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ABSTRACT

This document, which is designed for adult literacy practitioners, differentiates between the different types of literacy, explains the principles of neurobiological learning and their relationship to the development of literacy and numeracy skills, and presents a neurobiology-based technique of literacy instruction. The differences between conventional, functional, and cultural literacy are explained, and conflicting theories of literacy outlined. Discussed in a section on the relationship between brain anatomy and learning are the following topics: molecular mechanisms underlying mental processes, role of the brain's different parts in perception and learning, physiological and behavioral activities involved in learning, incidental versus intentional learning, and development of working and associative memory. The relationship between memory and reading and writing is explored. Described next is a neurobiology-based method of teaching remedial reading that involves using alternative assessment measures to match adult learners' reasons for entering literacy programs with the competencies necessary for functional literacy, centering specific learning strategies to specific cerebral cortical organization, and using a knowledge-based teaching strategy to enhance learners' word recognition and reading comprehension skills. Concluding the paper is a discussion of the relationship between attention and literacy and the prerequisites required for literacy and intentional learning to occur. Contains 51 references. (MN)

Neurobiological Learning and Adult Literacy

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Abstract

Research indicates that learning is a combination of physiological processes. In this paper we will explain and discuss the important role of neurobiological learning in increasing Adult literacy.

Neurobiological Learning and Adult Literacy

As America rushes headlong into the 21st Century, increasing emphasis is being placed on literacy among Americans, so the United States can compete with other countries around the world. It is difficult to define what constitutes literacy but in general we know that literacy is the possession by an individual of the ability to read, write and compute.

The ability to read, write and compute are cognitive processes (Hunter and Harman 1985). An understanding of neurobiological learning will help us comprehend the brain mechanisms responsible for literacy. The aim of neurobiological learning is to enhance the learner's skills in the areas of computation, reading comprehension and word attack skills (Winters 1994; Diaz 1992).

The American Heritage Dictionary, defines literacy as "the condition or quality of being literate, especially the ability to read and write". Although we can agree that literacy is important for an individual's success and survival in contemporary America we disagree over what literacy is.

Literacy can be viewed from the perspective of the society and the individual learner (Costa 1988). Granted, the individual must desire literacy for his survival. But the individual's push toward literacy is often the result of society's establishment of requirements a person must meet to be literate (Costa 1988;

Hunter & Harman 1985; Binkley & Rust 1994; ECS 1983; NACAE 1980; Kirch & Jungeblut 1986; Harman 1987; Knoblauch & Brannon 1993).

There are three general distinctions for literacy conventional literacy (Street 1984; Kirch & Jungeblut 1986; ECS 1983; Harman 1987), functional literacy (Hunter & Harman 1985), and cultural literacy (Purves 1990; Macedo 1994; Moss 1994; Guerra 1992; Szwed 1981; Heath 1987). The ability to comprehend texts on familiar subjects is conventional literacy. To be conventionally literate an individual can understand directions, instructions, labels and signs related to their environment.

Functional literacy is the possession of skills necessary for adult living that meet the requirements determined by the community, family and self related to the ability to read, compute and write. To be functionally literate a person meets the demands placed on them by society.

Cultural literacy attempts to place literacy into the context of a people's culture within the context of America as a multiethnic country (Macedo 1994; Purves 1990). These authors see literacy as an ideology, defined by its social practice, within the context of a communities social structure (Street 1984; Moss 1994; Guerra 1992).

The conflicting theories of literacy make it clear that there is a dichotomy between literacy skills and literate behavior (Moss 1994; Heath 1987; Guerra 1992). We need to know more about neurobiological learning to help adults attain the basic ability to decode and encode graphic symbols and information or the ability to read, write and compute (Moss 1994; Heath 1987; Knoblauch & Brannon 1993).

The ability of the brain to form new synapses as individuals learn gives the brain considerable plasticity (Bigler 1992,p.495 ; Diaz 1992). Given the neural plasticity of the brain there is no reason why illiterate students can not improve their math and reading skills. The aim of neurobiological learning is to enhance the illiterate person's skills in the areas of computation, reading and writing.

Relationship of brain Anatomy and Learning

There are molecular mechanisms that underlie any mental process (Kandel & Hawkins 1992). As a result, learning causes structural changes in the brain. Each learned experience causes connections between brain cells called synapses. To gain an understanding of neurobiological learning we must review the normal anatomy of the brain (Rothstein & Crosby 1989).

