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el proceso sensorial en el hombre: su análisis por medio de potenciales evocados corticales y subcorticales

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the sensory process in man: its analysis by means of cortical and subcortical evoked potentials

Resumen

El proceso sensorial del hombre se puede analizar por medio de los potenciales somatosensoriales, auditivos y visuales evocados que se registran a partir de la superficie del cuero cabelludo en todos los pacientes, y de las profundidades del cerebro en algunos pacientes que tienen electrodos implantados con finalidades diagnósticas y terapéuticas.

La sensación y la percepción son dos etapas consecutivas del proceso sensorial por medio de las cuales se perciben y analizan los estímulos ambientales. La atención selectiva es un filtro funcional que facilita la percepción de los estímulos importantes y bloquea los que carecen de importancia. La sensación se valora mediante potenciales evocados de latencia breve (tempranos) que revelan la activación del receptor, de las vías específicas y de las cortezas primarias; en tanto que la percepción se valora por los potenciales de latencia larga (tardíos) que revelan un sistema reticulotalámico inespecífico que media de manera parcial las funciones de filtrado de la atención y de análisis perceptual.

La modulación de los impulsos sensoriales por un asa corticorreticulotalamocortical (sensorial en la primera etapa cortical y motor en la segunda) en el hombre, y no a nivel periférico como ocurre en los animales, permite al cerebro humano estar informado de manera continua sobre los acontecimientos periféricos y afrontarlos con patrones sensoriales y motores organizados en tiempo y espacio mediante vías receptoras y centros corticales específicos. Esto es, permite comprender y manipular el ambiente por medio de su representación en un mosaico somatosensorial cerebral.

Abstract

The sensory process in man can be analyzed by means of the somatosensory, auditory and visual evoked potentials recorded from the surface of the scalp in all patients and from the brain depth in some patients with implanted electrodes used as a diagnostic and therapeutic procedures.

Sensation and perception are two consecutive stages in the sensory process, by which environmental stimuli are detected and analyzed. Selective attention is a functional filter which facilitates perception of the relevant stimuli and blocks those that are irrelevant. Sensation is evaluated by short latency (early) evoked potencials which reveal the activation of the receptor, specific pathways and primary cortices; whereas perception is evaluated by long latency (late) evoked potentials, which reveal of a nonspecific reticulothalamic system partially mediating the attention, filtering and analyzing perceptual functions.

Modulation of sensory impulses by a cortico (sensory) —reticulo— thalamo cortical (motor) loop in man, rather than in a peripheral level as in animals, allows the human brain to be continuously informed of the ongoing peripheral events and to deal with sensory motor patterns organized in time and space by the specific receptor pathways and cortices. That is, it permits the understanding and manipulation of the environment through its representation on a sensorymotor cerebral mosaic.

Sensation, perception and attention

The sensory process in man, by which the environmental stimuli are detected and analyzed, consist of two consecutive stages: sensation and perception. During sensation, stimuli are detected and during perception stimuli are analyzed. To see vs. to watch, to hear vs. to listen and to feel vs. to palpate; are the equivalents of sensation vs. perception in the visual, auditory and somatosensory modalities. It is of the general experience, that not all the environmental stimuli can be perceived (anlayzed) in a given moment; although they are present and eventually detected. In practice, only one or one group of related stimuli relevant for a given situation are perceived. Stimuli relevant for a given situation are perceived. Stimulus relevance depends on the quality, intensity and information content of the stimulus; as well as the instinctive and aquired characteristics of the stimulated individual.

For example, if an individual is driving a car and at the same time is listening to the Beethoven's Fifth Symphony (relevant stimulus); he can analyze the melody, harmony and rhythm of this musical composition; while the steering wheel, accelerator, clutch, brake, etc., are automatically commanded (irrelevant stimuli and actions). If in a given moment, a pedestrian suddenly crosses the car's trajectory (now a relevant stimulus), the driver is urged to manipulate the car's controls and avoid the pedestrian's injury; while the perception of Beethoven's symphony (now an irrelevant stimulus) is totally blocked. The music will be again perceived, when this particular situation is over.

In order to explain similar sensation-perception events, Von Leibniz (14) introduced the concept of attention. Accordingly, attention was a mental function by which consciousness is able to be aware or "to perceive" a limited number of relevant "sensation" while blocking the irrelevant ones. This phylosophic concept of attention was subsequently explained by Lord Adrian (1) in terms of Brain Physiology, with the following idea: our body is continuosly bombarded by a number of relevant and irrelevant environmental stimuli impinging upon our sensory internal (pressoreceptors, mechano, receptors, chemo-receptors) and external (retina, cochlea and skin) receptors. These receptors are in turn continuously generating nerve impulses which are transmitted to the brain for producing perceptual images. In this process however, there is a functional filter which facilitates those impulses produced by relevant stimuli and blocks those that are not. This functional filter separates sensation from perception and constitutes one of the neurophysiological bases of attention.

Operational definitions

Psychologically, the process is sequentially organized: 1 sensation and 2 perception separated by the selective attention. Therefore, the sensory processis initiated with an environmental stimulus and finished with a sensory or perceptual response (I); which can be remembered or forgotten (II) and followed or not by a motor respose (III) correlated to the environmental stimulus (figure 1, rectangles).

Neurophysiologically (figure 1, circles), sensation is due to the receptor activation or generation of nerve impulses, and to the transmission of these impulses through specific pathways to the primary receiving cortices. Here, these impulses are classified in time and space forming sensory patterns by a short memory process (memory I).

We propose that perception is due to a subsequent activation of a non-specific reticulo-thalamic system (see below) where the organized sensory patterns from the specific cortices are facilitated or inhibited (funcional filter); and those facilitated patterns are compared to learned brain "engrams" to form a perceptual response (I). Subsequently, this non-specific system activates the frontal, temporal and parietal memory mechanisms to produce mnesic responses (II) and the pyramidal and extrapyramidal mechanisms to produce motor responses (III) associated to the environmental stimuli.

