ADDITIONAL CONTRIBUTIONS TO THE SENSORIMOTOR INDUCTION SYNDROME IN UNILATERAL DISEQUILIBRIUM WITH SPECIAL REFERENCE TO THE EFFECT OF COLORS[1]

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The sensorimotor induction syndrome in unilateral disturbed equilibrium occurs more frequently than supposed and would be recognized more often if the knowledge of its symptoms and methods of examination were brought into closer range of neurologic interest. Therefore, each additional observation is valuable since it confirms former experience and furnishes new facts suitable for expanding the theory and practice of the sensorimotor induction. With this aspect in view the following observations are discussed below.

Clinical Observations

A. General clinical picture

Case 1: R. Sch., a woman, aged 26, had been healthy up to three years ago when her illness began. At the onset of the disease she suffered from attacks of vomiting which persisted for about 2 weeks. She then suddenly lost consciousness and remained so for 3 hours. After regaining consciousness she could not see well with her right eye and, when standing, was not able to hold her balance. The vision in her right eye improved but remained blurred, and her gait was still uncertain. As a space-occupying process was suspected, pneumoencephalography was performed in another hospital on three different occasions with negative results. Afterwards the patient suffered from headache and dizziness. At the same time mobility of her legs became impaired so that she was confined to bed. She also became aware sometimes of using her right arm clumsily.

On first admission, 2 years ago, no pathological changes in the internal organs were found. Neurologic examination revealed slight bilateral nystagmus, absence of the abdominal reflexes and of the patellar reflex on the right as well as Rossolimo's sign on the left. In addition, the patient showed at this time a systematized *disturbed equilibrium* on the *right* which presented the features of the *syndrome of sensorimotor induction*. The diagnosis of multiple sclerosis was considered. After 2 months' hospitalization the patient's gait improved, and she was discharged from the hospital.

She was admitted for the second time 6 months ago after an attack of loss of consciousness which lasted for about one hour and which was preceded by a general feeling of ill-health and exhaustion. After regaining consciousness vision was blurred in her *right eye*, and she could not walk well because the power in her right leg was impaired. Neurologic examination revealed diminution of power at all the joints of the right arm and leg, the leg assuming a varus position. All qualities of superficial and deep sensibility as well as stereognosis were intact. The abdominal reflexes were absent, but the ankle and patellar reflexes were elicited, the latter being more lively on the right. In addition, a slight bilateral nystagmus on fixation was found. The reaction of the pupils, visus (5/5 on both sides), fundi and fields of vision were normal. Hearing was also normal on both sides. Caloric examination, after Kobrak, showed no reaction, but on testing with 10 cc. ice-water a transient aggravation of the existing nystagmus resulted without effecting a deviation in the pointing test. The spontaneous impairment of the equilibrium, affecting the right side of the body, and its manifold influences on sensory perception will be demonstrated later. X-ray of the skull, the electroencephalogram, and the spinal fluid were normal.

B. Special examination of the induced sensorimotor manifiestations

a. Features of the right-sided disequilibrium. The patient, with eyes open, kept her head straight. However, with her eyes shut, her *head* and whole body inclined increasingly to the *right*, without her being aware of it. When standing, with her eyes shut, a tendency to fall to the *right* and backward resulted. When standing and closing her left and right eye alternately, the tendency to fall appeared only when the *right* eye was *open*. When seeing with her *left eye only*, the tendency to fall was *eliminated*. It was also influenced by changing the position of the head, in that turning it to the left increased the tendency to fall to the right, while turning it to the right abolished it.

When the patient, with her eyes shut, was asked to stretch out both arms and to keep them in this position, the *right* arm *descended* and *deviated* outward without the patient's being aware of it (fig. 1). When asked to raise

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FIG. 1

one arm and then place the other at the same level, the patient, with her eyes shut, placed her *right* arm always *lower* than her left. When asked to raise her legs and to keep them at the same level, the right leg descended, a movement which in this instance was felt by the patient. Turning of the *head* to the *left* accelerated the change in the position of the right extremities, while turning it to the *right diminished* and delayed the change. The position of the extremities on the right was also tested after closing her left and right eye alternately, with the result that an effect concerning the right arm only was noted. When seeing with the right eye only, the same spontaneous deviation of the arm occurred as on closure of both eyes, while when seeing with the left eye only, the deviation was diminished and delayed.

When performing the finger-nose test and localizing the midline of her body, the patient past-pointed with her right hand to the right. The same past-pointing outward was noted when executing the knee to heel test with her right leg. With her left arm and leg she performed these tests correctly. However, on repeated performance of the pointing test a swinging deviation of the left arm to the right appeared as a result of the ever-increasing deviation of the whole body to the right. The patient, however, corrected this movement and correctly localized the target. These findings were confirmed on repeated examination.

b. Perceptual disturbances in the haptic and tactile spheres. When the patient, with her eyes closed, was asked to hold a rod vertically, she always placed it with its upper end *inclined* to the *right*, and when asked to hold it horizontally, she placed it with its *right* end inclined slightly *downward*.

With her eyes shut, a small rod was placed on the patient's chest, first on the right and then on the left side. She perceived its position on the left side correctly, but on the right side it seemed to be inclined with its upper end outward to the right. A small rod placed horizontally on the right side seemed to be inclined with its right end downward. When the rim of a water-glass was pressed on the left side of the patient's chest, she felt it correctly as being round (fig. 2a); on the *right side*, however, the rim appeared *ellipsoid*, with its long diameter extended to the *right* (fig. 2b). Corresponding changes were perceived when the glass was placed in the middle of the chest (fig. 2c). This faulty perception of coordinates and figures became aggravated with increasing inclination of the body to the right.

When the same tests were performed after *alternately* closing the left and right eye and after exclusion of visual control, different results were obtained. On closure of the left eye only the same effect was obtained as on closure of both eyes. However, on closure of the right eye only, the deviations in tactile perception mentioned above were not observed any more, and the spontaneous inclination of the body to the right was eliminated too.

When the patient, with her eyes shut, was given two identical wooden cubes, the one in her *right* hand seemed to be *bigger*. When she continued holding them, she expressed herself more exactly by saying that the cube in her right hand was enlarged at its right outer edge which appeared elongated, thicker and spread out. This finding which was always obtained on closure of both eyes appeared likewise on closure of the left eye only. On closure of the right eye only this effect was completely removed, and the patient correctly perceived the objects in both hands.