Everyday we are learning more and more about the brains anatomy and learning (Rothstein & Crosby 1989; Grady 1984). This knowledge of brain behavior correlates can help us to better understand the role learning strategies instruction can play in the remediation of many problems associated with illiteracy.

The brain is composed of four layers the spinal cord, cerebral cortex, the hippocampus and thalamus. The cerebral cortex is the outer or wrinkled layer of gray matter neurons or nerve cells making up the brain.

The cerebral cortex is divided into two hemispheres. Each hemisphere has four lobes: the frontal, parietal, occipital and temporal.

The occipital lobe processes visual information. The **primary visual cortex** interprets the raw information. The **secondary visual cortex** recognizes (remembers) that something has a particular purpose or meaning.

Visual perception and visual imagery activates the primary visual cortex (Miyashito 1995)The occipital lobe processes the visual information and sends it out to other parts of the brain for interpretation.

The processing of cognitive information takes place in the temporal and parietal lobes during different mental activities (Miyashito 1995). The temporal lobe processes auditory information. This lobe names objects, people and animals. The **primary auditory cortex** interprets the raw auditory information. The **secondary auditory cortex**, recognizes (remembers) that something has a particular purpose or meaning. In general the temporal lobe discriminates between general experiences. Many brain-behavior activities associated with doing cognitive activities are coordinated in the temporal lobe.

The Parietal lobe processes tactile-kinesthetic information. The right **parietal cortex** plays an important role in self-awareness and visual-spatial processing. The parietal lobe and the occipital lobes are mainly used to process information.

The prefrontal lobe is important in many cognitive activities. In this region visual and spatial working memory is carried out (Goldman-Rakic 1992). This region is critical as an intermediary between action and memory. It has multiple memory domains specialized in encoding different information including color, shape and size: and mathematical and semantic knowledge.

The frontal cortex is a very important part of the brain it houses memory and language centers. In the prefrontal cortex decisions are made about what to do or planning things. In this area verbs are processed. Problems in this area would affect a student's ability to pay attention.

The hippocampus is situated on both sides of the brain in the temporal lobe, it is shaped like a finger. In the hippocampus learned memory is controlled, episodic and long-term memory is established. They are conveyed from this region to the neocortex (Crick 1994, 83).

A ball shaped object called the thalamus is located in the middle of the head. The thalamus is primarily involved in attentional mechanisms (Crick 1994, 251).

The perisylvian region and basal ganglia are also important in learning. The left basal ganglia, for example, assembles word forms and controls systems for cognitive abilities and movement. The perisylvian region establishes auditory, kinesthetic and motor correspondences for phonemes.

Learning

Learning is the accumulation of experiences. Hebb (1964) developed a simple model for learning. The Hebbian model makes it clear that the modification of the neuronal connections at the synapses is the process of learning.

Learning takes place through an integrated process of physiological and behavioral activities. These activities are controlled by neurons.

The neurons have four parts: dendrites (the branches of the neuron).soma (the cell body).axon (the structure that goes to the terminal buds) and terminal buds (that part of the neuron which touches new dendrites). The space between the terminal buds and the dendrite is called the synapse. The number of neurons do not grow it is the connections that grow through stimulation.

Learning is a combination of behaviors, nerve cells and associated molecules and memories produced by events (McShane 1991; Kandel & Hawkins 1992; Winters 1994). Each time an individual accumulates new experiences neurons are formed. These cellular mechanisms for learning make evident the neuronal correlate of learning (NCL).

As a result of NCL each brain is individualized due to the individualized nature of human experience, which in turn will construct the neuronal network in each person (Crick 1994). In other words, our experiences mold our brains to reflect the sum total of the experiences and/or related knowledge base we have learned during our lifetime.

The foundation of cognitive development is the ability of humans to represent the external events mentally (McShane 1991. 121). To learn, we must process visual and auditory information.

Stored information in the cerebral cortex is encoded representation of the stimulus input (McShane 1991, 94). The environmental input represents the external world. It becomes a representation in the brain. Crick (1994) defines a representation as "neuronally encoded, structured versions of the world that could potentially guide behavior" (p.66).