Actually, we are in the position to analyze, at least partially, the sensory process in man by means of surface and depth brain potentials evoked by somatosensory, auditory and visual stimuli. These potentials (transient changes in brain potential time locked to the stimulus presentation) are produced by simple signals (shocks, clicks and flashes) and are recorded from the scalp surface or depth brain structures by means of automatic average computers, which cancel or attenuate the spontaneous changes in brain potential or electroencephalogram. The topography and

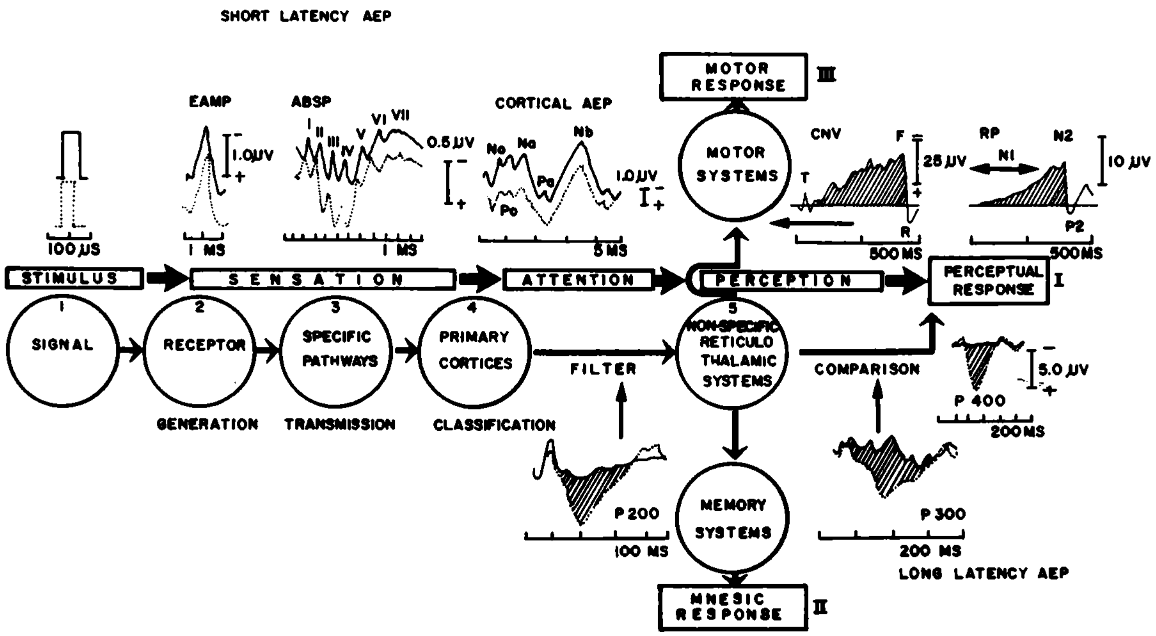

Figure 1. *Sensory process in man.* Psychological events (rectangles): 1 stimulus, 2 sensation, 3 attention and 4 perception. Possible responses to stimulus: I perceptual response, II mnesic response and III motor response.

Neurophysiological events (circles). Sensation: 1 signal, 2 receptor activation, 3 transmission through specific pathways and 4 activation of the specific cortices. Perception: 5 activation of a nonspecific reticulo-thalamic system participating in the filter, comparison, memory and motor mechanisms.

Operational definitions

Brain potentials recorded from the scalp surface (vertex or Cz) evoked by similar transient acoustic stimuli (click 100 μs and 65dBSPL) delivered to the right ear of a normal individual in different (continuous graphs) or performing a series of tests related to the stimulus presentation (discontinuous graphs).

Sensation: Short latency or early evoked potentials: External auditory meatus potencial (EAMP) = receptor activation (4), auditory brain stem potentials, (ABSP) components I to VII = successive activation of specific auditory pathways.[12, 13, 22, 23, 36, 37] Cortical potentials (No, Po, Na, Pa, Nb) = activation of the primary auditory cortex.[5]

Attention and perception: Long latency, late evoked potentials (also named event related potentials): P200 = filtering.[2, 8, 12, 28, 38] P300 = comparison or "recognizing" [24, 39] and P400 = perceptual response.[21] These functions are postulated to occur within a nonspecific reticulo thalamic system.[27]

Premotor responses: In addition, expectancy for performing a motor response is evaluated by means of the contingent negative variation (CNV) [19, 43] and preparation and decision to perform a motor response is evaluated by means of the N1 and P1-N2 readiness potentials (RP).[16]

Tasks for auditory stimuli: Task required from patient to record the event related potentials were: P200 = patient presses a bottom (continuous) vs. reading a newspaper (discontinuous) when clicks of similar intensities are presented. P300 = patient counts the low intensity (40dBSPL) and infrequent (P = 10/100) vs. ignores the high intensity (60dBSPL) and frequent (P = 90/100) clicks P400 = patient counts the omitted infrequent while ignoring frequet clicks.

In the case of CNV, the patient presses a bottom to an imperative visual stimulus (flash) when a warning auditory stimulus is presented (click); and in the case of RP, patient moves his second finger whenever he wishes, not related to the auditory stimulus presentation.

polarity; and the latency and amplitude of the evoked potentials provide information about brain processes in terms of activated anatomical pathways and centers; as well as sequence and facilitation-inhibition, respectively. These brain processes occur, when the patients are indifferent to or performing a series of sensory (sensation, attention, perception) and motor (expectancy, preparation, decision and execution) tests related to the stimulus presentation.

Figure 1 illustrates some of the evoked potentials which permit the operational analyses of the sensory process in the auditory modality; as well as the motor events related to an auditory stimulus in a normal individual. All these potentials are produced by similar auditory signals (clicks of 100 us duration and 65 dB-SPL amplitude) and their morphology depends on the analysis time and the task performed by the individual to the stimulus presentation. We will be referring here mainly to the short latency *PV, P20 and P40* and the long latency *P200* potentials, since they permit the evaluation of some elemental aspects of the sensory process, particularly the selestive attention as a functional filter.

Specific and non-specific systems

A.*Animal model*

Hernández Peón 10, 11 was the first to study the sensory process by means of the visual, auditory, somatosensory and olfactory evoked potencials in cats with acutely and chronically implanted electrodes.

To understand Hernández Peón's concept of the organization of the sensory process, it is necessary to mention that there was previous experimental evidente on aspects related to attention such as: 1. the functional role of the reticular system in the regulation of wakefulness and general aletness, 2. the existence of a polysensory system parallel to the specific afferent pathways and 3. the supraspinal modulation of the afferent conduction of the somatic pathways.

