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ABSTRACT

Literature is reviewed which discusses the role of proprioceptors in basic perceptual and motoric functions. The author cites research on the functions of the muscle spindles in controlling muscles which in turn provide energy, stimulation, and activation of the central nervous system. Research on the relation of motor functions to language development, concentration, visual discrimination, and reading is presented. The Fernald Method, a multisensory method of teaching basic academic skills, is discussed as exemplary of programs which utilize the various kinds of learning processes of the brain. The author suggests that further research be done on how our knowledge of brain functions can contribute to the development of efficient teaching and learning methods. (AL)

TEACHING READING - VISION VS. THE MUSCLE SENSE (THE PRO-PRIOCEPTORS)

BY

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This paper is a summary of a series of lectures on The Importance of Proprioceptor Stimulation to Human Development at the Psychological Counseling Center, 3759 Atlantic Avenue, Long Beach, California 90807, in the Spring of 1971.

Errata

On page 3 at the end of the first line add the following:

- Before correction -

Science Symposium at Florence, Italy, in 1964 (Simons, 1964)

- After correction -

Science Symposium at Florence, Italy, in 1964 (Simons, 1964)[1.]

then add this footnote at bottom of page:

It took the astronauts 7-10 days to overcome difficulties in the cardiovascular system...post flight disturbances were largely related to the central nervous system, the cardiovascular system and metabolism. (This let one American to ask "What else is there?")

On page four at the end of the fourth paragraph before starting the last paragraph on the page.

- Before correction -

help to clarify the issues.

- after correction -

help to clarify the issues. (Bottom of page 4 through page 9)

TEACHING READING- VISION VS THE MUSCLE SPINDLES (PROPRIOCEPTORS)

Fascinating developments have been taking place in the Neurosciences with startling implications for the entire field of education. Since men have been placed in space, beyond the influence of gravity, new knowledge has been gained about the functioning of the human body. Some of this scientific research suggests that vision does not have a pre-eminence but is of secondary importance in learning. Motor patterns are of primary importance in learning basic academic skills--particularly in the teaching of reading. The most effective educational techniques of the future will be based on how to use our motor patterns most efficiently. This paper will quote some of the findings from the fields of developmental neurobiology, physiology, anatomy, and psychology and relate them to instruction in the classroom.

An important clue to the possible importance of motor patterns comes from the observations of Nauta and Karten (1970) who point out that the human brain is composed exclusively of intermediate and motor neurons. The cell bodies of the primary sensory neurons (vision, etc.) are outside this central organ even though their centrally directed axons must enter (and often extend far into) the brain and spinal cord to establish synaptic contacts. Many mammalian brains contain at least as many as 2,000 intermediate neurons for each motor neuron. Whether in the form of a simple reflex or a complex goal-directed behavior, it is only by way of the motor neurons that activity of the central nervous system (CNS) can be expressed in movement. A numerical relationship of this order suggests a very high degree of convergence of the central neuronal conduction pathways toward Sherrington's characterization of the motor neuron as the final common pathway of the nervous system.

Nauta and Karten point out that the CNS is organized around the motor neurons. This may be the first disturbing clue showing that educational procedures organized around a See-Hear-Memorize-Decode Method of teaching reading is not based on sound neurological principles.

The further importance of the motor neurons [illegible] out by S. R. M. Reynolds (1970) who states that the absence of gravity causes the "thermostat" for homeostatic regulation to be set high. This is shown in much of the work done on the floatation of human subjects, but especially by the work of Graveline, Balke, McKinzie, and Hartman (1961). Moreover, these effects are duplicated and exaggerated by men in space flight, unless the precaution is taken to maintain adequate sensory input and not to push the limited physiological reserve of men in space too far. This has been described in AMERICAN ASTRONAUTS (Dietlein, 1966) and was referred to with respect to the Russian Astronauts at the Fifth International Space

Science Symposium at Florence, Italy, in 1964 (Simons, 1964). The lack of muscle stimulation caused serious problems due to the lack of gravity pull.

The proper, adequate, and correct type of stimulation to the motor neurons is vital to man's engagement of and functioning in his environment. Education and educational procedures have been made a part of this environment. A closer examination of the role or muscles fill in this process is needed.

