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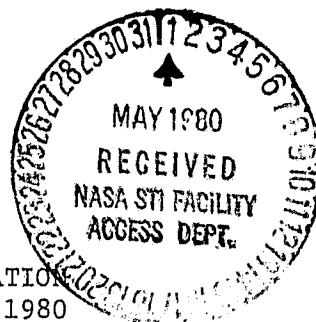
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VESTIBULAR RECRUITMENT

By

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The concept of recruitment was introduced into neurophysiology by Sherrington in 1923 to designate the pathologically fast increase in intensity of the muscular response as compared to the rise in the magnitude of the stimulus. Fowler in 1928 transferred this concept to the physiology of sense organs to designate the pathologically rapid increase in the strength of sound as compared to the strength of the sound stimulant. Merison and Dempsey (1942) used the term recruiting response in describing the function of the nonspecific nuclei of the thalamus. The latter with weak stimulation yield a limited (zonal) effect, while strong stimulation induces an intensive response which results in excitation of the entire cerebral cortex.

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The term vestibular recruitment was introduced for the first time by Van Egmond et al. (1949). The authors, having used small angular accelerations, during rotating tests did not reproduce the vestibular reaction, and with large accelerations obtained normal vestibular reactions. An analogous ability of the vestibular system to react differently to the stimulants that increase in strength under different conditions of affection was observed by N. S. Blagoveshchenskaya (1962); she explained this capability by the phase phenomena in the vestibular analyzer. V. S. Olisov (1973) based on the data of Van Egmond et al. (1940) believes that in Meniere's sickness a unique vestibular hyperpathia is observed

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that in its nature is very close to the known audiological phenomenon of accelerated increase in loudness. Upon the suggestion of the author this phenomenon is governed by summation of the excitation in the centers discovered by I. M. Sechenov in 1863. Azzi et al. (1953) used caloric stimulation by different quantity of water of the same temperature; here in patients with affection of the labyrinth the vestibular excitability was reduced, however with a rise in the stimulus it became normal. The same phenomenon was observed by Albano (1957) who used rotation during stimulation of the vestibular system in patients with affection of the labyrinth. Van der Vis (1957) conducted rotating tests in 150 patients with vertigo of varying etiology and revealed in them a leveling of the vestibular excitability. Andersen (1956) also reported vestibular recruitment in certain cases in patients with vertigo. Horak (1962) equated the vestibular excitability from both sides in patients with hydrops of the labyrinth and in patients with affection on the level of the vestibular nuclei during rotating tests of great intensity. He believes that the phenomenon is important for a topical diagnosis of affections of the vestibular system. Greiner et al. (1965, 1969) used for detection of the vestibular recruitment sinusoidal rotation varying in intensity. With strong stimuli they established normal vestibular excitability on the affected side in patients with hydrops of the labyrinth, traumas of the pyramid of the temporal bone and traumas of the skull. With weak stimuli the excitability on the part of affection in these same patients was reduced. The phenomenon of leveling of the vestibular excitability was revealed in 5% of the patients with peripheral affection of the vestibular system. Greiner assumes that the phenomenon of vestibular recruitment indisputably plays an important role in determining the topics of affection of the vestibular system, and also has prognostic and expert value. Moser (1972) who used the sinusoidal rotation noted in 2 out of 36 patients with Meniere's sickness leveling of the vestibular excitability from both sides during strong stimuli, and Janczewski (1975)--in 12% of the patients with peripheral affection of the vestibular system. I. A. Sklyut and S. G. Tsemakhov (1978a), Conraux and Gentine (1976) established that with a rise in the stimulus the vestibular excitability on the painful side sometimes not only is levelled with the excitability on the healthy side, but even "overtakes" it. Ikeda (1964), Mendel (1971) and Gramowski (1972) revealed the vestibular recruitment in 100% of the patients with Meniere's sickness. Torok (1970) found it in 95% of the cases of affection of the peripheral lobe of the vestibular system, I. A. Sklyut and S. G. Tsemakhov (1978) established vestibular recruitment in 19 of the 21 patients with Meniere's sickness. To stimulate the

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vestibular system Mendel (1971) used rotation, while the other authors used calorizing.