1. Magoun et al 15, 17 have shown the existence of an ascending reticular activating system responsable for the state of wakefulness and general alertness, a condition which is fundamental for the selective attention operation. This system is formend by the mesencephalic reticular formation, the intralaminar thalaminar thalamic nuclei and the association cortices. Electrical stimulation of this system leaded behavioral arousal; and electrolitic lesions leaded to an state of coma and irresponsiveness.

2. French et al.[6] described that this reticular system was also a polysensory, non-specific system, which was activated by impulses from different sensory modalities through collaterals from the specific pathways at the level of the brain stem. These impulses produced a double effect: A. activation of the wakefulness ascending reticular system and B. synthesis and interaction with those of different sensory modalities. The specific evoked potentials showed short latencies, were recorded from only one sensory modality pathway and were resistant to anoxia and anesthesia; while the non-specific evoked potentials show long latencies, were recorded together with those of other modalities in the same locus of the non-specific polysensory system and were sensitive to anoxia and anesthesia.

3. Hagabarth and Kerr[9] have shown the afferent impulses from somato sensory receptors were normally regulated by descending supraspinal influences, which were evidenced for sectioning of the reticulo spinal fibers traveling through the posterior columns of the spinal cord (figure 2A).

Taking advantage of this experimental background, Hernández-Peón studied the modulation of the afferent impulses from different sensory modalities during "attention" and "inattention". This modulation was evaluated by means of amplitude changes of brain potentials evoked by visual, somatic, auditory and olfactory stimuli; and simultaneously recorded at the first synapsis of their central nervous system pathways, at the reticular system and at the specific and association cortices.

Accordingly, the evoked potentials in all recorded sites were large when stimuli were applied the first time (novelty), they decreased when stimuli were repeated monotously (habituation). They increased again when stimuli were reinforced (attention) and they decreased again when other intercurrent "more relevant" stimuli were presented which deviated the "fo-

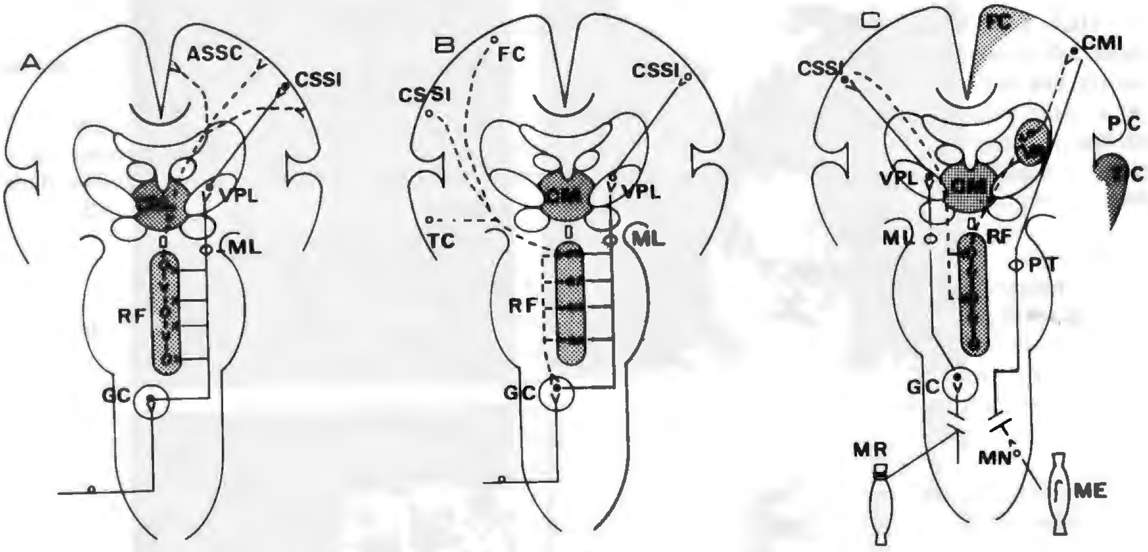

Figure 2. Selective attention mechanisms within a reticular, extralemniscal, nonspecific, polysensory system.

A. Lemniscal and estralemniscal system in animals: Afferent somatosensory impulses are transmitted from the periphery to the somatosensory cortex (CSSI) through classic lemniscal or specific pathways including the gracillis and cunneatus nuclei (GC), the medial lemniscus (ML) and the ventroposterolateral thalamic nucleus (VPL). These impulses are also transmitted through collaterals at the brain stem level from the lemniscal to the extralemniscal or ascending reticular activating system, including the mesencephalilc reticular formation (RF), the reticular thalamic system (CM) and the association cortices. According to French el al.[6]

B. Animal model of the filtering mechanism of the somatosensory afferent impulses at the level of the first synapses (GC) by descending inhibitory influences from the low reticular formation (RF). This mechanism is activated through collaterals from the lemniscal system (ML) to the reticular formation (RF) and by descending influences from the frontal (FC), somatosensory (CSS1) and temporal cortex (TC). According to Hernández Peón. [10, 11]

C. Human model of the filtering mechanism of the somatosensory afferent impulses at the level of a cortico-reticulo-thalamo-cortical loop. Somatosensory impulses are transmitted without modulation from the muscular receptors (MR) to the specific somaosensory cortex (CSSI) through lemniscal pathways (GC, ML, VPL) to be organized in time and space. From here, these organized impulses are reverted from the specific cortex to the nonspecific reticulo (RE)-thalamic (VA) system. From here, reticulothalamic impulses are projected to the motor cortex (CMI), pyramidal tract (PT) and distal muscles (ME) to produce skillful muscular responses. According to Velasco and Velasco.[27]

cus of attention" from the tested response (distraction) (figure 3).

In acute conditions, habituation was present both in an intact, awake and paralyzed animal and in a decorticated or decerebrated animal by means of a high mesencephalic transection. In contrast, habituation disappeared either by the section of the spinal posterior columns or by an extensive lesion of the bulbar reticular formation.

