

VERTIGO.

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There are variable sensations variously described by physically normal individuals under the term of vertigo. One person will describe vertigo as a sensation resembling that which he had on looking into a ravine, or that of an unexpected glance downward from a high tower; another recalls a ride in a merry-go-round; the third recounts the sensations of discomfort and uncertainty experienced in a suspension car; and the fourth compares it to the vertigo felt on landing after a stormy sea-voyage. The productive factors of vertigo are as varying as are the descriptions of it.

The dweller in the valleys experiences these unpleasant sensations when mountain-climbing. The thought that he might fall into the depths, disquiets him and this compelling force grows almost irresistible. It overpowers him even though the path may be protected by a hand-rail which eliminates all chance of falling.

This forced sensation, associated with discomfort and fear due to altitude-vertigo is produced by the novelty of the surroundings. The lowlander on his first mountain trip is unable to appreciate the relative depths and heights and the changing views. These unaccustomed optical impressions disturb his habitual ideas of space and produce a vertigo which in turn deranges his bodily equilibrium. The optical impressions are augmented by the unaccustomed walking on a steep path. Climbing brings into action other muscles and the position of the body in walking upward is different than when walking on level ground. The body must adjust itself to the changed attitudes and movements so that its equilibrium is preserved. Bodily statics and dynamics must become adjusted at each changing attitude if vertigo is to be avoided.

Let us consider another example: Why is a passenger in a suspension car or airship seized with dizziness and why does the same passenger riding under the same external condition of stability in a railway car experience a feeling of certainty and pleasure? There, too, he is safe from falling. The maintenance of equilibrium is not disturbed by any movement of the body.

From this stationary point of observation the eye becomes accustomed to the rising and falling landscape, but in spite of this the upward and downward motion causes dizziness. This sensation

continues even when the eyes are closed. That organ which is involved in this instance is the one which gives us the sense of orientation when impressions of sight, touch and muscle senses are excluded. It is the organ which has its seat in the semi-circular canal apparatus.

From this we gather that by vertigo we understand those sensations occurring when the organs which preserve our equilibrium and our sense of orientation are disturbed.

This complicated process is not due to one single organ, but to a whole system of sense organs which all function systematically under the control of a superior sense organ. Through them we are conscious of our position in space and of any changes in position and movements and through them our bodily equilibrium is maintained by purely unconscious mechanical, muscular action. Among such sense organs we may class the external and internal sense of touch with its corresponding muscles, the sense of sight and eye muscles and that static organ which is situated in the semi-circular canal apparatus.

We know that all our impressions are formed from previous impressions that through repetition become imprinted so that the slightest stimulus will reproduce them unconsciously.

Where impressions are formed by a combination of different perceptions, all of the contributing sense organs may be aroused by stimulating just one organ. It is characteristic that we can no longer isolate the single sense stimulations but that all the senses combine to produce a composite impression in which we cannot recognize the individual phases of the various impressions.

This combined system reacts unconsciously as a whole when any one of its component parts is stimulated.

The separate apparatus which maintain our equilibrium and prevent dizziness must be regarded in the light of a system combining to work in unison. The various impressions made upon the periphery of the several sense organs are conveyed to a central organ which probably has its seat in the medulla.

Impressions resulting from a stimulation of the touch organs, the sense of sight and the semi-circular canals differ in their specific sense energy, but all combine in the function of sustaining the equilibrium of the body.

As has been said, the co-ordinates of the various impressions are combined into a single result. For example, we do not note the isolated tone or character of a single instrument in an orchestra, but are aware only of a harmonious whole which leaves an impres-

sion of a unified, inseparable ensemble. The whole system of organs of equilibrium is controlled from a centralized point in which the various routes meet but the separate organs stimulated at certain points along their individual routes may set the entire system into action, because the single organs are in constant communication.

For this reason we notice the same result whether the equilibrium is disturbed by a stimulation of the touch sense, sight organ, semi-circular canals or central organ. The stimulation will always pass through the whole co-operating system.

For example, a stimulation of a touch organ or muscle is communicated to the eye and semi-circular canal and these will respond in their habitual co-operative manner.

On the other hand, it follows in this closely associated system, that a single deficiency along any one route will affect the whole system. Equilibrium is at once disturbed. Vertigo results as soon as one of these single organs working in combination fails to function. With this premise established, I shall discuss the single factors which affect the sense of bodily equilibrium and our orientation in space.

