive vs. cognitive behavior. Although all behavior is under sensory guidance, reflexive or sense-dominated behavior is controlled by direct connections, whereas higher mental processes involve mediating mechanisms (Hebb, 1972, p. 92).

Hebb proposed his cell-assembly theory as the mechanism of such mediation. He believed that repeated transmission of neurological impulses between neurons leads to permanent facilitation of future impulses along the same pathway. He hypothesized assemblies of neurons, which could contain up to thousands of individual cells, as reverberatory loops. Thoughts may be regarded as the activity of reverberating circuits of neurons called “cell-assemblies”. Mediation or thought consists of activity in a cell-assembly or closed pathway. A series of such activities is a “phase sequence”. The nature of mediation is determined by the specific assemblies that are involved. Associated assemblies form as a result of repeated sensory input. Higher processes such as problem solving and decision involve supra-ordinate phase sequences, which are combinations of cell assemblies or phase sequences (Hebb, 1972, ch. 5).

For Hebb mediation is a brain activity that has been formulated in the framework of cell-assembly theory: “When an axon of cell A is near enough to excite B and repeatedly or persistently takes part in firing it, some growth process or metabolic change takes place in one or both cells such that A’s efficiency, as one of cells firing B, is increased” (Hebb, 1949, p. 62). The brain basis of mental representation is groups of neurons that tend to be active at the same time because of Hebbian learning (a rule by which the strength between neurons and groups of neurons increases in a similar way to muscle strength). In other words, when the neurons bridged by the synapse (the pre-synaptic and post-synaptic neurons) are activated simultaneously, the strength of the connection enjoys a permanent increase. Today, this increase in strength of a neural connection is known as long term potentiation.

For Vygotsky, however, mediation is a semiotic mechanism by which information from the outside as well as the inside world is filtered, changing the “mind” of the child in a qualitative way. Speech is a complex semiotic system that has evolved in the course of history and that transforms “historical” events to the mind of child through internalization and signification. As an example, we may consider attention in a small child, which is initially a more or less sense-dominated natural process, but later in the course of development, and as a result of social communication—the sign system—tends to become a non-contextualized deliberative process.

This process is very close to Hebb’s view that the brain does not merely “do what it is told” by sense organs, but each stimulus contributes both to general arousal, by helping to tune the cortex, and activates cell assemblies from past experience. In other words, the child develops a mind of its own, no longer fully controlled by its input (Hebb, 1972, p. 79). This shift from sensory to self control may relate to the recent finding that between 2 and 4 years of age, the dominant attention network changes from one mostly regulating sensory input to one more generally reflecting top down executive control (Posner, Rothbart, Sheese & Voelker, 2012).

It is understandable that the psychology Vygotsky was advocating was of a cultural-historical nature, and the unit of analysis in his system was the meaning of the sign (word meaning) (Vygotsky, 1962, p. 5). But for Hebb, psychology was a biological science, and the unit of analysis in his system was the integrative activity of the brain as a basis of mind (Hebb, 1972, pp. 16-17).

Hebb and Vygotsky Today and a Possible Integration of Their Views

The subtitle of Hebb’s *Organization of Behavior* is *A Neuropsychological Theory*. Some authors such as Cooper (2005) have indicated the publication of *Organization of Behavior* as a key factor in the emergence of biopsychology and contemporary neuroscience. Prior to 1949, some scientists were engaged in biopsychological research—most notably Hebb’s mentor Karl Lashley, who is regarded by some as the father of biopsychology. But the publication of Hebb’s book triggered a rapid expansion of the discipline (Pinel, 1990, p. 3). For Hebb “the problem of understanding behavior is the problem of understanding the total action of the nervous system, and vice versa” (Hebb, 1949, p. xiv).

Hebb emphasized the role of experience in determining higher mental activities. He argued that every bit of behavior is jointly determined by heredity and environment (Hebb, 1953). Hebb’s studies of the rearing of rats in an enriched environment initiated the ideas that environmental input could alter neural development and that sensory-neural connections were shaped by experience. In our era the mechanisms for the interaction of environment and heredity are being studied under the name of epigenetics.

In Vygotsky’s theory, psychology also emerged from its constricting naturalistic boundaries and became the science of the social formation of natural phenomena. According to Rogoff (1990), Vygotsky emphasizes development as a process of learning to use intellectual tools provided through social history. Social interaction promotes development through the guidance provided by interaction with people who have achieved some skill in the use of those intellectual tools. The model of the most effective social interaction is thus joint problem solving with guidance by a person who is more skilled. Vygotsky’s concepts of “scaffolding” and the “zone of proximal development” are based on such guidance. Thus Rogoff (1990) calls her book on culture and development *Apprenticeship in Thinking*.