On these bases, Hernández Peón postulated that selective attention was a function of the bulbar reticular formation, which modulated afferent transmission through descending influences impinging upon the receptor or the first synapsis of entrance to the CNS. i.e.: the nuclei gracillis and cunneatus for the somatosensory, the cochlear nucleus for the auditory, the lateral geniculate thalamic nucleus for the visual and the olfactory bulb for the olfactory sensory modalities. In this way, the filter function of attention consisted in a peripheral valve, which automatically operated, blocked all nonrelevant stimuli; avoiding the brain to be continuously bombarded by a great variety of irrelevant stimuli and interfering

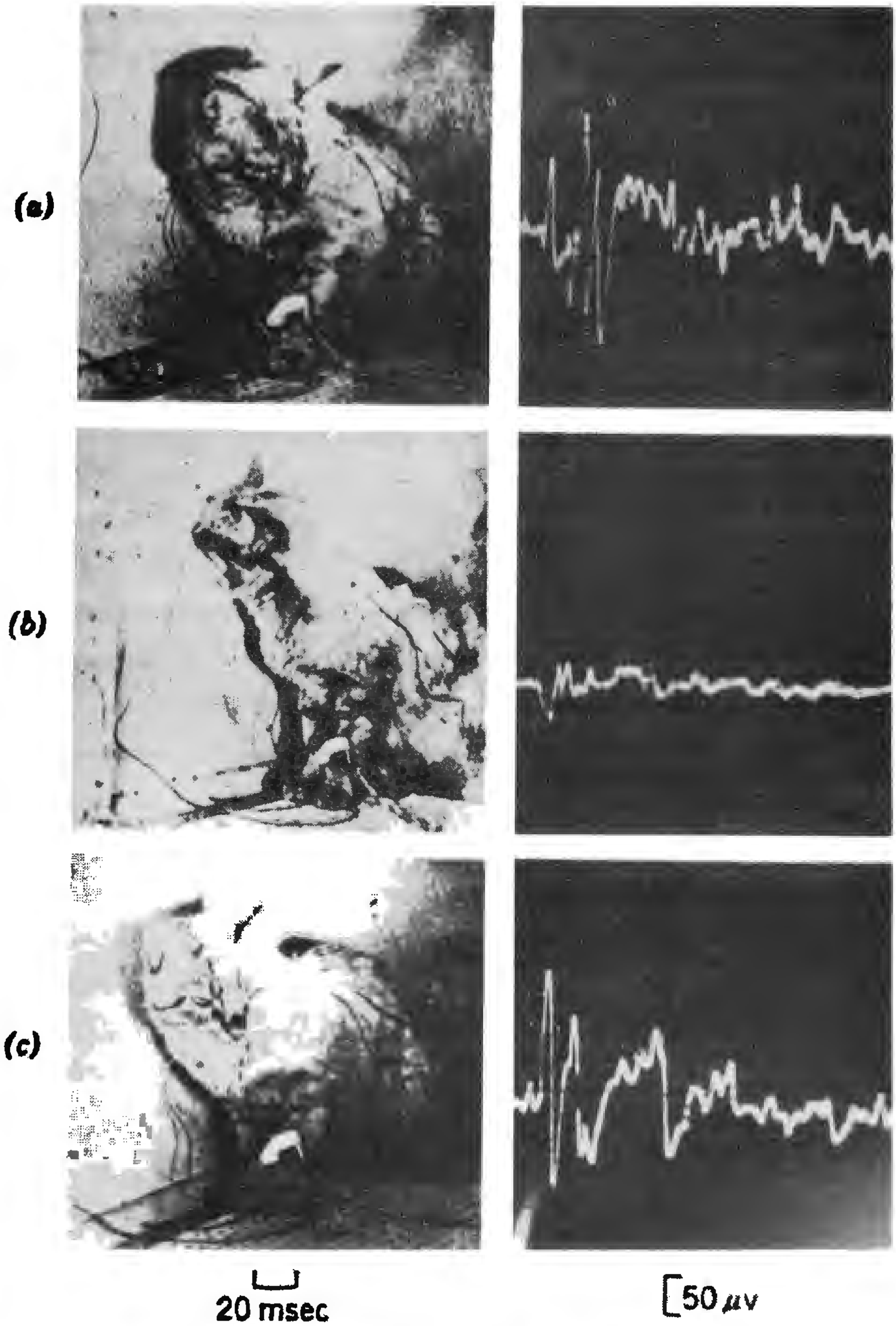

Figure 3. Blockage of the somatosensory evoked potentials produced by single sohck stimulation of the left median nerve and recorded from the posterior columns of the spinal cord, when the "selective attention" of a cat is shifted from the median nerve stimulus to one intercurrent odorous stimulus applied into the cage through a catheter.

A. Cat attentive to the somatosensory stimulus
B. Attention is shifted from the somatosensory to the odorous stimulus
C. Cat attended again to the somatosensory stimulus Taken from Hernández Peón 1961.[10]

whith the perceptual image, memory and the motor action related to the relevant stimuli.

According to Hernández Peón [7] this automatic control of the sensory process could be "consciously" regulated by means of cortico-reticular descending influences (figure 2B).

The pioneer experiments on the sensory process by Hernández Peón represent so far, the only systematic neurophysiological analyses on selective attention in animals; and they motivated a number of experimental and clinical investigators to proceed with this approach all over the world. On the other hand, these pioneer experiments were subsequently criticized because various methodological failures: first, there was a lack of the control in the constancy of sensory input, in relation to both the stimulus intensity and the receptor and parareceptor activities. Second, the lack of an appropiate analysis on the polarity and latency of different components of the evoked potentials revealing the level and sequence of activation within the CNS. Third, the lack of control of the spontaneous motor activities of cats, interfering with the spinal afferent transmission; and fourth the system manipulation by reticular lesions, which may indirectly affect the attention process, through changes in the level of vigilance and general alertness.

B. *Human model*

Following an approach similar to that used by Hernández Peón and the above mentioned variables under control, we studied the attention process as a functional filter on the auditory, visual and somatosensory cerebral responses in our patients, with depth electrodes utilized as a diagnostic or therapeutic procedure for improvement of their symptoms. Material included: 20 patients with pain, 180 patients with Parkinson's disease and other dyskinesis and 90 patients with temporal lobe epilepsy, refractory to conventional medical treatment. In these patients, sistematically evoked potentials were recorded from a wide cerebral area comprised between the rostral mesencephalon, caudally; to the base of the frontal lobe, amygdaloid complex and hippocampal formation within the temporal lobe, rostrally. This area included the subthalamus, the mesial, intralaminar and basolateral thalamus and other structures of the forebrain (figure 4).