The exterior sense of touch controls our impressions of our position in space as well as ideas of pressure and temperature.

The touch sense determines our ideas of the pressure of the support under us when reclining and the changing pressure on the various parts of the body makes us aware of the form of our own body as well as the form and material of the support. The newborn child is minus these impressions and only by exercise does he gradually develop unconsciously those brain centers which control the ideas of position of the body and its members and his sense of orientation. A more complicated process develops when the child learns to sit erect and to walk.

The touch sense comes into play now and that of the sole of the foot is of utmost importance in standing and walking. We recognize this easily when our toes come into unaccustomed or partial contact with the floor and cause us to totter or when we lose equilibrium in standing on an unsteady base. Walking in bare feet may at times produce uncertainty due to the unusual touch sensations which are strange to the clad foot.

However, the external sense of touch is not alone able to regulate our complicated movements. These are also influenced by an internal touch sense, which comprises those impressions, gained also through practice and controlled by the musculature of the

body, the ligaments and joints, all of which we designate as the kinesthetic apparatus.

The young child learns the movements of his body through his muscles, ligaments and joints, since the inner touch sense is stimulated by single movements which arouse associations in the central organ. These, through constant practice, cause an automatic co-ordination. Thus systematic co-ordinated movements are acquired which in their impulse are influenced by the will but which in their execution are entirely mechanical.

This unconscious and purely mechanical process is first noted when we make movements that are unlike those associated with distinct impressions which we perform unconsciously.

No matter how securely we usually walk, we are unsteady as soon as we undertake a new method of locomotion. Walking on stilts illustrates the point. New groups of muscles must become adjusted in order to make walking possible with these elongated legs. The readjustment of equilibrium requires other musculature; the arms find support at the sides of the stilts and the rump muscles restore balance. A large number of instances might be cited to show that new movements performed under changed exterior conditions can only be acquired through practice. When this practice is lacking, disturbed equilibrium and unusual movements are the result. Gymnastics, tight-rope walking, and balancing must be practiced as well as bicycle riding, which requires a special adjustment of equilibrium, which, after it has been learned, acts automatically.

The foregoing remarks lead to the conclusion that lack of practice and adaptation of the internal and external touch sense cause uncertainty and giddiness that result in purposeless movements, defeating the desired result. Instead of sustaining equilibrium, they add to the unsteadiness of bodily statics and dynamics. The inexperienced ice skater, in trying to maintain his equilibrium, increases his dilemma by misdirected movements and only his fall restores his balance, because the accustomed stimulation of centers which control orientation in the reclining posture re-establishes the relation of the various parts of the body in space.

All of our movements are controlled by the eyes. We accustom ourselves to sight impressions in space and adjust the kind and direction of our movements to them.

Sudden changes in our surroundings through false estimates of space produce wrong impressions of our static relations. When riding in a train the landscape seems to be moving and we appear to be stationary until the train suddenly halts and produces in us an

unpleasant feeling of lack of orientation. While our train remains standing, a train moving in the opposite direction, produces in us the feeling that it is we who move. When this train has passed by, our eyes receive an annoying, jolting impression of our position and instead of the moving train we see the stationary objects about us. An optical illusion may thus produce dizziness even when the body is in repose and when no movement of the body has given cause for disturbances in equilibrium.

Sensitive persons may experience equilibrium disturbance when obliged to pass over a bridge in walking along the road. The road appears to be a dam from which the ground slopes away to increasing depths. The eye looks beyond such depressions that seem to connect with the lower strata, and receives the natural impressions of this space. This optical association is suddenly lost when we reach the bridge and see the depths below. The surface impressions are changed and the flowing current and other objects in the valley below appear in different proportions than those to which the eye is accustomed. With this we receive a false impression of space, and we are overcome by the uncertainty in the estimate of the static relations of our own body to space. The results of such optical impression is an unsteadiness of movement, a groping walk, and an erroneous relation between the roadway and the depths below. This most frequent type of vertigo we term *altitude vertigo*. Hitzig ascribes this to a diminution of static sensibility; Wollenberg attributes it to our helplessness in estimating our relation to space.