Looking backwards in time to evidence from the science of evolution, Washburn and Harding (1970) developed the hypothesis that language development in human beings came about as the result of early tool using. This may have forced a new manner of concentration on these objects. What evolved were the hand skills and the technology making them possible. This included the development of social skills involving increased memory, planning, and control, and the development of linguistic skills which are the basis of human communication. These scientists point out that the increase of three to four times in the size of the cerebellum in the last million years must be explained by the evolutionary importance of these substantial new functions. They agree with Eccles et al (1967) that the cerebellum plays a major role in the performance of all skilled actions. Obviously, language is an extremely skilled action requiring many complex motor functions. An interesting side note is the the cerebellar granule-cell population is enormous (Sidman 1970). In man it has been estimated at one hundred billion neurons (Braitenberg and Atwood, 1958) more than all the neurons of the cerebrum combined.

Not only is the brain organized around motor neurons, but the development of motor skills makes language not only possible but a necessity.

There is a relationship in evolution between need and use leading to change. There is feedback between behavior and its biological base, so that behavior is both a cause of changing gene frequencies and a consequence of changing biology. Since evolution is an adaptation over time, there are no ends except those that result from continuing selection (Washburn and Harding, 1970).

In this regard, education may have neglected a classic text by D. and K. Stanley-Jones, The Kybernetics of Natural Systems (1960), which deals primarily with the importance of the muscle spindles, the motor neurons, and proprioceptor stimulation to man's successful engagement of his environment. Due to the importance of this work, the following paragraphs quote from their work quite extensively, as their observations help to clarify the issues.

The human brain has an ancestry of at least five hundred million years, possibly three times that figure. The vital features of neural networks were evolved long before even the humblest vertebrates arose from their unknown ancestors. The essential quality demanded of such a network is reliability.

The network in its turn must look for reliability to its primary source of neural dynamic. Hence, it is those sense-organs whose contributions are intermittent that are unreliable. This is particularly true for the eyes, which nearly cease their output in the dark and are thus virtually useless as a continuous source of neural input.

Nervous energy is wholly different from chemical energy derived from food. The neural level of cerebral activity is conceived as a pattern of nerve impulses constantly maintained in circulation. This is the only state in which a nerve impulse can exist. When there is no longer any electrical activity in the brain, the individual is dead. Each impulse is a unit, a wave of electro-chemical energy. It can survive only so long as it keeps moving. Hence the unequivocal necessity for postulating re-entrant, or closed-loop, circuits among the neurons within the brain, around which trains of nervous impulses circulate like an idling flywheel, as an ever-ready and immediately available source of neural energy. The primary reason why vision cannot meet this requirement is that its neural impulses are unreliable due to being intermittent. Vision cannot maintain a constant source of nervous energy necessary for the functioning of the human brain.

Each local area of the cortex interprets the message according to its local pattern of response. Nothing in the message itself can indicate its source of origin. If an operation could be devised to change the pathway of the optic nerves so that they deliver their messages to the auditory nerves rather than to the visual area, the patient would then hear noises when the lights were turned up and see patterns and colors when the bell was rung. Stanley-Jones' work seems to have been confirmed by Gindes, B., and Ballentine, E. W. (1969). In their work, their patients were able to see brilliant twinkling lights by mildly electrically stimulating their temples through the use of electrodes attached to a high frequency oscillator.

The neural impulse, or permeability-wave, is the unit of currency in the nervous system. Not only does this currency operate on the sensory side of the reflex arc, it also provides the dynamic of muscular contraction on the output side. With the doubtful exception of the respiratory center in the medulla, there is no area of the brain which is capable of creating or emitting these quanta of neural energy. <u>The brain can use only the motive power that is fed into it on the sensory side. It cannot create that power.</u> The nerve-impulse is therefore the unit of energy not only for the kybernetic circuits of muscular activity but it also supplies the dynamic for muscular control.

The force of gravity is the most unchanging, and therefore the most reliable, physical fact on the surface of the earth, whether on sea, land, or in the air. It is on the gravity-receptors, by their unchanging response to an unchanging stimulus, that the nervous system has come to depend for an unceasing and therefore reliable source of energy. The CNS is unable to perform any part of its function without this reliable source of dynamic or temporary substitutes.