Emami-Nouri (1973) who studied patients with Meniere's sickness used to stimulate the labyrinths rotation, sinusoidal rotation and calorizing. He noted that the most rarely manifest is the phenomenon of vestibular recruitment with sinusoidal rotation and most often during calorizing and rotation. Henriksson (1956) who obtained vestibular recruitment during rotating stimulation, assumed that during calorizing it cannot be revealed; Greiner (1965) holds the same opinion. Claussen (1969) to reveal the vestibular recruitment used calorizing as a weak stimulant and rotation as a strong stimulant in patients with peripheral affection of the vestibular system. He evaluated the findings with the help of the scheme of "butterflies" (Schmetterlingschema). The author isolated three types of vestibular recruitment: a) inhibiting recruitment (Hemmungs-Recruitment), when with weak stimulation the graphs reflecting the vestibular excitability lie lower than the normal, with strong--in the area of the normal; b) uninhibiting vestibular recruitment (Enthemmungs-Recruitment) where with weak stimuli the graphs lie in the region of the normal, with strong--above the normal; c) inhibiting-uninhibiting recruitment (Hemmungs-Enthemmungs-Recruitment): with weak stimuli--below the norm, with strong--above the norm. The first variant the author calls strictly recruitment (Claussen, 1969a; Claussen, 1969b; Claussen et al., 1973; Estelrriich and Claussen, 1975).

Schulz (1976) used an analogous technique and evaluation of the reaction; he revealed vestibular recruitment in patients with peripheral affection of the vestibular apparatus of infectious etiology. Niedballa (1974) in using the described method of evaluating the reaction of the vestibular analyzer used air calorizing and revealed vestibular recruitment. Lukomski (1975) found vestibular recruitment in 20% of the patients with Meniere's sickness. In his opinion, the question of the diagnostic value of the given phenomenon remains questionable. Litton and McCabe (1966), Steffen et al. (1970) and Reker et al. (1975) did not observe the phenomenon of recruiting in any case of peripheral and central vestibular affections. These authors used calorizing as a stimulus of the vestibular system. Wilnot (1974) who used rotation of varying strength in patients with Meniere's sickness revealed an increase in amplitude of the nystagmus under the influence of an intensive stimulus.

The data given above indicate the contradiction in the opinions in relation to the existence of vestibular recruitment and its diagnostic value, although the majority of authors speak in favor of the great importance of the given phenomenon for topical diagnostics of peripheral and central affections of the vestibular system (I. A. Sklyut, and S. G. Tsemakhov, 1978; Horak, 1962; Greiner, et al., 1969; Gramowski, 1972; Emami-Nouri, 1972; Claussen et al., 1973).

On the basis of the aforementioned one can assume that the frequency of detection of vestibular recruitment depends, first, on the methods of stimulation, and second, probably, on the selection of parameters for evaluating the vestibular nystagmus reaction. The least percentage of accelerated increase in the vestibular excitability was observed by the authors who used sinusoidal rotation (Emami-Nouri, 1973). All the authors who did not reveal vestibular recruitment used one parameter to evaluate the nystagmus reaction--the rate of the slow phase of nystagmus. Probably the frequency of nystagmus in the given case is a more suitable parameter. Such a hypothesis coincides with the opinion of Torok (1969). According to the data of I. A. Sklyut and S. G. Tsemakhov (1978a, b) the phenomenon of vestibular recruitment can be manifest only in frequency or only in amplitude, as well as simultaneously in frequency and amplitude. /78

The given information makes it possible to conclude that the vestibular recruitment is a phenomenon that is characterized by leveling of the vestibular excitability of the painful and healthy sides during strong stimuli, while with weak stimuli there is a clear difference between the excitability of the painful and healthy labyrinth, or such a phenomenon in which the weak stimulation reveals vestibular excitability below the norm, while with strong stimulus a normal vestibular reaction is observed. Gramowski (1972) in determining the reaction of recruitment started from computation of the percentage of increase in excitability of the labyrinth with strong stimulation as compared to the vestibular excitability manifest in response to the weak stimulus.

The biological meaning of the vestibular recruitment consists of compensation for the state induced by disorder in the equilibrium between the labyrinths, by the restoration of this equilibrium (Mittermaier, 1965). The mechanism of vestibular recruitment is explained by many researchers based on a study of the peculiarities of the morphological structure of the vestibular system. Based on published data it is known that the sensitive epithelium of the ampullae of the semicircular canals and the otolithic apparatus by analogy with the epithelium