When the patient was asked to estimate the weight of two identical wooden spheres, the one in her *right* hand seemed to be *heavier* than that in her left. This faulty perception was also found on closure of the left eye only, but did not occur on closure of the right eye only.

c. Various disturbances of visual perception. The patient stated spontaneously and also on questioning that at times vision in her right

eye was blurred. At the same time she generally felt worse. Reading too was difficult occasionally, in that the letter she looked at seemed to be doubled and the printed line to be inclined downward to the right. The patient became aware also that she could not estimate distances well. As an illustration she was convinced that a chair which was lifted and put down behind another patient would directly hit that patient. When she wanted to grasp an object, she sometimes made too short a movement and had to make an additional movement in order to reach it. She also observed that she groped outward with her right hand. When smoking she did not flick the ash off into the middle of the ash-tray but deposited it at its right outer rim.

Thorough examination revealed various disturbances of the *visual* functions which manifested themselves in the *right* eye only.

Visual perception of geometrical figures was impaired. This became apparent when she looked with her right eye at an objective vertical line. The upper end seemed at first to move jerkingly to the right till finally the whole line seemed inclined to the *right*. This deviation was confirmed on repeated tests, and its degree could be influenced by a motor or a sensory stimulus. The motor stimulus consisted in the deviation of the right outstretched arm described above. The test was now performed in such a way that the patient was asked to look with her right eye at a vertical line while her outstretched arms were covered with a blanket in order to exclude visual control. The patient who perceived the vertical line with its upper end inclined to the right was astonished to note that on continued fixation the line deviated more. This visual effect on the right eye corresponded with the increasing deviation of the right arm, of which the patient was not aware. The sensory stimulus originated from the left eye which remained open, but was separated by a partition. Then, on seeing the vertical line with her right eye, the angle of deviation was reduced by a half. Also horizontal lines when looked at with the right eye seemed inclined, although to a smaller degree, with the right end downward. Corresponding to these deviations of the coordinates, a right angle when looked at with the right eye seemed to be rotated, while it was perceived correctly when looked at with the left eye. When looking with the right eye at a circle, the right part of it seemed at first to move jerkingly outward but was finally perceived as being elongated to the right, so that the circle appeared to be an ellipse. When seeing with the left eye only, she perceived the circle correctly.

When the patient was asked to write and to draw, seeing alternately with her left and then with her right eye, she performed this task correctly when seeing with her left eye only.

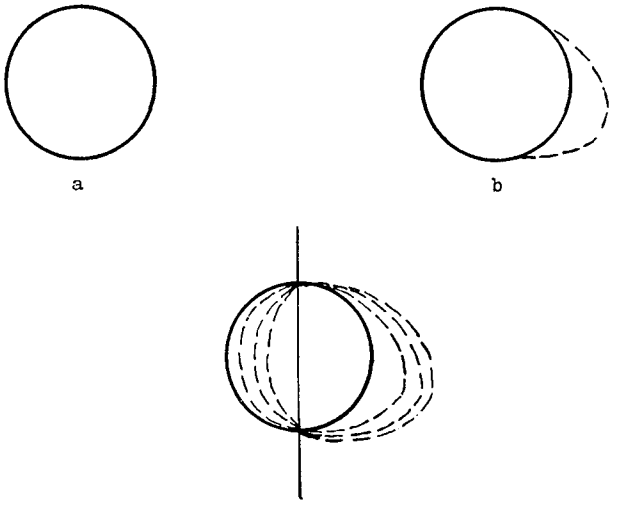

FIG. 2

When seeing with her right eye only, the line of writing deviated downward to the right. So, when writing Hebrew script from right to left, it ascended to the left, while when writing Latin script from left to right, the line of writing inclined downward to the right. The patient was not aware of these deviations.

Another difference when using the left and right eye alternately concerned the size and shape of the drawings. When the patient was asked to use her right eye only and to copy drawings which she had made before, using her left eye only, it became apparent that the figures were seen altered and enlarged at once or after repeated performance. This alteration affected the drawing of simple figures, like rectangles and circles, as well as that of complicated ones like houses, etc. This alteration concerned the right outer part of the figures in that the vertical lines deviated to the right and the horizontal lines were elongated downward to the right. It further became evident that closed figures like circles or squares remained *open* at their *right outer* part and became *elongated* (fig. 3). This corresponds with the faulty visual localization to the right, mentioned above, which became apparent in the flicking off of the ash of a cigarette on the right outer rim of the ash-tray. It is of interest that the corrective influence of the left eye manifested itself here also and resulted in an essential reduction of the deviations. Further it must be stressed that the drawings in this instance were not performed with the disequilibrated right hand but with the left one, as the patient is left-handed. This fact must be mentioned in particular, in order to exclude every doubt as to the visual origin of these disturbances.

The difference in the visual perception with regard to form and size, when seeing with the right and left eye alternately, became evident in this patient not only when drawing but also when *looking* at objects like square or rectangular building-blocks, which were correctly perceived when viewed with the left eye only. On continued observation with the *right* eye, the patient stated that the right outer part of the building-block began to change, to move outward, and to become thickened and *elongated* at its right outer part. These results which were found on repeated testing could not be obtained when the patient used her

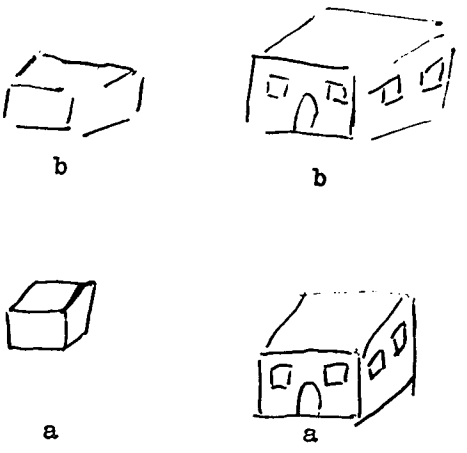

FIG. 3
a—drawn when seeing with the left eye.
b—drawn when seeing with the right eye.

right eye only while the left eye remained open but screened, as was demonstrated above. Another visual disturbance manifested itself in the perception of dotted lines. While these were seen correctly with the left eye, they were perceived as being continuous when using the right eye, the distance between the points being 1–1½ mm. This disturbance could be influenced too by the motor and sensory stimuli mentioned above. The increasing deviation of the right arm, of which the patient was unaware, coarsened the differentiation and she saw the line as continuous, even if the distance between the points was bigger, but the corrective influence of the left eye effected an improvement of differentiation, even if the distance between the points was smaller.