Cerebral potentials were recorded from indifferent patients or performing a series of tasks to the stimulus presentation. In addition, subjective and objective responses to the electrical stimulation of the recorded cerebral loci were studied in all patients; and the effect of thalamic and subthalamic lesions on brain potentials and behavior were studied in patients with pain and Parkinson's disease.[3, 30]

The effect of lesions in the gyrus cingulum for the treatment of pain; in other basal ganglia for the treatment of dyskinesias; and in the temporal lobe for the treatment of complex partial seizures on brain potentials and attention, will be reported elsewhere.[41]

Our results suggest that in man as in animals, there are specific sensory systems transmitting afferent impulses separately, originated from somatosensory, auditory and visual receptors.[28, 36, 37, 38.]

Short latency P20 somatosensory, P5 auditory and P40 visual evoked potentials were recorded within specific pathways and thalamic nuclei (figure 5 left). Electrical stimulation of these loci elicited in patients specific sensory responses, referred by patients as paresthesias of the contralateral body (stimulation of the medial lemniscus and ventro postero lateral thalamic nucleus), buzzing at the contralateral ear (stimulation of the medial geniculate thalamic nucleus) and black white scotomas at the ipsilateral eye (stimulation of the optic radiations and lateral geniculate thalamic nucleus). These data suggest that the specific sensory systems participate in the stage of sensation of the sensory process (figure 4, shaded areas and filled circles).

In addition, these results suggest that in man, there is a nonspecific sensory system; which transmits to the cerebral cortex impulses together from different sensory modalities (polysensory).[28, 38] In this system, late potentials, with peak latency of about 200 msec (P200) are evoked by somatosensory, auditory and visual stimuli (figure 5, right). This system includes: the mesencephalic reticular formation, the intralaminar and oral thalamic nuclei, the caudate nucleus, the medial and lateral pallidum, the amygdala and hippocampus and the orbito frontal cortex. The electrical stimulation of the thalamic portion of this system may modify the EEG background of the frontal, central and parietal cortical regions, increases reac-

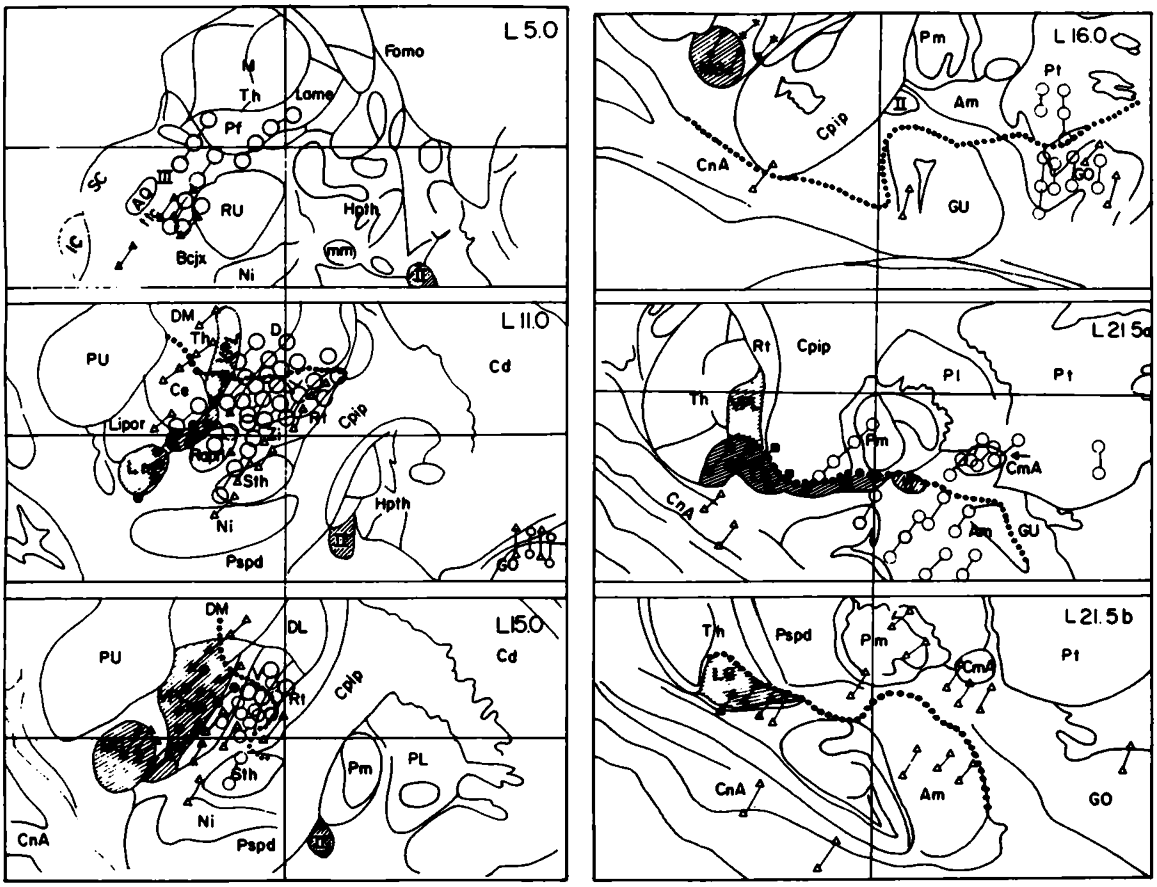

Figure 4. Subcortical position of the electrodes radiologically determined by the methods of Velasco et al[31] and Talairach et al[25] and superimposed on parasagittal sections of the anatomical atlas of Schaltenbrand and Bailey.[20] Section L5.0 shows the electrode tips at the rostral mesencephalon and medial thalamus in patients with pain; Section L11.0 and 15.0 at the subthalamic and ventrolateral thalamic regions in patients with Parkinson's disease; and Sections L16.0 and 21.5A and B at the forebrain and temporal and frontal lobes in patients with temporal lobe epilepsy.