Sense-organs may accordingly be divided into two categories--reliable and unreliable--measured in quantitative terms of their sustained or unsustained output in response to unchanging stimulae. The unreliable receptors are those that fail to sustain their output--those that quickly adapt their response by their impulse falling off rapidly after the first outburst. The receptors sensitive to stretching in the muscles have a low rate of adaptation. They continue to discharge neural impulses in spite of the unchanging intensity of the stimulus. The force of gravity is the stimulus providing the stretch in regard to the postural muscles of the body. These sustaining, constantly emitting or non-adapting receptors, are the most indefatigable and therefore the most reliable source of supply for the units of neural energy on which the brain is wholly dependent. These are the actual creators of the units of neural currency, without which the elaborate machinery of kybernetic control would break down from failure of its power supply.

The receptors sensitive to stretching in the muscles are part of the lateral nervous system which is represented in the higher animals by the balancing organs of the inner ear. The otoliths in the inner ear, part of the vestibular organ, are the simplest part of the lateral system and whose kybernetic workings are easiest to understand. In the human ear, there are two otoliths on each side. Each otolith-organ consists of an oval spot or macula about three millimeters long, covered with hairs or short filaments like a pile of velvet. The free ends of the hairs are attached to floating particles of chalk (the actual otoliths or ear stones) and their function is to register the position of the head in regard to the constant pull of gravity. Movement and balance are maintained during the pull of gravity.

When the chalky particle rests on the macula, stimulation is at its lowest; when the head is rotated through two right angles so that the chalk lies under the macula and pulls on the hairlets, stimulation is maximal. The sense organs attached to the hairs are the stretch receptors located in the muscle which respond quantitatively to the degree of pulling by the weight of the chalk.

The nerve which conveys the output of the otoliths into the brain is the vestibular nerve. This is the eighth cranial nerve and it takes its name from the vestibule of the bony labyrinth which houses the otoliths and their maculae. The nerve leads into the vestibular nuclei in the brain stem, from where the impulses are relayed into the cerebellum. The cerebellum is a bulky part of the hindbrain which is concerned with the quantitative build-up of postural tonus. In the human it lies in contact with the back of the skull below the occiput, or posterior, pole. The cerebellum is the central headquarters of the lateral nervous system. Its function is the multiplication, by neural dichotomy and reverberation, of the impulses fed into the vestibular nerves from the otolith, together with other impulses emanating directly from the anti-gravity postural muscles of the limbs.

Afferent impulses over the vestibular nerve maintain a background of reverberative activity in the lateral reticular formation. It is the facilatory region of the bulbar reticular formation which Neimer and Magoun (1947) have shown to be a continuum of the reticular connections which influences both sides of the cord in the same manner.

The greater part of the otolithic influx into the vestibular nuclei is relayed upwards into the cerebellum, thence to the red nucleus and then to the various reticular formations of the brain-stem. Only a fraction (and in man it seems, only an insignificant fraction) is directed downward along the vestibulo-spinal tract to the muscles of the neck and arms.

The muscle spindle can be considered the little machine inside the big machine. It not only controls the movements of the whole muscle by a servomechanism which releases great power with the application of little power; it also supplies the dynamic, the power itself, without which the servomechanism would not avail.

The conclusions of Stanley-Jones have been independently confirmed by Reynolds (1962) in his work on lamb fetuses in utero versus post-natal life. Lambs are born mature animals and, just prior to birth, the CNS is able to function in the uterus, but does not. The mechanism is set in operation by the function of the muscle spindles which are stimulated by gravity which occurs when the animal is born. When in the uterus (a liquid environment) gravity does not exercise the same stimulus. While in the uterus, the lamb does not stand, walk, regulate its body temperature, eat, nor use its carotid chemoreceptors, although it is morphologically equipped to do so. This work has been substantiated also by K. W. Cross and J. L. Malcom (195 .

It is the muscle spindles that provide the source of energy, stimulation, and activation of the CNS. The lamb fetus remains nonresponsive to adequate sensory stimulus as long as it remains in its floatation existence in the uterus. Men in outer space must thus make adequate compensation for the lack of normal muscle spindle stimulation. Also, children in the first grade are dependent upon motor stimulation while learning in the classroom.