Another impairment of interest, which manifested itself in the right eye only, concerned *color perception*. The patient was able to distinguish and to arrange all colors correctly even the most delicate shades when using her left eye only. When using her right eye, however, and asked to look at a series of colored samples, it became evident that the colors *changed* immediately and more definitely the longer she looked at them. The darker colors like blue, brown, and grey were perceived as being black and were arranged accordingly. Lighter colors, however, seemed to be greyish, whereas red and yellow changed least of all. When the colored samples were arranged in a row, it became apparent further that the impairment concerned chiefly that part of the

samples which was situated in the *right outer* sector of the field of vision and which was regularly noted, even when the sequence of colors was changed. The extent of impaired color perception was diminished also in this instance by the corrective influence of the left eye and increased by the motor effect of the right arm.

d. The influence of colors on the pathological phenomena. As was demonstrated above, the alternate closure of the right and left eye produced throughout a different effect on the motor and sensory functions. When the patient used her right eye, the same results were obtained as when closing both eyes, while, when using her left eye only, a corrective influence on the existing disturbances was always produced. This latter finding of a corrective effect of the contralateral eye gave rise to the idea of testing the influence of colors on the existing disturbances. The first rough tests with colored glasses, while the right eye remained closed, yielded surprising results. Thorough examination of the effect of the various colors was performed with Kodak Wratten filters. The postural attitude of the patient using her left eye served as the basic point of comparison. In this attitude the body remained straight while the right arm descended for about 10 cm. without deviation outward and was kept in this position. When a pure red glass of Wratten Filter 24 was placed before the patient's left eye, her whole body started rocking immediately and became inclined markedly to *the right* while at the same time the right arm descended and deviated widely to the right. Orange light of filter 21 produced a much lesser disturbance than pure red. After red, yellow of Wratten filter 8 and 3 produced a less disturbing effect on the postural pattern. Green of filter 11, although subjectively perceived correctly, was in its disturbing effect most similar to yellow of filter 3 but had a more aggravating influence on the postural attitude than green of Wratten filter 63. This is explained by the fact that green of filter 11 allows the rays of the red spectrum to pass and shows plainly that the organism reacts here more sensitively than the eye. The same results were obtained on testing with the color blue of filters 38 and 44 A which both were subjectively perceived as being blue. Blue of filter 38 caused a deviation of the head to the right and descent of the right arm for 40 cm. Blue of filter 44 A, however, caused a lesser deviation of the head to the right and descent of the arm for 15 cm. This difference in the biologic effect is explained by the spectral difference in the color, as blue of filter 38 lets through the red spectrum, while blue of filter 44 A hardly lets through any red at all. When pure blue of Wratten filter 50 (4250 A) was placed before the patient's left eye, the postural disturbances described above did *not* appear at *all*, and the effect was even demonstrably better than when using the left eye only. Surprisingly, it became apparent further that this blue produced an active corrective influence even after the postural changes caused by red had already started and progressed. It was then sufficient to put blue of filter 50 before the left eye, whereupon the postural displacement of the body and the right arm soon ceased and a return to complete normality began. The marked inclination of the body to the right lessened and reversed by rocking movements, while at the same time the right arm ascended jerkingly till it reached the level of the normal left arm. It must be mentioned that the patient was *not aware* of all these postural changes as the tests were always performed after exclusion of visual control. The patient stated that, when looking at red, breathing became difficult and palpitation and nausea developed. In contrast to these disturbing sensations caused by red and which were also clinically apparent, the patient felt subjectively completely well when using a blue glass. The same basic subjective and objective effect of red and blue was also found in the right eye, with the difference that the deteriorating effect of red was much stronger here than in the left eye and that the corrective effect of blue was less manifest in the right eye than in the left. The influence of these colors concerned not only the motor components of the unilateral disequilibrium but also the homolateral sensory disturbances such as overestimation of size and weight in that they were increased by red and eliminated by blue. All these findings were obtained invariably on repeated testing during a period of several months, though the results would vary sometimes in their degree.

e. Acoustic discomfort and optic function. The effect of colors on disturbances of body

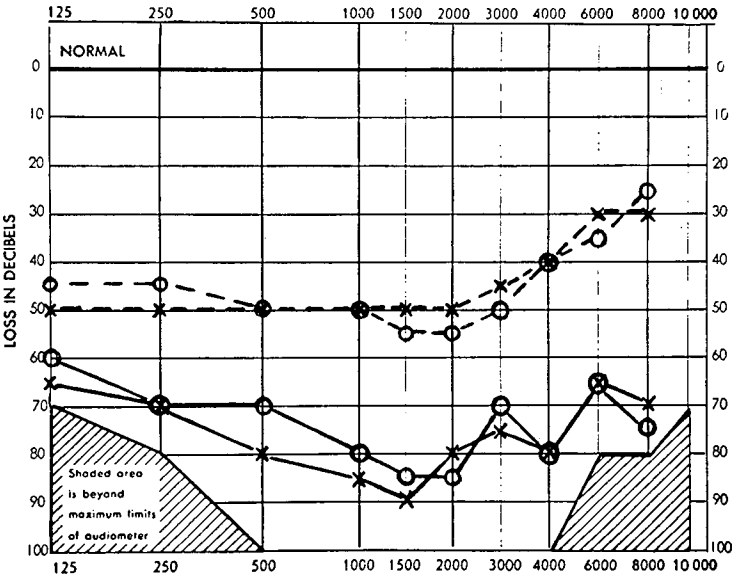

FIG. 4

0—right ear.
x—left ear.
– – – – Threshold of acoustic discomfort under influence of red.
——— Threshold of acoustic discomfort under influence of blue.