There are two types of learning incidental and intentional learning. Incidental learning can be defined as learning without instruction. In school we seek from our students intentional learning, which can be defined as learning with instruction. This form of learning requires explicit memories that are located in the temporal lobe (Goldman-Rakic 1992).

Memory

Information for the nervous system comes from transducers. The transducer converts the physical experiences into electrochemical signals (Crick 1994, 82).

In processing information the cognitive system stores information. In the cognitive system stored sensory information is manipulated while the representation of sensory input is stored (McShane 1991, 61). These representations become memories.

Memory development is based on ones "knowledge base". This knowledge base represents the experience one gains from his interaction with his environment (McShane 1991, 163).

Today neuroscientists theorize that there are two memory systems identified as habit and cognitive. The habit system is a group of behaviors that exist as a result of "habit". The cognitive or declarative/ explicit system is made up of "stored representations of stimuli" that are retrieved (Fox 1983).

Atkinson and Shiffrin (1968) theorized that the human cognitive system has three memory storage areas: a sensory register, a short-term store and a long term store. Baddeley and Hatch (1974) believes that we should replace the idea of long and short term stores, with a single memory store which can be activated to process information. According to this cognitive model when part of permanent memory store is activated it becomes "working memory". In the Baddeley and Hatch model for memory working memory functions the same as short-term memory.

Tulving (1972) has made a distinction within the long term memory store between semantic memory and episodic memory. The memory of one's personal experiences and their temporal relations is episodic memory. Semantic memory is one's memory for facts and concepts that transcend individual experience.

Today scientist usually agree on the presence of two memory systems in humans: short-term and long-term. These memory systems have submemory systems which include associative and working memory (Baddeley 1990).

To become literate children and adults must be able to access associative and working memory. Working memory can be defined as the simultaneous processing, including recalling and storage of information. A person employs working memory when they must hold a limited amount of data in mind for a limited time while they simultaneously complete further cognitive activities.

Associative memory is the result of facts and figures held in long-term storage, that are retrieved for current use. Working memory is short term memory used to carry out the manipulation of symbolic information without requiring access to associative memory (Goldman-Rakic 1992).

The initial response of the central nervous system to learning are neuroanatomical changes at the synaptic regions in the brain (Shashoua 1982; Thompson 1986). These neuroanatomical changes at the synaptic regions of the brain and receptor sites after a learning experience probably represents short-term (STM) memory. This leads one to speculate that extracellular neurochemicals: proteins and peptides play an important role in the process of long term memory (LTM) or long-term potentiation (LTP) formation, and encoding of the LTM onto the memory trace. As a result, learning requires certain modulating factors that strengthen the MT (Lynch & Baudry 1984; McKean 1983).

This means that learning is a series of memories. A memory occurs when an electrical signal carried by the axon causes a change in the spine. This chemical change encourages postsynaptic LTP that last for months. The LTP is strengthened by repetition and can last indefinitely (Lynch & Baudry 1984).

Memory is stored in the circuits between the cortex and the hippocampus. Memories are believed to have been made when chemical messenger compounds , called neurotransmitter, cross from the **axon** through the terminal bud to the **spine**. Calcium which is excited by the electrical charge carried by the axon enters the **dendrite** which form the spine. The calcium invigorates the **calpain**. The activated calpain causes a physical change in the spine, which researchers have hypothesized "contributes" to memory function.

The electrical charge changes the nerve circuits. this change is hypothesized as evidence of a MT. The calcium is then eliminated from the spine (too much calcium can cause damage) while the structural and receptor changes remain constant. The growth of the spine is a postsynaptic change that indicates that learning has taken place.

The new LTP, remains in the hippocampus as a MT for sometime until it is sent on to "relevant" centers of the brain for long term storage (Mckean 1983; Kandel & Hawkins 1992). The LTPs are strengthen through repetition.

These memories from the various sites in the cerebral cortex are then coordinated when ever necessary by the prefrontal cortex. The prefrontal cortex decides and guides how plans will be carried out. It is also in the prefrontal cortex that attention is controlled.

The plasticity of the brain, which allows corollary brain systems to form new neural pathways indicate that "repetitive treatment strategies" can help people without literacy improve CNS functions.

This makes practice important in an individual's quest for literacy. This results from the fact that repetition of learned behavior creates the memory trace necessary for the smooth retrieval of stored information.