There are two phases of altitude vertigo: mountain vertigo (*Bergschwindel*), tower vertigo (*Turm-schwindel*). Huguerin describes the sensation of altitude vertigo as follows: 'The first glance into the depths causes a peculiar sensation in the legs, as though the base on which the individual stands firmly were sinking, the legs tremble, the body sways and were it not for a firm support, the subject would pitch downward. This sensation disappears upon closing the eyes.

Fear of the possible consequences of such a fall accompany the impression that the base is giving away. A slight attack of altitude vertigo may develop after climbing a spiral stair in the interior of a tower and stepping onto a platform or balcony and suddenly glancing downward.

The pleasure which such a bird's-eye view gives to the observer who is free of altitude vertigo changes to a distinct feeling of discomfort in one who is subject to such vertigo. It remains with him until he is again on *terra firma*.

The above-mentioned sense organs, the tactile impression and sight, do not wholly account for the preservation of equilibrium. We can walk securely and perform complicated movements in the dark without the aid of the eyes in the maintenance of equilibrium. For this reason we cannot consider sight essential to prevent attacks of vertigo or loss of equilibrium.

In the water when diving or swimming we have no stimulation of either our sense of touch or sight to aid in the orientation of the body, and notwithstanding we are aware of the position of the body in space and are able to assume either a vertical or horizontal position. Accordingly we can also exclude the impressions gained from the tactile sense in the preservation of equilibrium.

The organ which assists in orientation is situated in the labyrinth and in that special part called the semi-circular canals which we must look upon as the sense organs which receive the impressions of position and movements of the head, thereby the head becoming the chief center of orientation for the whole body.

The position of the head influences our appreciation of our position in space. When the normal head position is changed through bending, lowering, or turning, the localized sense of equilibrium situated in the head becomes active; it signals to the remaining organs of equilibrium that the position of the head has changed, and accordingly the tactile and sight senses are obliged to react to this stimulation.

The semi-circular canals indicate the position of the head as well as that of the body, which is determined in the co-ordinated muscle action of the entire body. Certain gymnastic exercises prove that a change in the position of the head can produce equilibrium disturbance, unsteadiness and vertigo. Sensitive individuals experience vertigo in various calisthenic exercises executed with eyes closed.

The semi-circular canals make us aware of the horizontal and vertical position of the body as well as upward or downward movements.

How can we otherwise explain the sensation of ascending and descending when in a closed elevator with the body perfectly at rest than by an organ that unconsciously influences orientation? How else could we explain such sensations as diving or the turning of a somersault without other influences?

The semi-circular canals are so closely linked to the organ of hearing and because of the nerve trunk which they share in common, so bound up with it that the older physiologists believed it the

seat of the hearing function. The arrangement, however, of the semi-circular canal apparatus into a geometrically co-ordinated system of triple planes suggests the probability of an independent organ which interprets the three dimensions of space: height, depth and breadth.

Long and wearisome experiments upon animals were necessary to establish a scientific basis for the study of the static function of the labyrinth. The experiences gained through observing animals were substantiated by observing the human who suffered from similar disturbances of equilibrium. One hundred years ago, Flourrens noted peculiar disturbances in locomotion in doves whose semi-circular canals he had removed. Much later, experiments upon animals were again undertaken and it was noticed that a dove whose labyrinth had been removed, staggered, moved more and more unsteadily and more hastily until she finally fell.

Another peculiarity is the direction taken by the subject. The walk is not in a straight line but swerves from the healthy labyrinth. Since this swerving is constant at every step, the direction takes on the form of a circular path. It is the so-called Manege-movement which causes the pigeon to move with a hasty, awkward, fluttering walk in a circle. The head assumes a peculiar, downward position turned toward the affected side. These experiments prove that the semi-circular canals control the equilibrium of the body and the muscle functions of the body in motion. The semi-circular canals contain two elements of stimulation of the sensory nerve located there. The otoliths rest on the sensory hairs of the nerve endings in the utricle and saccule, and these, by their weight, stimulate the filaments of the vestibular nerve with every change in the position of the head; this stimulus is modified by these changed positions of the head. These two stimuli, known as the "maculae staticae," are arranged in two planes and seem to control our sensations of horizontal and vertical movements. The nerve-ends in the ampullae of the semi-circular canals assist us further in orientation. Here, too, we find sensory hairs as end-organs of the vestibular nerve. The maculae are controlled by the otoliths (Verworn terms them the statoliths) which stimulate the sensory hairs by their weight, while the sensory hairs of the ampullae are suspended freely in the labyrinth fluid and movement of this endolymph stimulates them. According to the theory of Mach-Breuer, we assume that changes in position of the head produce currents in the endolymph which, by its motion, stimulates the sensory hairs. The arrangement of the semi-circular canals in a