posture gave rise to the thought that sound might produce a corresponding influence. Audiometric testing did *not show* any effect on the existing disturbances when using pure sounds of 125 to 10,000 dv. But it became evident that the right-sided postural disturbances were *affected* adversely by *acoustic discomfort*. As soon as the threshold of discomfort was reached by increased intensity in all the frequencies, a visible deterioration of the spontaneous disturbances set in. The stronger the intensity, the stronger and quicker the inclination of the body to the right and deviation of the right-sided extremities occurred. Further examination showed, on the other hand, that the threshold of acoustic discomfort was influenced invariably by visual function and by colors. The threshold of discomfort was then tested on alternate opening and closure of both eyes. With eyes open, the threshold of discomfort was within the normal limits of 60 to 75 db., while it dropped to 55–25 db. when the eyes were shut. On closure of the left eye only, the threshold of discomfort was reduced like on closure of both eyes to 55–25 db., especially in the higher frequencies. On closure of the right eye only, nearly similar values as on opening of both eyes were obtained, namely 60–80 db. When the influence of color was now tested on the open left eye, it was always found that red light of Wratten filter 24 lowered the threshold of discomfort from 60–80 db. to 55–25 db. mainly in the higher frequencies, while it was raised by blue light of Wratten filter 50 to 60–90 db. (fig. 4) even above the original level. These positive and negative changes with regard to the threshold of discomfort were always accompanied by corresponding improvement and deterioration of body posture.

A. General clinical picture

Case 2: N. J., aged 18, came to Israel with her parents 8 years ago. Being followers of the Bahaite religion they made their home near the tomb of their prophet in Haifa.

The patient, who is the fifth child in a family of eight, seems to have developed normally. She began her schooling in Teheran, and after her arrival in this country she continued her studies in a mission-school in Acre. This Bahaite family suffered greatly from the hostile attitude of the Arabs in whose midst they were living. This unfriendly atmosphere did not fail to make an impression on the sensitive girl. She became introverted, did not take part in the social life of her school, and became the more attached to her family.

The patient stated, that her illness began 3 years ago with loss of consciousness following an alarming

incident. She was present when Arabs attacked her brothers, and when she saw them lying on the floor covered with blood, she thought they were dead. In the evening of this day she had her first attack of loss of consciousness which has recurred since repeatedly at varying intervals. Because of these attacks she received anti-epileptic treatment. During the last 6 months she has suffered from continuous *left*-sided headache and, as in addition *cerebellar* symptoms were found on examination, the patient was admitted to the department for diagnostic clarification.

During a 2 months' stay in the hospital she had several attacks which presented the same basic symptomatological features. Emotional factors seemed to play a part in their causation. The attacks always started with a *raising* of the *left arm* and a strong compulsing *turning* of the *head* and usually also of the whole body to the *left*. Sometimes the body turned then to the right. A generalized powerful *extension spasm* appeared thereafter in all extremities. Unconsciousness occurred at once at the beginning of the attack and lasted from 10 to 45 minutes. Sometimes additional turning of the body around its longitudinal axis occurred. During the attack the eyes were always shut spasmodically, and at its beginning a deviation of the eyes to the left was always found, while reaction of the pupils to light was always normal. The Babinski sign was not elicited, and tongue biting and urination did not take place. The patient stated that she sometimes felt the approach of the attacks in the form of a tremendous power which subdued her without her being able to resist and without her knowing afterwards what had happened to her.

General examination of the patient did not reveal any pathological signs in the internal organs. Neurological examination showed normal cranial nerves. Movements of the eyes, reaction of the pupils and fundi were normal. Visual function of the right eye was absolutely intact; a characteristic impairment was, however, found in her left eye. In the beginning the patient saw with her left eye as she did with the right one, but she soon stated that vision became darkened. This darkening occurred regularly in the right outer sector of the left eye and spread very quickly over the whole eye so that the patient was in fact not able to see with her left eye any more. Examination of the field of vision gave normal results in the right eye, while in the left eye it narrowed rapidly starting from the outer side till total darkening in the left eye occurred. Otological examination revealed perforation of the membrane in the left ear caused by a healed otitis media, and reduced hearing in this ear. X-ray of the skull and the electroencephalogram gave normal results.

Motility, tonus and power in all the extremities were normal as were the reflexes. Superficial and deep sensibility, stereognosis included, was completely intact. This patient showed, however, a systematized *disequilibrium* on the *left* side which presented the features of the *sensorimotor induction syndrome* and which will be described in detail below.

B. Special examination of the induced sensorimotor manifestations

a. Features of the left-sided disequilibrium. The patient kept her head *inclined* spontaneously to the *left*. When she was asked to place her head in the midline, after it had been turned passively to the right and left, she always put it back inclined slightly to the left. When both eyes were shut, inclination of the head to the left increased markedly while at the same time the whole body inclined to the left.

FIG. 5

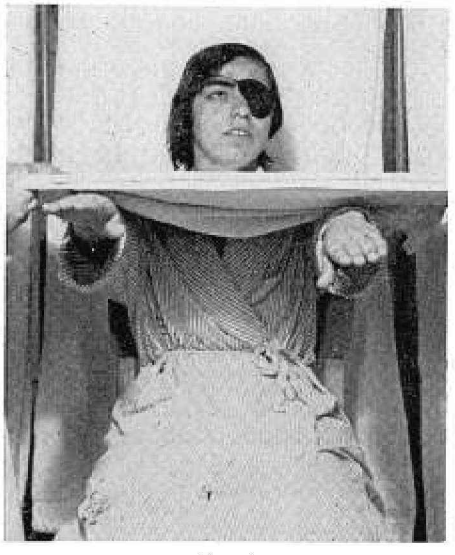

FIG. 6

When the patient, with her eyes shut, was asked to stretch out first her right and then her left arm and to keep them in this position, she could do so with her right arm, but the *left* arm began to *descend* at once and to

deviate markedly *outward*, accompanied by an increasing inclination of the whole body. The patient was not aware of these changes. At the same time her *head* turned *automatically* and strongly to the *left*, while her eyes deviated to the same side. When her head started to turn to the left, the patient regularly became *unconscious* and remained so until her head reached the extreme left, whereafter this condition subsided spontaneously. During this state the patient was not aware of the fact that she was spoken to or what had happened to her. The same proceedings occurred when the patient was asked to raise her left leg and to keep it in this position. The leg descended and deviated outward, while the automatic turning of the head to the left started at the same time, accompanied by the phenomena described above. When her left arm and leg were raised simultaneously, the turning of the head to the left occurred more quickly and powerfully with the descent and deviation of these extremities, while the whole body turned to the left as well. When the test was performed with the extremities on the right, this effect was not obtained.