Shaded areas represent specific thalamic nuclei and pathways of the somatosensory (LM = medial lemniscus and VPL = ventro postero lateral thalamic nucleus), auditory (MG = medial geniculate thalamic nucleus) and visual (II = optic radiations and LG = lateral geniculate thalamic nucleus) where early somatosensory (filled circles), auditory (filled triangles) and visual (filled squares) evoked potentials were recorded.

Late evoked potentials of the three sensory modalities were recorded together from the same locus of a nonspecific polysensory system which included mesencephalic (ttc = reticular formation), subthalamic (SN = substantia nigra, Sth = nucleus subthalamicus, Raprl = prelemniscal radiations), medial thalamic (Pf = parafascicular, lame = intralaminar, Ce = centro median thalamic nuclei), lateral thalamic (VL = ventro lateral thalamic nucleus), forebrain (Pt = putmen, Pm = pallidum medialis, Pl = palllidum lateralis and Cd = caudate nucleus) frontal (GO = gyrus orbitalis) and temporal cerebral structures (CnA = hippocampal formation and Am = amygdala). Modified from Velasco et al 1986[33].

tion velocity and amplitude of the Parkinsonian tremor. Moderate electrical stimulation of other portions of this system (less than 2000 μ A) in general elicits in patients no sensory or motor responses.

Selective attention modulates the amplitude of late (P200) but not early (P20) somatosensory evoked potentials recorded from either scalp surface or with in the brain (figure 6). Novelty and attention increase

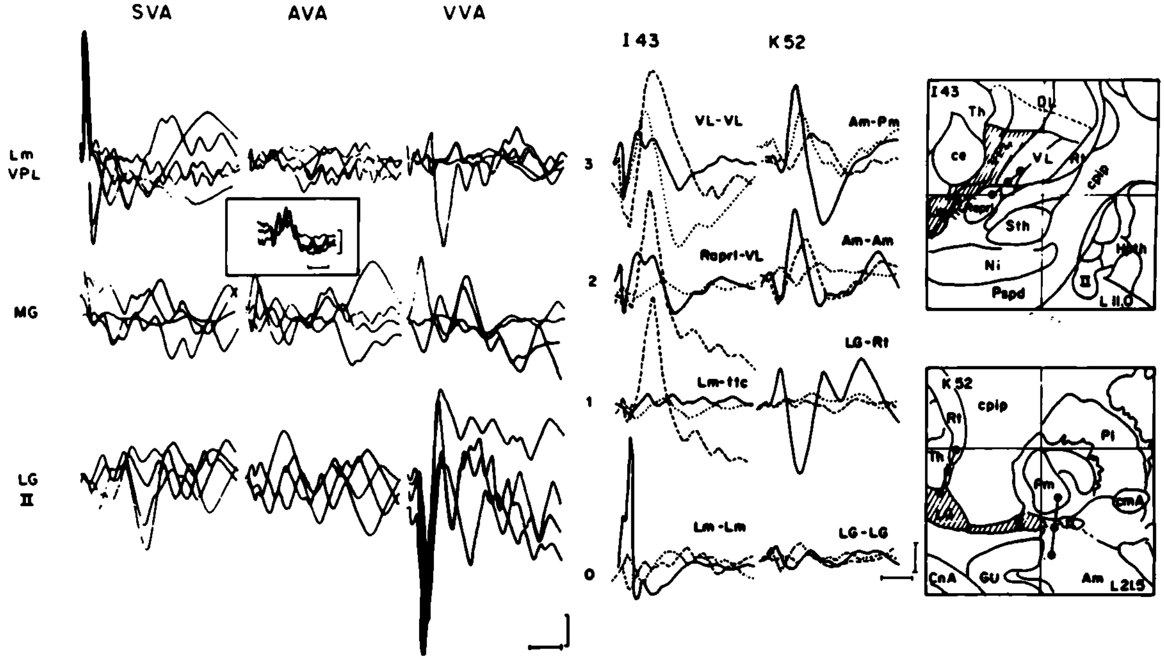

Figure 5. Subcortical distribution of short and long latency somatosensory, auditory and visual evoked potentials.

Left: Early (short latency) potentials recorded from the medial lemniscus (Lm and ventro postero lateral nucleus (VLP); medial geniculate nucleus (MG); and optic radiations (II) and lateral geniculate nucleus (LG) thalami, evoked by somatosensory (SVA) auditory (AVA) and visual (VVA) stimuli, respectively.

All recordings are bipolar and early potentials are recorded only form the corresponding specific thalamic nuclei and pathways contralateral to the median nerve, ear and eye stimulation. Calibration: somatosensory and visual evoked potentials: 20 μV and 100 msec; auditory evoked potentials: 1 μV and 5.0 msec.

Right: Late (long latency) potentials recorded together from same subcortical locus: ventrolateral thalamic nucleus (VL-VL of patient I43) and amygdala-pallidum medialis (Am-Pm of patient K52); evoked by somatosensory (continuous graphs), auditory (dotted graphs) and visual (discontinuous graphs) contralateral stimulation.

Note that late potentials are absent within specific structures: medial lemniscus (Lm-Lm of patient I43) and lateral geniculate thalamic nucleus (LG-LG of patient K52). In addition, late potentials from one or two sensory modalities are recorded together within intermediate regions comprised between specific and nonspecific systems, as shown in the enclosed diagrams other abbreviations as in Figure 4. Modified from Velasco et al. [38]

while habituation and distraction decrease P200 potentials evoked by single shock stimulation to the median nerve; under constant stimulation intensity (400 μ A) and uniform activation of the muscle spindle receptors (amplitude of muscular response = 400 μ V).[26, 31, 35]

These results initially observed for the somatosensory evoked potentials have been recently extended to those of auditory and visual modalities, under a constant sensory input monitoring by the cochlear potential and the electroretinogram, respectively.[41]

Selective attention modulation of late but not early evoked potentials suggest that functional filter of sensory impulses occurs at the non-specific rather than at the specific sensory system.