A. A. Volokhov, of the Institute of Brain Research in the USSR, writes that any kind of conditioned reflex activity (learning) represents a complex activity of the organism composed of MOTOR, visceral, and electrical phenomena. The activity of subcortical structures, including the corpora quadrigemina, hippocampus, and the midbrain reticular formation, establishes the necessary level of excitation in the cerebral cortex for the formation of a conditioned connection. The work of Stanley-Jones and others has pointed out that the primary basis of excitation in the brain is from the muscle spindles.

Therefore, it is important for educational methods to base their approach around the most effective means of using motor patterns and stimulation in the learning process.

Motor skills and motor involvements, s ch as talking, walking, writing our names, and recognizing the name and faces of old friends, can remain intact throu h brai damage or disease, intensive electro-convulsive therapy, old age, and other processes that erase less st ble emories (Frank R. Ervin and T. R. Anders, 1970). The m re effectively we can use motor patterns, the more prod ctive the results will be.

The importance of motor functions in the development of language has been pointed out by Detlev Ploog (1970), who states that social interactions are basic for all primates, including man. Non-human primates handle their affairs by means of vocal and nonvocal communication in which motor functions are a necessary component. In man, a similar communication system, with representation in limbic and other subcortical structures, still plays a role and is seen clearly in all vocal, facial, postural, and other motor expressions of emotions, in songs without words, and in the cooing and babbling of small infants. In fact, this motor system is involved in every human conversation and in every partner relationship, but is dominated by language. In this connection, it is important to note that speech depends not only on cortical, but also on subcortical structures, including certain thalamic nuclei, which are connected with parts of the diencephalon, the periaqueductal gray matter. Speech calls for the highly specialized and well-integrated coordination of some one hundred muscles, and its function is patterned in way similar to cognitive (especially perceptual) processes (Eric H Lenneberg, 1970). That motor processes have a close relationship with our emotions, is evidenced by the fact that motor patterns express emotions in non-verbal communications; from a physiological point of view, the limbic system is involved in the development of language.

H. W. Magoun, in the text, The Waking Brain (1963), reports several experiments that seem to have particular importance in the use of motor patterns in education. He reports that it is now additionally clear that corticifugal control of sensory input can be effected by the pyramidal tract as well as by the reticular mechanisms. This is significant, as Stanley-Jones points out, the interrelationship between the muscle spindles, the cerebellum, and the recitular formation. In this regard, the pyramidal tracts connect the cortical motor area with the final common pathway in the spinal cord. Magoun cites experiments of central regulation of cochlear excitability through changing tension of the middle-ear muscles. This was demonstrated by Hugelin, et al. (1960); analogous central control of retinal discharge, by modification of the pupillary aperture has been shown by Naquet, et al. (1960), and by

Fernandez-Guardiola, et al. (1961); degeneration studies of Kuypers (1960); and pyramidal tract excitation by Towe and Jabbur (1960). These experimenters seem to be providing a base for suggesting that the muscle spindles not only have a primary function in neural integration, but can indirectly control and affect other sensory outputs. When all the parts of the whole are put together, an interesting pattern of control is apparent.

Again, Magoun, in his text, maintains that the feedback control of input by the reticular system may serve to prevent the intrusion into consciousness of information irrelevant to the task at hand, and thus contribute to the focus of attention. He cites Hernandez-Peon, Scherrer and Jouvet (1956), Kuffler, 1952, and Mountcastle, (1961). The implications to education are enormous, as the effective use of motor patterns, or motor involvement, enhances concentration.

Teaching reading as a visual-auditory function makes the process much more difficult. In this regard, Magoun reports that, during experimental reticular stimulation, visual discrimination is improved (Fuster, 1958), and the recovery cycle of the optic cortex has been found to be reduced (Lindsley, 1958, 1961); in agreement, Bremer and Stoupel (1959) and Dumont and Dell (1960) have demonstrated dramatic reticular facilitation of responses induced in the visual, auditory, or somatic cortical areas of appropriate thalamic stimulation. From these findings, both facilitary and inactivating influences from the central brain stem contribute importantly to the cortical state upon which most higher nervous activity depends.

As stated previously in this paper, the cerebellum is the central headquarters of the lateral nervous system. R. Llinas (1970) states that the cerebellum may have a type of function that is related to the temporospatial organization of body image which develops from sensory and motor information. This is then utilized as an error-correcting servomechanism. The cerebellum may well be an analyzer, organizer, and selector. Even when the body is at rest, the CNS is constantly receiving stimuli from the muscle spindles. This may be evidenced by the fact that, although the human brain comprises two to three per cent of the body in weight, yet it commands up to fifty per cent of the resting energy consumption and oxygen utilization (Galambos, Robert, and Hillyard, Steven A., 1970).