When these tests were carried out after alternately closing the right and then the left eye, the same change in the position of the left arm and the automatic turning of the head to the left were observed on closure of the right eye as on closure of both eyes (fig. 5). When the left eye was shut, there appeared only a slight descent of the left arm, but turning of the head with loss of consciousness did not occur (fig. 6).

When the patient performed the finger-nose test and localized the midline of her body, she did it correctly with her right hand, while she regularly past-pointed outward to the left with her left hand. The same past-pointing outward to the left with her left hand was also observed when she tried to touch external objects. This impairment of localization was apparent also in the left leg. When performing the heel to knee test or trying to reach with her big toe the finger of the examiner held above her leg, she always deviated outward to the left. With her right leg she performed these tests correctly. When standing or walking with her eyes open, no spontaneous disturbances were observed. However, when standing with her eyes shut, a tendency to *fall* to the *left* became apparent immediately. When the right eye only was closed, the same tendency to fall appeared as on closure of both eyes. However, when the left eye was shut, there was no change at all. When the patient was asked to go forward and backward with her eyes shut, the soon deviated to the left. The same deviasion to the left appeared also when she walked backward with her eyes shut. A zigzag walk resulted when she was asked to go back and forward several times with her eyes closed.

b. Perceptual disturbances in haptic and tactile spheres. When the patient, with her eyes shut, was asked to place a rod vertically, she always held it with its lower end inclined to the left (fig. 7). When asked to place the rod horizontally, she inclined it with its left end downward (fig. 8). The degree of inclination in the horizontal plane was three times more than that of the vertical plane. When a small rod was placed alternately on the right and then on the left side of the patient's chest, she felt its position correctly on the right side, but on the left side she perceived the vertical rod inclined with its lower end to the left and the horizontal rod with its left end inclined downward. The rim of a glass was correctly appreciated on the right side of her chest, but on the left side she only felt the right half of the rim correctly, while she was unaware altogether of the left half. When this test was done repeatedly in the same position, the rim

FIG. 7

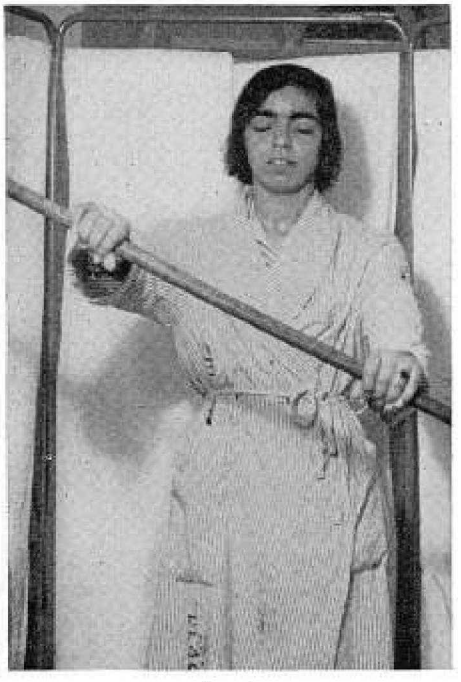

FIG. 8

of the glass was not felt at all. The faulty tactile perception of the coordinates and of objects became worse and more evident with the increasing inclination of the body to the left. When the same tests were performed on alternately closing the right and then the left eye, the same result was obtained on closure of the right eye as on closure of both eyes, while on closure of the left eye only, the faulty perception was not found any more and the spontaneous inclination of the body to the left disappeared too.

When two wooden cubes of the same size and weight were placed in each hand, with her eyes shut, the patient felt the one in her *left* hand as being *bigger*. When she closed the right eye only, the same impression was obtained as on closure of both eyes. When the same test was performed with her eyes open but her hands covered, to exclude vision, the cube in her left hand again seemed to be bigger than that in her right hand although not so much as before. During the performance of this test a slight deviation of the eyes to the left was observed. When the *left* eye was *closed*, the objects were *correctly* perceived. The same results were also obtained with regard to perception of weight. The objects in her left hand seemed not only to be bigger but also heavier, and perception of weight was influenced in the same way as that of size.

c. Disturbances of visual perception. The patient, who had had no disturbances whatsoever concerning visual orientation in space, stated that during these last 6 months she had had severe difficulties when reading, so that she had to give it up altogether of late. When she was asked to read some text, it became apparent that she could read only 2–3 lines and then could not continue as her vision became obscured and everything disappeared from sight. Thorough examination with each eye revealed that she could read well when using her right eye, and only after reading 10–12 lines did she ask to rest as her vision started to become darkened. When the patient was asked to read *using* her *left* eye, she was hardly able to finish the first line as the left part of her field of vision became obscured at once, and on continued fixation everything became black. When reading English she only perceived the right half of the line well, and when reading Hebrew, from right to left, she could not see the left part of the line properly and, therefore, read only the right half of it. It must be mentioned that during the test the patient's head and eyes deviated slightly and the body inclined increasingly to the left.

When seeing with her right eye only, the patient perceived the coordinates of space correctly, but when using both eyes, she perceived a vertical line with its upper end inclined to the right. A horizontal line was perceived with its left end inclined downward. The angle of deviation on repeated tests was 5°–8°. This disturbed perception was much more evident in the left eye where the angle of deviation amounted to 12°–16°. When the patient was asked to draw figures of the same size alternately using her right and then her left eye, those drawn using her left eye only regularly turned out larger. Another difference between both eyes concerned perception of dotted lines. While these were perceived correctly with the right eye, they were seen as being continuous when using the left eye, when the intervals between the dots were less than 1½–2 mm. When these tests were performed using her left eye, while the right eye was open but separated by a partition, all perceptual

disturbances described above were significantly reduced.