There would be a great benefit from an integration of the neural network approach from Hebb with the perspective of early learning as an apprentice to culture provided Vygotsky

and his followers. Current efforts to develop a cultural neuroscience reflect this goal (Chaio, 2009). Studies of neural networks involved in language, have argued that cultural inventions such as reading rework older brain networks related to object recognition and spoken language (Dehaene & Cohen, 2007). This and other evidence suggests that sustained experiences of cultural artifacts may rewire brain networks (Dehaene & Cohen, 2007; Park and Huang, 2010). Examples of the rewiring of networks are the use of visual areas specialized for object recognition in animals that in humans are activated by sequences of letters after learning to read (Dehaene & Cohen, 2007). The early development of the language areas in relation to orienting of attention and later association with executive control (Posner, et al 2012) relates to Vygotsky's idea of a shift from language as communication to language as a tool for thought.

Vygotsky's discussions of the semiotics of information processing have also received support. In cognitive neuroscience it has usually been found that even a single word will activate a broad range of brain areas corresponding to the visual, phonological and multiple meanings of that word (Posner & Raichle, 1994). This widespread brain activation supports the finding that an ambiguous word presented in a context which allows only one interpretation will still prime words related to the meaning that is not selected (Posner, 1978). These studies support semiotic ideas that we have reviewed from Vygotsky, but they are stated in terms of the kind of brain activity Hebb posited in his cell assembly idea and thus form a strong basis for integration of the two. Nowhere is the importance of such integration clearer than in the study of attention. Luria (1973) (following Vygotsky) argued for a posterior attention systems involved in orienting to sensory events that was entirely automatic and biological. Luria also proposed a separate voluntary attention system that he argued was an entirely social construct.

Current studies based on neuroimaging have given physical reality to the distinction Luria made, although they are not entirely in agreement with his idea. The brain network involved in orienting to sensory events consists of two parts, a ventral network driven by input and mostly automatic and a dorsal network involving internal goals and mostly voluntary (Corbetta & Shulman, 2002). The ventral system fits generally with the posterior automatic system of Luria.

Voluntary actions are more completely under the control of a frontal network. Like the posterior network it has several separate anatomical areas including the anterior cingulate gyrus, anterior insula and striatum (Posner & Rothbart, 2007) The physical development of this network has been traced by a combination of resting state MRI studies (Gao et al., 2009; Fair et al., 2009) and behavior studies (Berger, Tzur and Posner, 2006; Posner et al., 2012). Hebb was right and Luria wrong about the biological basis of this system, but Vygotsky was certainly right about the importance of cultural and social input in shaping its development.

A synthesis of the Hebbian biological framework together with Vygotsky's ideas of culture and learning can provide us with a more complete description of the development of the whole person. This paper has argued that such a synthesis would be entirely congenial to the two figures who have done much to shape its theoretical base. We believe that the scientific basis for the integration is already on the scene, and that potentially integrated efforts under the names of cognitive, affective, social and cultural neuroscience have already appeared (Posner and Rothbart, 2004, 2007).

Summary

Both Hebb and Vygotsky were trying to build a new theory of mind that emphasized objectivity and explanation as aspects of a scientific approach. They both responded to behaviorism by stressing the mediation between stimulus and response. Mediation for

Vygotsky is a mechanism by which elementary mental processes can be transformed to higher mental processes. He paid particular attention to language and other semiotic mediators, from simple signs to the complex semiotic systems that have evolved in the history of mankind. Hebb saw the mediating process as the element of thought, capable of holding an excitation and thus bridging a gap in time between stimulus and response.

Both Hebb and Vygotsky adopted the distinction between man and animal in terms of sense-dominated reflexive behavior on the one hand, and the non-direct cognitive aspect, on the other. Both of them also believed that man is a social animal. But the emphasis is on *animal* in the Hebbian system and *social* in the Vygotskian system.

They also accepted that a transformation takes place in the course of development in which the “developed” brain does not merely “do what is told” by the sense organs. With development, the mind’s reaction to stimuli becomes no longer direct and immediate, but indirect and mediated. Hebb and Vygotsky’s followers have developed separate biological and cultural approaches to the development of mind. Despite these differences, the idea of brain networks shaped jointly by genes and experience provides a framework in which language and culture can be understood within a biological structure.

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Fig. 1.
Schematic presentation of mediation between stimulus and response in Vygotsky's theory

S ————— Sign system ————— R

Fig 2.
Sign system as mediator in the Vygotsky theory.

Fig 3.
Reverberatory path (reproduced from Hebb, 1972, p. 85)