Reading and Writing

The first goal in adult literacy is enhancing the adult learner's ability to read. In understanding a word the individual must both perceive the word and create an image of the word (representation), either in terms of the phonological patterning of the letters within the word, or the object that the word represents (i.e., chick--a small yellow bird which becomes a chicken). This means that an individual must review representational structures in the LTM and STM that subserve perception (the matching of word or visual input to stored data to achieve recognition) and the generation of an image to define the word (Ishai & Sagi 1995). This results from the important role memory plays in imagery facilitation.

Research indicates that people with a reading problem suffer from dysfunction in the left hemispheric parietal-temporal cortical areas (Rourke 1985; Rourke, Bakker, Fisk & Strange 1983). Reading illiteracy does not have to remain forever because neurological research indicates that new synapses can be formed through learning. As a result, many individuals that lose selected neuropsychological functions can recover (Bach-Y-Rita, 1990).

Neurobiologically Based Teaching Technic

Teaching changes the circuitry of the student's brain during periods of learning. In reading instruction, intentional learning takes place through the individual's interaction with other people (teachers and parents). and with the environment (books. phonetic sounds and written letters).

To remediate reading illiteracy we must first conduct assessment. This allows us to determine specific learning problem and help develop a specialized learning program for illiterate students .

Assessment in adult literacy is complicated. Standardized test are intimidating, because they remind the adult learner of his past school failure. Although standardized test are threatening to many adult learners they should at least take the Test of Adult Basic Education so the instructor can determine the students abilities and limitations in computation and reading (French 1987).

Alternative assessment measures can also be used on a nonthreatening basis to supplement the TABE test. Instructors can use informal test to determine specific reading difficulties for example, reading level can be ascertained using an informal reading inventory and a miscue analysis will determine a person's reading strategy. Informal math test reviewing basic math concepts and computation skills can also be used to assess the adult learner. This would match up the adult learners reasons for entering a literacy program with the competencies necessary for functional literacy.

This in turn would allow us to center specific learning strategies to specific cerebral cortical organization. There are several teaching strategies used to teach adults. Brown (1980, 473) has encouraged work on metacognition. Malicky and Norman (1989) believes that adults can benefit from the whole language approach in reading instruction.

The most popular teaching approach is the knowledge based strategy. This strategy takes advantage of what the reader already knows (Malicky & Norman 1989). This approach calls for the use of predictable passages and language experience materials during instruction (Malicky & Norman 1994, 33).

In reading multiple areas of the brain are employed. Visually presented words are processed in the visual system, while aurally presented words are processed in the temporal lobe (Diaz 1992).

As a result, reading out loud a presented word is associated with motor areas of the brain. To consciously assess words for meaning or choosing the correct response to verbal or visual stimuli from the written page activate the Broca and Wernicke's areas of the brain (Raichle 1994, p.62).

The reading process involves several processes:

1. Recognize groups of letter that form words
2. Recognize the meaning of words
3. Recognize the meaning of phrases and sentences
4. Use recognition of words and sentences to create mental images.

There are two components of reading: word recognition (phonics, structural analysis, context clues, sight vocabulary and picture clues) and comprehension (literal, inferential, critical reading and vocabulary).

The phonetic sound are received by ear receptors and turned into chemical and electrical signals. These signals are carried by the nerves to specific sections of the brain. The sounds of words and letters. the vibrations of touch (when writing words) . and the visual image of words and letters are turned into electrochemical signals (information) that are stored in the brain.

The use of multiple centers of the cerebral cortex in reading encourages a multisensory approach for the remediation of learning disabilities and illiteracy (Bigler 1992, p. 502). Diaz (1992, p.91) has discussed the use of the multisensory approach as an effective remediation technic to positively impact the neural network(s) related to reading.

Reading is therefore the creation or reinforcement of connections in the brain related to reading. This makes the goal of special education instruction to strengthen knowledge or information (sensory experiences) stored in the brain by sensory input associated with the learning and practice of new knowledge.

Learning strategies instruction encourages illiterate students to perform new tasks. This type of instruction is neuropsychological (Learner 1985).

The information mastered during learning strategies instruction is modulated by different circuitry in the brain. where diverse elements of the learned experience are stored.

These methods are successful in special education instruction because the more often you perform a task, the greater your skill becomes at performing that particular task.