Color perception tested with woollen samples was correct when the patient used her right eye, but when she used her *left* eye, the *colors* seemed to be *blurred*. This disturbance concerned dark colors especially which appeared to be equally black, while red and its shades seemed less changed. It became apparent further on repeated testing that the disturbed color perception concerned chiefly the left outer sector of the field of vision and increased gradually on continued vision.

d. Influence of colors on the pathological phenomena. In view of the corrective effect of the contralateral right eye on the spontaneous postural and sensory disturbances, the influence of colors on these disturbances was also examined in this case. The postural attitude of the patient when using her right eye only served as a basis and point of comparison. In this position the patient's body and head remained straight and the left arm descended for about 10 cm only. The tests were performed with the colors of the Wratten filter which were put before her right eye, while the left eye remained shut. Pure red of Wratten filter 24 was used first to which the patient assented unwillingly as she could not bear to look at red of late. She stated that she felt sick and suffered such severe attacks that she had carefully *avoided* putting on her *red dress* for the last half year. Examination revealed that this subjective feeling was in fact based on real causes, and this could also be demonstrated objectively. As soon as *red* was put before her *right* eye, an *increasing* inclination of the body to the left started, the left arm deviated strongly downward and outward, while at the same time a compulsive turning of the body to the left started accompanied by deviation of the head and the eyes to the left and loss of consciousness. When pure blue of Wratten filter 50 was put before the patient's right eye, no changes in her postural attitude were evoked. The patient remained sitting straight, and even the slight descent of the left arm which appeared when she used her right eye did not occur. The *corrective* effect of *blue* became still more evident after the postural changes caused by the red color were already in full motion. It was only necessary to replace the red color by blue in order to interrupt the inclination of the body downward to the left and to cause a gradual return movement of the body and the left arm until a normal position was reached. It must be mentioned that the patient, who felt unwell under the influence of red and showed accelerated breathing and palpitations, felt absolutely well when given the blue color. In view of the striking contrary effects of red and blue the effects of the other mixed spectral colors were examined by means of Wratten filters. It became apparent that the degree of the deteriorating subjective and objective effect depended on the smaller or greater content of red in the mixed colors and that this effect became less evident the more pure blue was contained in them. This color effect influenced the unilateral postural as well as the homolateral sensory disturbances.

e. Acoustic discomfort and optic function. Tests performed by audiometric methods to determine whether sound influenced postural conditions in analogy to the color effect showed no change. It was seen, however, that on increase of intensity until the threshold of discomfort was reached, a deterioration of the postural disturbances resulted. Also in this case the threshold of discomfort could be influenced regularly by optic function and color effect. The patient was very sensitive with regard to the threshold of discomfort in all frequencies, even when both eyes were open. The threshold was then between 40 and 60 db. for the right ear and between 50 and 90 db. for the left ear. If one considers that hearing in the left ear was diminished to 55–80 db., it is apparent that the threshold of discomfort coincided in fact with that of hearing and was even more sensitive than in the right ear. It is of interest to note that the alternate closure of each eye gave constant results. When the right eye was closed while the left eye on the disequilibrated side remained open, the threshold of discomfort was very low and lay between 35–55 db. for the right ear and between 55–70 db. for the left ear. However, when the left eye was closed while the contralateral right eye remained open, the threshold of discomfort was raised to 60–85 db. for the right ear and above 100 db. in most frequencies for the left ear. When a red glass was put before the right eye, marked lowering of the threshold of discomfort resulted together with the onset of

disturbances of body posture described above. The threshold of discomfort lay now for the frequencies of 1,000–4,000, between 35–40 db. in the right ear and 60–65 db. for the frequencies of 1,000–1,500 respectively in the left ear. Thorough examination could not be performed as loss of consciousness occurred very quickly under the influence of red. The corrective effect of blue on this sensation was in this case not so distinct as the deteriorating effect of red.

Comment and Conclusions

Both cases discussed above presented the symptomatology of the sensorimotor induction syndrome (4–7, 21). As far as is known at present this syndrome is composed of the following symptoms: 1) motor disturbances resulting in a unilateral postural deviation of the whole body and its ipsilateral extremities; 2) monocular or even binocular impairment of the visual perception of spatial coordinates and of geometrical figures; 3) monocular micropsia or macropsia; 4) monocular or even binocular dissolution of color perception; 5) change in the size of written script and displacement of the line of writing; 6) disturbed discrimination of spatially close optic stimuli; 7) deviation in the tactile and haptic perception of the vertical and the horizontal; 8) unilateral acoustic deviation from the midline outward of a sound transmitted to both ears; 9) change in the tactile perception of size of objects, resulting in unilateral microstereognosis or macrostereognosis; 10) unilateral faulty estimation of weights and distances; 11) unilateral disturbed discrimination of closely spaced tactile stimuli; 12) unilateral diminution of the sense of vibration; 13) extensive mutual influence of motor and sensory functions. As has been pointed out before elsewhere these seemingly unrelated symptoms can be traced back to common basic disturbances by a differentiation between primary and secondary symptoms.

To the primary symptoms of the sensory motor induction syndrome belong the phenomena of unilateral deviation, which manifest themselves systematically in the motor and sensory spheres on the same side of the body, the motor disturbances constituting the preliminary condition of the syndrome. These phenomena are the basic symptoms because by their equal inductive effect they represent the characteristic features of the syndrome and are in fact its constant components. All the disturbances mentioned above were found in both patients; in the first patient on the right and in the second patient on the left side of the body. The unilateral disequilibrium manifested itself in both patients as a tendency to fall to the affected side, as a deviation of gait to the homolateral side and as a deviation of the homolateral extremities downward and outward, all unknown to the patients. A characteristic feature of the syndrome of sensorimotor induction is the fact that this displacement of the statokinetic system of the body causes inductively a deviation in the sensory perception of the vertical and horizontal coordinates in the visual, haptic, tactile and sometimes also in the acoustic spheres, and that this sensory deviation manifests itself characteristically on that side of the body which corresponds with the side of disequilibrium. As will be remembered, this induced sensory deviation in the perception of the coordinates was also found in these patients, manifesting itself in visual, tactile and haptic spheres on the affected side of the body. The optic deviation of the horizontal caused also in the first patient a deviation of the line of writing when she used her right eye only.