of the cochlea is represented by two types of cells--spontaneous-active cells of the I type and spontaneous-passive cells of the II type. Wersall (1954) who made a great contribution to the study on the structure of the vestibular epithelium found two types of cells of the I type (spontaneous-active) located primarily on the top of the ampullary crest of the semicircular canal; due to this the deformation of the hair of these cells occurs even with a small movement of the endolymph. Stimulation of these cells activates only one afferent nerve fiber (like the retinal cones). The cylindrical cells of the II type (spontaneous-passive) are primarily located on the base of the ampullary crest of the semicircular canal. One cylindrical cell is linked to a set of afferent fibers (like the retinal rods). In addition the efferent vestibular fibers approach the cells of the II type). Such an arrangement of the receptors and the fact that from the central part of the ampullary crest of the epithelium thick vestibular fibers emerge, and from its basal part--thin, indicate the capability of the cells of the I type to rapidly differentiate different stimuli. Correspondingly to this the hypotheses are advanced that the central part of the ampulla is designed for phase-kinetic action, while the peripheral part--for tonic action (S. N. Khechinashvili, 1958; Ross, 1936; Cawthorne et al., 1942; Loewenstein and Roberts, 1951; Loewenstein, 1964, 1972; Loewenstein et al., 1964; Wersall, 1954, 1956, 1960; Wersall et al., 1954; Wersall and Flock, 1965; Smith, 1956; Engstrom, 1958, 1961, 1965; Engstrom and Wersall, 1958; Monnier, 1965; Spoendlin, 1968). In the composition of the synapses formed by cells of the I type nerve endings are included that are rich in granules that consist of ribonucleic acids (RNA), and the latter is bonded with protein (p-RNA). This RNA is linked to protein synthesis and determines the activity of the cell (depending on the number of granules and their capability to be stained with the main stains). The composition of the synapses formed by cells of the II type includes nerve endings, rich and poor in granules. The granule-poor nerve endings are equipped with projections in the form of tongue going into the cell; the first endings rich in granules have a thickened presynaptic membrane (Wersall, 1956; Wersall and Flock, 1965; Engstrom, 1965; Shade and Ford, 1976). Such a structure of the vestibular epithelium, probably, can explain the high activity of cells of the I type and the low activity of the cells of the II type. /79

There exists the opinion that in the semicircular canals and in the otolithic apparatus there are special receptors that react only to strong stimuli which induce a considerable deviation of these cells; other receptors respond with a



reaction to the weak stimuli that are constantly encountered in life during turns of the head by several degrees (S. N. Khechinashvili, 1958; Ross, 1936). Probably this explains the biological meaning of the existence of two types of cells of the vestibular epithelium and susceptibility to damage of cells of the I type. Spondlin (1968) assumes that in certain cases of affection of the peripheral section of the vestibular apparatus the cells with high sensitivity that react to stimuli of any intensity are broken down. When a strong stimulus is used, the maximum reaction is mobilized of all preserved sensitive cells (mainly cells of the II type). The impulses thus released induce kinetically useful nystagmus from the affected labyrinth of the same intensity as from the healthy labyrinth. Mittermaier (1960) believes that the law of Ewald is applicable only for some limits of intensity of the stimulus. With a drop in the vestibular excitability of one labyrinth the stimulus that is normal in strength induces a stronger response to the ampulla-petal rotation, with a further increase in the strength of the stimulus the rotation to any side induces equal vestibular reactions--the law of Ewald as if ceases to act. In the opinion of S. N. Khechinashvili (1978) the peripheral theory of recruitment is confirmed by that fact that its manifestation is reduced with surgical interference on the endolymphatic sac.

We have stated the peripheral theories for the mechanism of the vestibular recruitment, however there are opinions, according to which the given phenomenon is linked not only to the features of cellular structure of the labyrinth, but also the central sections of the vestibular system that implement the compensatory function during affection of the labyrinth. This opinion is correlated with the biological meaning of the vestibular recruitment. Certain researchers indicate that this vestibular compensation is implemented on the level of vestibular nuclei. Thus, according to the data of Magnus (1962), after removal of the cerebrum in animals compensation occurs faster than with an intact brain. With extirpation of the mesencephalon and cerebellum the vestibular compensation remains in force (Spiegel and Demetriades, 1925). However in the experiments on animals E. A. Asratyan (1947) showed that with removal of the cortex of the large cerebral hemispheres and labyrinthectomy central compensation does not occur. He believes that it occurs precisely due to the cortex of the large hemispheres; other authors hold the same opinion (V. I. Voyachek, 1927; A. N. Krestnikov and A. I. Yarotskiy, 1938; N. N. Lozanov, 1938; S. A. Zlotnikov, 1949; A. P. Yaroxlavskiy, 1950; K. L. Khilov, 1952; V. A. Kislyakov, 1953; S. N. Khechinashvili, 1958; V. M. Gusev et al., 1978; Kreindler, 1960).