Our understanding of neurobiological learning indicates that if we desire to teach illiterate students better word attack skills using the synthetic phonics approach we might use pictures and the color coding of words to evoke an emotional response to reading.

Nouns and verbs can be taught holistically when you use words and pictures. The words will stimulate auditory centers of the brain, while pictures will form new connections in the visual motor center.

The use of pictures to present words and nouns, and colors to write words create emotion. An emotionally arousing picture of a word can be affective because emotional experiences can enhance memory (Diaz 1992). Knowledge that emotion can effectively make LTPs helps us to find a specific mechanism to help the illiterate reader in many cases obtain better reading skills.

Learning requires continuous practice. This means that illiterate students will only continue to show positive progress in over coming a reading problem through active practice of any reading strategy he has learned.

ATTEHTION AND LITERACY

Literacy requires both associative and working memory. Associative memory is the result of facts and figures held in long-term storage, that are retrieved for current use. Working memory is short term memory used to carry out the manipulation of symbolic information without requiring access to associative memory (Goldman-Rakic 1992).

Attention is divided into three types: focusing attention, maintaining attention, and shifting attention. These three types of attention must be intact for learning to take place.

There are two types of learning incidental and intentional learning. Incidental learning can be defined as learning **without** instruction. In literacy programs we seek from our students intentional learning, which can be defined as learning **with** instruction. This form of learning requires explicit memories that are located in the temporal lobe.

Three prerequisites are necessary for literacy and intentional learning to take place, they are:

(1) Good discrimination of auditory and perceptual /visual stimuli;

(2) Good attention, i/e. the student must be able to pay attention to the material s/he is to learn;

(3) Good short term and long term memory; and

(4) Good fine and gross motor movements.

People have trouble doing math because they fail to possess one or more of the prerequisite skills required to perform math.

To help literacy students learn we must take control of the reticular formation which is stimulated by visual and auditory stimulation. The reticular formation is a cluster of neurons in the brain stem. The reticular formation makes you aware of your environment. This is where you obtain your level of awareness.

People learn because they are able to pay attention-- be aware of the subject matter they are being taught. You must get the student's awareness before s/he can learn .

Awareness makes the student ready to learn. It is the reticular formation that sends the electrical impulses throughout the body and prepares one for learning.

An understanding of the neurobiology of literacy indicates that manipulatives can help remediate math difficulties because they encourage use of the cognitive and direct teaching methods. The cognitive approach emphasizes the individual as an active learner in control of his learning situation, with the teacher and the manipulative inculcating in the student planning , self-evaluation and self-monitoring skills.

The direct teaching method emphasizes active effort of the teacher to structure the student's environment. The direct teaching method includes (1) grouping immediate instructional needs; (2) sequencing academic skills to be remediated: (3) model -ing successful academic practice: and (4) pacing academic skills that encourage many response opportunities (Rourke & Strange 1985).

In conclusion, there is a neurobiological basis to literacy which involves the development of LTPs through repetitive strengthening of memories which constitute learned behaviors (Diaz 1992; Winters 1994; Bigler 1992). Neurobiological research also makes it clear that an understanding of the localization of specific centers for learning in the brain, can help literacy instructors develop an appropriate individualized instructional program for adults in literacy programs.

Synaptic plasticity allows us to become literate (Bach-T-Rita 1990). The connections in the cerebral cortex allows the mediation of complex cognitive phenomena such as computing , writing, interpreting the phonetic values of letters and reading graphic symbols used to form words (letters).

The concerted use of knowledge about the neurobiological basis of learning knowledge base and selected literacy instructional methodologies will make learning less boring while the literacy student uses metacognition to increase their own literacy. Neurological research suggest that the whole word method can be an effective teaching method in adult literacy. The whole word method of instruction may be successful because during the first moments of linguistic processing , people attempt to establish reference to encapsulated relevant nonlinguistic information as the linguistic input is processed (Tanehaus , Spivey-Knowlton, Eberhard & Sedivy 1995).

Neurobiological research reviewed above makes it clear that functional literacy is obtained as adults create neural pathways that allow them to read, write and compute with functional competence. Moreover, this research makes it clear that if a neural circuit is not used you lose it (Winters 1994: Diaz 1992). The strengthening of LTPs enables the learner to employ the use of both working and associative memory in overcoming illiteracy.

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