In contrast to these constant primary sensorimotor symptoms, the *inconstant* secondary symptoms concern only the *sensory* functions. As has been demonstrated the disorganization of statokinetic stability, which manifests itself in the primary symptoms of sensorimotor deviation, can under certain circumstances effect a qualitative dedifferentiation and a quantitative changed perception of the sensory stimuli. The resulting sensory disturbances are called "secondary disturbances of perception" (6) as they appear despite the integrity of the sensory organs and are phenomenologically entirely different. Of secondary sensory phenomena which are based on the *qualitative* dedifferentiation of sensory perception, the symptoms of impaired discrimination of tactile and visual stimuli, including the perception of colors, of weight differences and of fine vibratory stimuli, must be mentioned. In addition to these phenomena belong the symptoms of *quantitative* changes of perception which manifest themselves as micropsia or macropsia, microstereognosis or

macrostereognosis. These secondary sensory disturbances were found almost without exception in both patients and manifested themselves regularly on *that side* of the body which *corresponded* with the side of the *disequilibrium*. In the first patient with right-sided disequilibrium macropsia was found as well as a coarsened perception of colors and of spatially close optic stimuli when using her right eye, and at the same time macrostereognosis and an overestimation of weight were found in the right hand. In the second patient with left-sided disequilibrium exactly the same sensory disturbances as above, but on the opposite side, were noted when she used her left eye. While these findings belong to the already known features of the syndrome and confirm earlier experiences, these patients presented some new features which are able to broaden and deepen our knowledge of these phenomena. These features concern chiefly visual perception and confirm a finding (5) made in another patient suffering from left-sided disequilibrium who presented a difference in visual perception between the outer and inner sectors of the left field of vision. This became apparent from the fact that the upper and middle parts of a dotted line which lay in the outer sector of the eye were perceived as being continuous, while its lower part which extended beyond this zone was correctly perceived. Further, it became apparent that color dissolution did not extend equally over the whole left eye, but affected chiefly its left outer sector. This later finding was also found in both patients discussed in this paper, where this disturbance showed itself most severely in the outer sectors of the eyes. When the second patient used her left eye only, darkening set in very quickly in the left outer sector of the field of vision. To the first patient, on prolonged looking at a cube with her right eye, its right outer part seemed to be larger and thicker. Of basic significance is the fact that this patient felt the same enlargement and thickening of the right outer edge of a cube when touching it with her right hand. This finding of unequal dedifferentiation in the same sensory organ seems to be of special interest. The fact that the greatest degree of impairment was found in the extreme outer sensory field, which is situated functionally nearer to the effect of motor deviation, confirms the close connection of these sensory proceedings with the homolaterally disturbed body posture. The fact that unequal qualitative dedifferentiation was also found in visual and tactile perception on the same side confirms in addition the existence of a general fundamental tendency.

Both patients presented moreover some new interesting features, all of which belong to the phenomenology of the mutual influence of motor and sensory functions (7–13). This phenomenon which is one of the most interesting symptomatological features of the sensorimotor induction syndrome shows itself in many ways.

This mutual influence takes place chiefly in the motor sphere and becomes most apparent in the relation between head posture and posture of the extremities. The influence of head posture is of main importance and is encountered most frequently, but in contrast an influence of the extremities on head posture is very rarely met with. These two forms of mutual influence were also found in both patients. In the first patient with right-sided disequilibrium, turning of the head to the right resulted in a reduction and retardation of displacement of the extremities on the right, while by turning the head to the left, displacement of the extremities was accelerated and aggravated. In the second patient with disequilibrium on the left, the position of the left extremities was not influenced at all by changed head posture. However, changed position of the extremities on the left caused an impressive change of head posture. When, with her eyes shut, the left arm or leg or both together began to deviate outward and downward to the left, an *automatic* turning of the head to the left appeared, unknown to the patient, accompanied by deviation of the eyes to the left and loss of consciousness.

The fact that by automatic turning of the head loss of consciousness could regularly be provoked in the second patient is of special interest in many respects. The spontaneous convulsive attacks should be kept in mind here as they presented the same features and were composed of several well-known neuropathological components. These attacks began with a raising of the left arm and a convulsive automatic turning of the head and eyes to the left. This conjugate deviation of the head and eyes, which movement originates in the mesencephalon according to clinical experi-

ence and the experimental work of Hess (14) and the anatomical control studies by Minkowski (17), was followed by cerebellar opistotonus and finally by a generalized tonic extension spasm which presented the picture of decerebrate rigidity. It must be stressed that these convulsions with loss of consciousness were mostly preceded by spontaneous raising of the left arm and by conjugate deviation of the head and eyes to the left. This introductory first phase of the spontaneous attacks corresponds phenomenologically with automatic deviation of the head and eyes to the left, with loss of consciousness following intentional raising of the left arm. The provoked attacks can therefore be regarded as the physiopathological link between them and the spontaneous attacks.

This fact deserves to be noticed all the more as it reveals the special nature of these attacks. It is common knowledge that spontaneous attacks of unilateral conjugate deviation of the head and eyes with loss of consciousness occur also in epilepsy. It must be mentioned that electroencephalography in this patient revealed no signs of epileptic activity either on spontaneous or on provoked attacks. They are therefore unique in their type as they are caused *solely* by unilateral disequilibrium and are closely connected with this *basic* impairment. The attacks observed by Zingerle (23) in the framework of his "Automatosesyndrome" and to some extent also those of turning of the head and body with visual hallucinations described by de Morsier (18) must be mentioned here. Unilateral disequilibrium cannot only blur the distinct separateness of the single functions, causing thereby the described phenomena of mutual influence, but occasionally may affect deeper lying mechanisms too. The special nature of these attacks is based on the extensive disintegration of these kinetic automatisms as a result of unilateral disequilibrium. After stabilization of the equilibrium these attacks, like the phenomenon of mutual influence of the various functions, disappear gradually or are abolished altogether. In this patient, too, after the left-sided disequilibrium had receded to a large extent, attacks of turning of the head and loss of consciousness could no longer be provoked. In contrast to the distinct character of the attacks at the height of the disease, the now diminished deviation of the left arm caused only slight turning of the head without loss of consciousness. The patient's statement that her spontaneous attacks had decreased lately in appearance and power were in accordance with these findings.