As speech and other symbolic thought processes are related to and are a part of our perceptual processes, some mention of psychological experiments in this area will have relevance. The Werner-Wapner Sensory-Tonic Field Theory (1952) states that, since any neuropsychological entity is neither sensory nor motor, but a dynamic process prior to both, it may be affected in a similar way by stimulation of the muscles. This conclusion, which is based upon experimental evidence, again points out that language formation can be developed by muscle stimulation through our perceptual processes.

Witkin's (1949) experiments in perception pointed out the existence of marked sex differences. These differences are always in the same direction. Women are oriented along the visual field much more than men and respond less to bodily experiences or proprioceptor stimulation. For some men, their entire orientation is on a kinaesthetic basis. Of even greater significance, is the illness-producing condition, even under laboratory conditions. This resulted when the subject had difficulty orienting himself when frustrated in using his mode of perception in solving a problem.

Caukins (1970) further develops the hypothesis that the muscle spindles (proprioceptor stimulation) can destroy previous learning as in Communist techniques of "brainwashing ; can rebuild capacity in the integrative process where brain tissue has been destroyed, as in cases of aphasia; can develop perceptual abilities, as in the case of non-readers; can incorporate individuals, groups, machines, and locations as extensions of ourselves; can circumvent higher brain functioning, as in hypnosis; can have a similar effect with the other five senses in higher brain functions; and can distort integrative functions resulting in emotional and behavioral problems.

The numerous individuals cited in the preceding paragraphs have contributed to a large pool of information concerning the vital part played by the muscle spindles in neural integration and functioning of the human brain. Of particular interest is the work of Edmund Jacobson who, in his text, Progressive Relaxation (The University of Chicago Press, 1938) treats emotional problems by training patients to be sensitive to, or aware of, their "muscle sense" and feelings so that they can use their muscle spindles in the treatment process. Such disabilities as hysteria, hypertension, spastic esophagus, and mucous colitis are treated by a program of progressive relaxation. The training involves the ability to control or inactivate the muscles, thus eliminating all residual tension. This researcher states that an essential part of mental and emotional activities consists of neuromuscular patterns; the LATTER ARE NOT JUST EXPRESSIONS OF EMOTION, as was formerly believed; in physical terms, the energy expended in a neuromuscular pattern is identical with, and is not a transformation of, the energy of the corresponding mental and emotional activity. (This is a conclusion reached independently by--and for different reasons--Stanley-Jones).

The extreme relaxation of a muscular pattern essential to a particular mental or emotional process must bring with it the diminution of that process. When patients, lying relaxed, with eyelids closed, engage in mental activity such as imagination or recollection, contraction (commonly slight and fleeting) occurs in specific muscles. Evidence is thus afforded that the <u>physiology of mental activity is not confined to closed circuits within the brain</u>, but that certain muscular regions participate. Certain patients suffering from nervous disorders, vascular hypertension, or chronic colitis, characteristically yield records showing marked inability or failure to relax.

The part played by educational methods to cause serious emotional disorders through the use of inappropriate teaching methods must be faced. College courses in "methods" to be used in the school can no longer afford to be "air and sun shine" courses, but need to have a sound basis in physiology. The damage has already been done. The need is now to develop more appropriate methods so that our children can be successful. These courses must be based on the most effective utilization of motor patterns, proprioceptor stimulation, or the involvement of the muscle spindles in the learning process, rather than on a visual-auditory basis.

One such method was developed as a remedial approach to reading problems. It is the Fernald Method (1943), The Visual-Auditory-Tactile-Kinaesthetic Method, which uses a multi-sensory approach to the learning of basic academic sklls. Basically, the method is a See-Hear-Say-Trace-Write Method that teaches writing, reading, and spelling all at the same time. The method strongly uses and stimulates th muscle sense while conditioning all the other senses to a basic motor pattern. Each sense becomes married to the other. The child is taught to write the word as a unit in cursory handwriting (first tracing) to make the operation a smooth flowing feeling for the word. The alphabet or printing is never taught first or as a separate function. Spectacular achievement has been accomplished in working with culturally disadvantaged, retarded readers with this See-Hear-Say-Trace-Write Method by Berres (1967) and Fesbach (1969). This method, adopted as a general classroom technique for all children in the first grade, is described by Caukins (1970). If the method is not done correctly, or according to the laws of conditioning, the results will be negative. The method seems so simple that it is hard for teachers to resist modifying or changing the procedures. However, if the method is done correctly, whatever mode of perception is used by the child in learning--vision, hearing, tactile, or kinaesthetic (lip-throat or hand-motor) or combinations of these, he has a free choice and an opportunity to be successful in his work.