The effect of thalamic and subthalamic lesions for the treatment of tremor and pain on somatosensory evoked potentials permitted a further analysis of the physiology of the attention process. For example, lesions of the specific somatosensory system (medial lemniscus), recommended for the treatment of some types of causalgia, produced total anesthesia of the

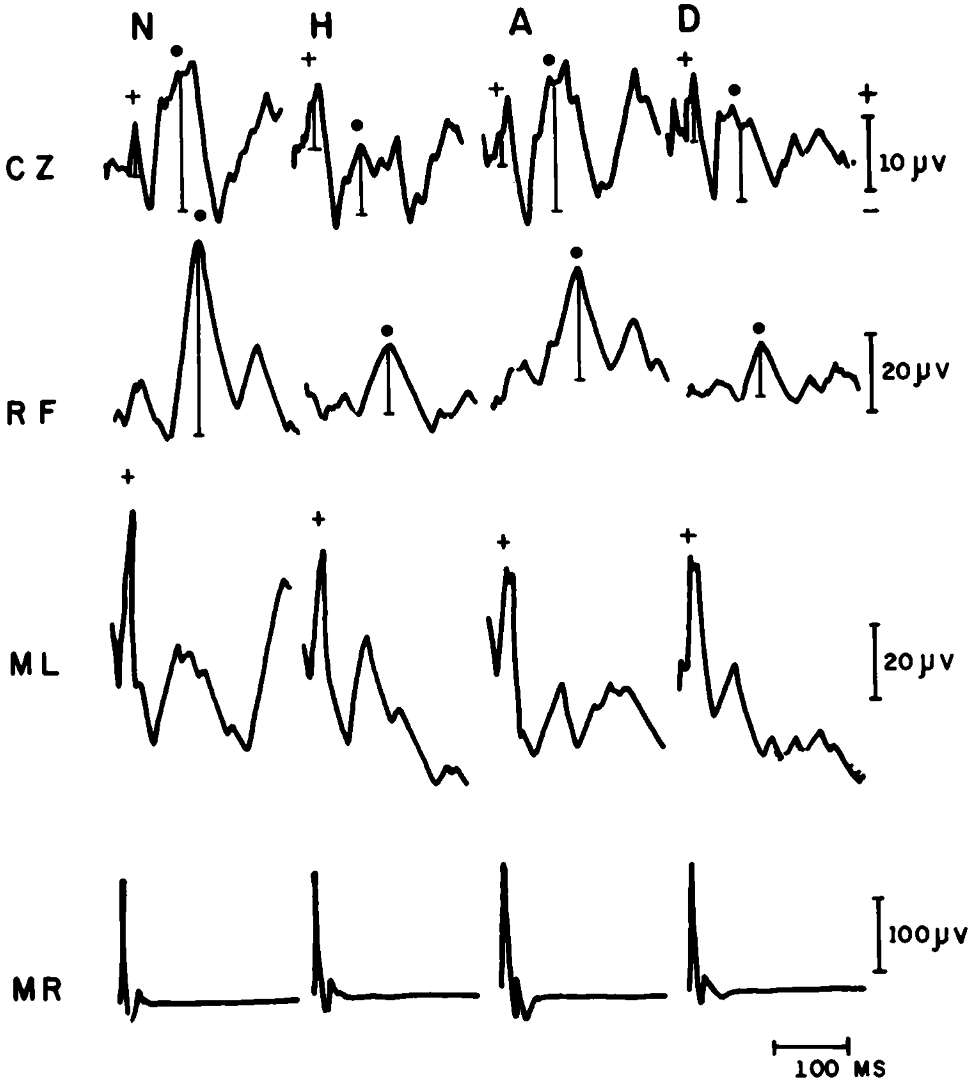

Figure 6. Effect of changes in selective attention on early P20 (+) and late P 200 (.) somatic evoked potentials (produced by stimulation of the median nerve) recorded from the scalp surface (Cz) and from the medial lemniscus (ML) and the mesencephalic reticular formation (RF) of a Parkinsonian patient under the following attentive conditions: Novelty (N), habituation (H), attention (A) and distraction (D). The constant amplitude of the muscular response (simultaneously recorded at the tenar muscles) guarantees the constancy of the sensory input along these conditions.

Novelty, is defined as a condition under which the patient is quiet, awake, with eyes closed and receiving the first series of stimuli to the median nerve.

Habituation, when the patient has received 10 series of 32 stimuli each, delivered to the median nerve in a monotonous sequence of 1 every 4 seconds.

Attention, immediately after habituation, the patient is instructed to respond by pressing a lever as fast as possible after each stimulus presentation; and

Distraction, when patient is required to ignore the stimuli delivered to the median nerve, but instedad, to detect and report, eyes closed, a number written on the palm of tne hand controlateral to the stimulated one. Modified from Velasco et al.[26, 35, 36] treated hand and blocked both early and late components of the somatosensory evoked potentials; while lesions of the nonspecific somatosensory system (prelimniscal radiations and/or ventro lateral thalamic nucleus) produced an "inattention" or "neglect" syndrome* and bloked the tremor at the treated hand; and produced an amplitude reduction of the late componets of the somatosensory evoked potentials. (figures 7E and 8).

Since ablations of the specific somatosensory cortex produced effects on sensation and evoked potentials

* The "neglect" syndrome consists in the preferential use patients have for the nontreated hand for performing a manipulation task; although it may be the dominant one (right hand). This syndrome appears free of detectable motor, coordination and sensory deficits on neurologic examination. Neglect of the treated hand is accompanied by decreased reaction velocity, decreased amplitude of the P200 evoked potential and decreased score of the Beta R psychomotor maze test performance.

In monkeys, "neglect" syndrome is observed following stereotaxic unilateral lesions circunscribed to the mesencephalic reticular formation.[34] In man, "neglect" syndrome is observed after stereotaxic unilateral lesions of the prelemniscal radiations,[27,30] only in patients with pre existent lesions of the intralaminar thalamic nuclei, revealed by a prominent dilatation of the III ventricle.[40] Whether this syndrome is due only to decreased selective attention to sensory stimuli (decreased amplitude of P200 potential) or to an associated deficit in motor performance and strategy (decreased velocity response and maze tests) is an open question.