According to the published data, the vestibular lobes of both labyrinths are linked to the vestibular nuclei of the trunk both by afferent and efferent fibers going in the composition of the vestibular nerve, and the latter innervate the cells of the second type (A. N. Razumeyev and A. A. Shipov, 1969; Leidler, 1914; Wersall, 1956; Cawthorne, 1957; Dohlman et al., 1958; Dohlman, 1960; Rasmussen and Gacek, 1958; Gacek, 1960; Gacek et al., 1974; Engstrom, 1961; /80 Balogh, and Nomura, 1964; Rossi, 1964; Bertrand, 1964; Nomura et al., 1965; Sala 1965a,c; Favre and Sans, 1977, 1978). Vestibular nuclei of one side are linked to the vestibular nuclei of the other side (A. N. Razumeyev and A. A. Shipov, 1969; Ferraro, et al., 1940; Vito et al., 1956; Carpenter et al., 1958). This link is implemented with the help of crossed fibers going from the nuclei of one side to the nuclei of the opposite side or through the reticular formation of the trunk (Albert, 1969; Trincker, 1965; Boenninghaus and Frank, 1970). In addition, both the afferent and the efferent fibers of the vestibular nerve are partially crossed (Sala, 1965a, c; Weber and Steiner, 1965; Wersall, 1965 and others). Each eye is under the influence of both labyrinths (V. M. Bekhterev 1882; Hogyes, 1880).

The mechanism of vestibular recruitment is viewed as the mechanism of compensation (defense) during affection of the vestibular epithelium (Mittermaier, 1950; Boenninghaus and Frank, 1970, 1972). This compensation occurs comparatively quickly and with full value, which has been indicated in many observations (V. M. Bekhterev, 1882, 1905; G. I. Gorgiladze, 1978; Schoen, 1950; Arslan, 1955; Mittermaier, 1960,a; Trincke, 1965; Greiner et al., 1967; Boenninghaus, 1970; Pfaltz and Kamath, 1971; Pfaltz, 1975; Janczewski, 1977, et al.).

As is known, from the labyrinths to the vestibular nuclei under conditions of rest the same strength neural impulses constantly flow. A symmetric tone of the vestibular nuclei is created (V. M. Bekhterev, 1882; Hogyes, 1880; Loewenstein and Sand, 1940; Adrian, 1943; Ledoux, 1949, 1975; Boenninghaus et al., 1952; Gernandt, 1952; Mittermaier, 1960; Magnus, 1962; Trincker, 1965, et al.). With one-sided affection of the labyrinth this equilibrium is disrupted, spontaneous nystagmus is manifest, vertigo, disorder in statics etc. As noted previously, all these phenomena rapidly disappear--central compensation occurs. Stimulation, rotation stimulation or hot calorizing of the affected labyrinth induces transmission of the impulses along the afferent fibers to the nuclei of its own and the opposite sides, and from the nuclei of the intact side to the

healthy labyrinth on the efferent fibers (feedback according to Trincker). From the healthy labyrinth on the afferent paths an impulse is transmitted to the nuclei of the painful side, the nystagmus response from the painful labyrinth is the same as in stimulation of the healthy labyrinth, or even stronger since excitation of the painful and healthy sides occurs, summing on the painful side (Mittermaier, 1960; Trincker, 1965; 1968; Greiner et al., 1967; Boenninghaus, 1970; Pfaltz and Kamath, 1975; Janczewski, 1977).

One can assume that in this process the main role belongs to the vestibular cells of the second type, since the efferent fibers pass only to these cells. This to a certain measure will permit unification of the central and peripheral theories of vestibular recruitment; this also explains the cause of the manifestation of the vestibular recruitment only to strong stimuli. Greiner believes that with a weak stimulus the difference in excitability is too small in order to induce the central correlation; with strong stimuli the mechanism of compensation appears. In the opinion of Niedballa (1974) during affection of one labyrinth and reduction in the tone of the nuclei from this side excitation of the nuclei of the healthy side occurs, as a result of which the flow of afferent impulses directed towards the affection compensates for its insufficiency (Mittermaier, 1960; Trincker, 1965). This occurs, apparently, due to the reciprocity of the relationships between the left and right labyrinths. The principle of reciprocity for the vestibular system was described almost simultaneously by V. M. Bekhterov (1882, 1905) and Hogyes (1880, 1912). In the opinion of B. N. Kolosovskiy (1934) the reciprocal inhibition is implemented by means of commissural bonds existing /81 between the vestibular nuclei of both sides. Studies of Soviet scientists, in particular of G. I. Goriladze (1964) confirmed this theory. Between the right and left sides of the vestibular analyzer reciprocal relationships were found that spread to the level of receptor formations with the help of the descending branch of the vestibular nerve (B. B. Yegorov, 1967).

Analysis of the data stated above makes it possible to draw the conclusion that vestibular recruitment is an objective phenomenon manifest during the affection of the vestibular receptor, due to which it can serve for topical diagnostics of the affections of the vestibular system. According to its presence one can judge the rapidity of restoration of the vestibular function. The meaning of this phenomenon is compensation for the vestibular function during affection of the vestibular receptor.

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