The activation of the muscle spindles will enhance focus and concentration on the project, will increase both visual and auditory perception, will stimulate the lower brain centers so that the transfer to the neo-cortex will be facilitated, and will furnish the energy and "fuel" so that learning will take place. As frustration and difficulties are being minimized, an overall and better emotional adjustment, including positive group conditioning, will take place. For those individuals who have a particular need for an action method--one that they can feel, touch, and personally experience--the Fernald method will be most appropriate. The use of the muscle spindles, proprioceptor stimulation, or kinaesthesis, is essential for adequate learning on the part of many children. The schools can no longer afford to ignore these needs.

SUMMARY

It has taken man many centuries to be aware of the law of gravity. Man is just now becoming aware of what this means in terms of man's neurological functioning. We are all gravitational creatures functioning under the pull of gravity twenty-four hours a day in any radius in a three-dimensional plane of 360 degrees. How the body uses this force, adjusts to this constant force, has opened up new doors of understanding of his own functioning and relation of these new facts to educational procedures, homeostasis, control of human behavior, and the treatment and development of mental illness.

A tiny receptor in the human body, proprioceptor stimulation, the muscle spindle sensitive to stretch in the human body assumes enormous importance. It becomes part of the lateral nervous system and is connected to the vestibular system (otoliths) of the inner ear. Through the cerebellum and the reticular formation, many key functions to man are performed. This would seem to include the following:

(1) Enables man to function in a constant force field, the pull of gravity, automatically.

(2) Maintains homeostasis in the human body.

(3) Provides a reliable and constant source of nervous energy for the CNS upon which all higher brain functions and activity are carried on, the dynamic, the power itself.

(4) Provides a source of kybernetic control.

(5) Constitutes one of the primary sources in providing the activity in subcortical structures for establishment in the cerebral cortex of the necessary level of excitation for the formation of a conditioned connection.

(6) Provides control of sensory input.

(7) Contributes to the focus of attention.

(8) Can improve sensory discrimination.

(9) Provides information for the time-spatial organization of the body image.

(10) Is an important factor in the communication--verbal and non-verbal--and in the formation and expression of symbolic thought.

(11) Demonstrates that sex differences exist in the neural organization and use of the muscle spindles, although both are dependent upon them. Women as a group tend to be more visual, while men tend to be more basic (primitive) in their use of proprioceptor stimulation (muscle spindles).

(12) Provides the basis of skill in the development of abstract reasoning, mathematical abilities, and space relationships.

(13) Develops perceptual abilities.

(14) Destroys previous learning in such procedures as brainwashing.

(15) Provides formation of faulty or negative group attitudes, emotional problems, and behavioral difficulties when frustration or prolonged stress is associated with their use.

(16) Can distort the integrative functions of the human brain.

(17) Can circumvent higher brain functioning.

Stimulation of the muscle spindles, proprioceptors, does not constitute learning any more than a visual stimulation, such as a colored light, constitutes learning. This is a function of what, how, and when other inputs, information, or emotions, are married to or related to the proprioceptor stimulation. The process of integration is an important factor in all learning situations. However, the muscle spindles (proprioceptor stimulation, or kinaethesis) is truly man's <u>sixth sense</u>. Its importance far outweighs all the other senses as they have integrative and energy creating functions, in addition to the sense of movement and being a servo-mechanism.

Just as man has always taken gravity for granted, the functioning of the muscle spindles has gone unnoticed. They function in a preconscious manner and are so vital and automatic in their performance, that man has failed to note their involvement, manner of functioning, and their critical importance to human development. Science has now given us the information. It is up to the Educators to implement this procedure. Due to the muscle spindles' close relationship in the formation of the emotions, Yesterday was already too late.

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