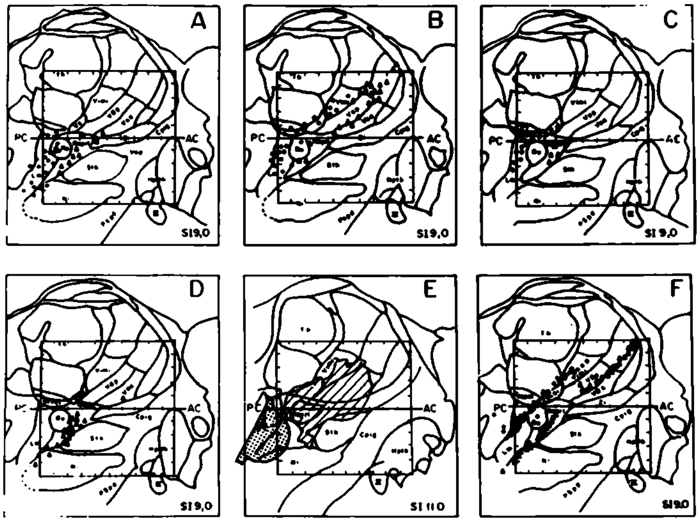

Figure 7. Specific (filled circles) and non-specific (filled triangles) somatosensory systems in man.

A. Electrical stimulation: specific = produced sensory responses (paresthesias). Nonspecific = increased tremor amplitude at the contralateral hand.

B. Multiunit activity: specific = rhythmic cellular activity evoked by tremor and by passive mobilization of the corresponding joints. Non-specific = spontaneous rhythmic cellular activity independent of tremor or muscle activity.

C. Somatosensory evoked potentials: specific = early (short latency). Nonspecific = late (long latency) potentials.

D. Critical area for blockage of tremor = nonspecific system (prelemniscal radiations).

E. Lesions taylored by a leucotome: specific (dotted area) = total anesthesia and blockage of early and late somatosensory evoked potentials. Nonspecific (shaded area) = permanent blockage of tremor, "inattention" syndrome (in patients with III ventricle dilatation) and amplitude reduction of late somatosensory evoked potentials.

F. Ventricular analyses: specific system vector = dorsolaterally located, includes medial lemniscus (LM) and the ventroposterolateral thalamic nuclei (Vcpci, Ccai, and Vimi) vs. nonspecific system vector, ventro medially lacated, includes the prelemnical radiations (Rapr) and the ventro lateral thalamic nuclei (Voa and Vop). After Velasco and Velasco.[27]

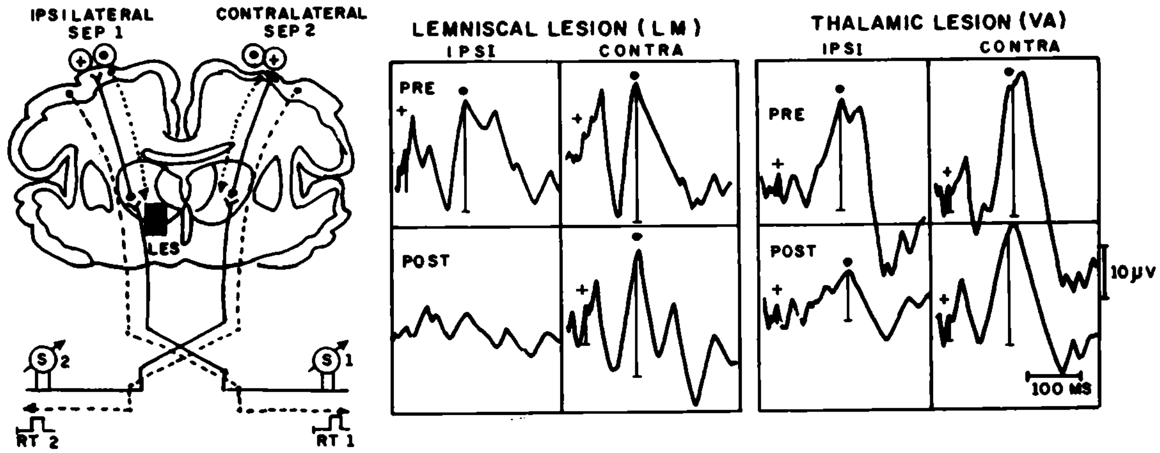

Figure 8. Effect of specific and nonspecific thalamosubthalamic lesions on early and late evoked somatosensory potentials.

Left: Experimental design and hypothesis: S1 and S2 = single shock stimuli independently delivered to left and right median nerve. SEP1 and SEP2 somatosensory evoked potentials and RT1 and RT2 reaction tunes, LES = lesion. S1, SEP1 and RT1 = tests related to the side of the lesion S2, SEP2 and RT2 = contralateral control tests.

Hypothesis: continuous lines and arrows = ascending lemniscal pathways related to early and late potentials. Dotted lines and arrows = descending and ascending extralemnical pathways related to late potentials only. Discontinuous lines and arrows = pyramidal pathways related to hand motor responses and tremor.

Right: Lemniscal lesions blocked early (+) and late (.) potentials, while extralemniscal lesions reduced amplitude of the late potentials. PRE and POST = pre and post operative, recordings. IPSI and CONTRA = recordings ipsi and contralateral to the lesion. Modified from Velasco and Velasco [27] and Velasco et al.[32]

similar to those produced by lesions in the specific lemniscal pathways,[33, 42] it is reasonable to postulate that specific sensory impulses associated to sensation, travel without modulation from the muscle receptors to the specific somatosensory cortex. From here, these impulses descend to the nonspecific reticulo-thalamic system to be modulated and filtered. Subsequently, "relevant" corticoreticulo-thalamic impulses are projected to the motor cortex, the pyramidal tract and the distal muscles to participate in the voluntary control of the skillful movements (figure 2C). Anatomical connections between structures of this postulated cortico (sensory)-reticulo-tahalamo-cortical (motor) loop can be widely documented.[7, 18]

A selective attention filtering mechanism at this cortico-reticulo-thalamo-cortical loop as visualized in man; rather than at the receptors or lower synapsis as visualized in animals; provides a number of advantages in handling the sensory process; First, it permits the human brain to be constantly informed of the ongoing environmental events, by means of afferent impulses automatically classified in time and space by the specific pathways and cerebral cortices. Second, it permits the nonspecific reticulo thalamic system to be fed by organized sensory patterns (rather than isolated bits of information) originating from the specific cortices; for being compared with other circulating impulses becoming from the periphery or from other integration and association systems of the CNS. Third, that organized sensory patterns can efficiently participate in the preparation, decision and dexterity. In other words, the existence of a cortico-reticulo-thalamo-cortical loop permits the manipulation of the environment through its representation on a sensory-motor cerebral mosaic.

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