geometric system, symmetrically bilateral and identical, admits of numerous sensations in the many possible positions of the head. The three planes of direction of the semi-circular canals do not correspond to the planes of the head but are grouped at an angle to the head. Furthermore, this offers an unusually exact orientation as two fixed planes are established by the otolith apparatus and the encapsulated semi-circular canal system transmits in a reciprocal relationship its varied sensations of space orientation.

The sensory impressions transmitted by the vestibular nerve to the muscle apparatus of the general system are very unusual and are as yet not fully determined.

The entire musculature of the body receives stimuli from this source by reflex routes which induce its activity and influence the general position of the body. (Tonuslabyrinth).

The symmetric bilateral construction of the body also plays an important role here because the evenly opposed semi-circular canals of each side must, correspondingly, conduct stimuli to the two sides of the body which must produce a different muscular impression on one side than on the other. Thus the superior right and the inferior left semi-circular canals, lying in a common plane and because of their similarly directed planes, are stimulated alike by a certain turning motion and the impression must thus reach a different group of muscles on either side. In this way it is possible to develop varying influences on the functions of the body-musculature by varying vestibular stimuli. The semi-circular canal system regulates the movements of the body. This is most marked in the reaction of the muscles of the eye and numerous observations have been made in this field.

Correct, systematic functioning of the eyes must be considered in the changing attitudes of the body when we admit the influence of the eyes in orientation. Therefore, the semi-circular canal system must be most intimately associated anatomically with the oculo-muscle system. Stimuli of the semi-circular canal system can produce characteristic ocular movement which in one apparatus must correspond to the function in the other. By slow and long-practiced movements, the one apparatus regulates the other by force of habit in that the stimuli of the semi-circular canal apparatus control the turning of the eyes. What is the result, however, when unaccustomed and augmented stimuli are produced to which the semi-circular canal apparatus and musculature through lack of habit cannot respond? We all know that form of vertigo due to rapid, active turning of the body as well as the passive form produced by

the turning-chair or merry-go-round, which may occur with eyes open or closed, but which manifests itself similarly whether the eyes be open or closed. In either instance the same ocular reflexes take place. Vertigo resulting from turning leads to nystagmus.

The unsteady eye moves back and forth in its search for a fixed point by which to establish the position of the body in space. In turning on the merry-go-round we look for a fixed point in the surroundings, which disappears as we continue to turn, while we attempt to follow it with our eyes which are being influenced by our movement. As we turn more rapidly, the eye, which has followed the impressions passing to the right, must, by means of jerky movements, attempt to fix the new impressions coming from the left. In this way the unconscious to-and-fro motion of the eyes is produced, which we term nystagmus and which we recognize as a symptom of vertigo. It has just been stated that this movement of the eye, after the body has rotated, may be noted whether the eyes have been open or closed and that after such movements with closed eyes we may distinctly observe the tremulous motion under the lids and the sensation of vertigo is experienced. Therefore the connection between the semi-circular canals and the muscle apparatus of the eye is so intimate that stimulation of the former produces reflexes in the latter without the need of optical impressions or stimulation.

This leads to the conclusion that the disorder produced by the unusual stimulation of the semi-circular canal apparatus also affects the eye muscles. But since, as we noted previously, the entire body musculature is regulated by the eyes, a general vertigo results, causing unsteady motions, as though the body were trying to find a footing. The futility of these movements leads to greater uncertainty in bodily statics and dynamics. That, through habit, we are able to suppress vertigo may readily be noted in observing the pleasure which children experience in a swing or merry-go-round. Another instance may be cited in the dervishes who indulge in the rotary motion to an extreme that causes the normal individual to shudder. These observations demonstrate my hypothesis.

It should be emphasized that vertigo does not exist as an independent impression because it is not produced by a single organ. We have seen that the consciousness of the harmonious sensation of equilibrium, which the normal individual takes for granted, results from a systematic co-operation of all the involved sense-perceptions. This fact explains the presence of vertigo resulting from abnormal stimulation of the special sense-organs.