The new symptom of spontaneous and induced spasmatic attacks with loss of consciousness enlarges therefore the symptomatology of the sensorimotor induction syndrome. The mechanism underlying these attacks presents a physiological analogy to the secondary disturbances of perception which are sensory changes of a special kind. They represent the induced secondary effects caused by the primary unilateral disturbances of the disequilibrium and appear despite the integrity of the sensory organs. It becomes apparent that the unilateral disturbances of body posture induce not only a change in the single functions of sensory perception, but effect in the same way secondary disturbances of the sensorium and consciousness despite a primarily intact brain.

To the same sphere of mutual influence of motor and sensory functions belongs also the influence of optic function on postural attitude (13). The necessity for bilateral closure of the eyes on performance of the Romberg test and on examination of the disequilibration of the single extremities is common knowledge and generally used. When this test was modified in such a way that the eyes were shut separately, patients with the sensorimotor induction syndrome showed a divergent reaction. When the patient used that eye which corresponded with the side of the disequilibrium, the same basic pathological tendency to fall and the same displacement of the homolateral extremities resulted as on closure of both eyes although occasionally diminished and nearly always retarded. However, when the patient used that eye which was opposed to the side of disequilibrium, the unilateral tendency to fall was entirely abolished and the displacement of the extremities was reduced or eliminated. This divergent attitude can be explained well by the neurodynamic mechanism underlying the sensorimotor induction syndrome. The unchanged persistence of the unilateral disequilibrium on vision with that eye which corresponds to the side of the disequilibrium is based on the characteristic visual deviation in

the perception of space, which manifests itself regularly in this eye. The positive corrective influence of the contralateral eye on the disturbances caused by the unilateral disequilibrium belongs, however, to the sphere of mutual influence of motor and sensory functions and represents an example of the influence of a sensory stimulus on motor function. One may refer to the special influence of a light stimulus on motor deviation observed by Metzger (16) in 1931. He found that illumination of one eye caused a homolateral reaction to fall with past-pointing. The optic influence on body posture which Magnus (15) observed in his classic animal experiments may be mentioned too. This optic influence was distinctly apparent in the patients described above. In both patients the tendency to fall was abolished, and deviation of the affected extremities reduced when the contralateral eye was used. In the second patient, turning of the head to the left and the resulting loss of consciousness which appeared when both eyes or the right eye only was closed disappeared entirely when the left eye was closed and the right contralateral eye only was used. The tests performed with these patients confirmed not only the effect of optic function on motor disturbances of body posture but proved that the corrective effect of the contralateral eye extended to the secondary sensory disturbances too. This effect concerned the visual and tactile functions and manifested itself differently in these patients. The angle of deviation in the visual perception of a vertical line with the homolateral eye was visibly reduced when the contralateral eye, although separated by a screen, remained open. The coarsened discrimination in the visual perception with the homolateral eye of a dotted line diminished visibly when the contralateral eye was kept open. In the first patient the alterations which appeared when she was drawing geometrical figures, using her right eye only, disappeared when the contralateral left eye was kept open. In the tactile sphere this effect influenced the faulty perception of tactile stimuli on the homolateral side of the body and also overestimation of size and weight in the homolateral hand. All these deviations did not appear when the contralateral eye was kept open. The optic effect on the sensory disturbances described above should not produce the impression that we are dealing here with a direct influence of a stimulus in one sensory sphere on the functions of another sensory sphere. My observations have shown that the influence on the secondary sensory disturbances became effective by means of body posture. The optic effect of the contralateral eye corrected *primarily* the unilateral disequilibrium and then *indirectly* the secondary *sensory disturbances*. The significance of body posture with respect to sensory perception was further confirmed by the examination on color effect as will be shown below.

In both patients the effect of *colors* on the unilateral disequilibrium manifested itself very impressively. As will be recalled on using the contralateral eye the postural pattern only served as a basis and point of comparison. In this position the body of the seated patients was slightly inclined and the homolateral arm deviated moderately. Systematic tests on the influence of various colors by means of Wratten filters on this postural pattern, when using the contralateral eye, resulted in an unvarying attitude of both patients. Pure red produced a definite worsening effect on the postural pattern while pure blue had a marked ameliorating effect on the existing disturbances. When red was put before the contralateral eye of the first patient, a dramatic change in her postural pattern took place. The inclination of the body to the right and deviation of the right arm downward to the right increased constantly with violent rocking movements till the patient fell to the right. In the second patient with the left-sided disequilibrium red produced the same changes effecting an inclination of the body to the left and deviation of the left arm downward to the left with the addition of automatic turning of the head to the left and loss of consciousness. In contrast pure blue had a wholly corrective influence on the postural pattern of both patients in that the primarily one-sided inclination of the body and the homolateral deviation of the arm disappeared until an entirely normal position was attained. As will be recalled, blue even stopped and reversed the pathological movements provoked by red. It was then revealed that body posture reacted to colors even more sensitively than the eye. While the eye perceived two kinds of blue as being really blue, body posture reacted differently. While one blue had an ameliorating

effect, the other provoked the pathological movements. It was revealed that this latter blue, when examined by spectral analysis, had an admixture of red which was not perceived by the eye. Between this extreme contrary effect of red and blue lay the other colors, the effect of which depended on the admixture and degree of contents of red and blue. The colors red, yellow, green and blue and their mixed nuances represent the order of succession in their effect from bad to good on the postural pattern. The effect of these colors did not only concern the motor phenomena of disequilibration but accordingly also the secondary sensory phenomena. The unvarying influence of these colors on acoustic discomfort, by lowering and raising of its threshold, must be mentioned in this connection. These tests on color effect confirmed too that this influence was exerted primarily through the effect on body posture, and the sensory phenomena were influenced only indirectly in the same sense.

Metzger when investigating the effect of light on rabbits and men stressed the effect of colored lights. Goldstein and Rosenthal (3) were the first to determine the effect of colors on cerebellar patients, while Quadfasel and Krayenbühl (19, 20) examined the effect of colors on spastic torticollis. In cerebellar patients the pathological tendency of deviation of the arm served as the indicator. The patients were asked to look at a colored screen. The different colors caused a different degree of deviation of the arm. Under the influence of red the arm deviated most strongly, somewhat less under that of yellow, still less under the influence of blue, and least under that of green. My results agree with these findings only with respect to the sequence red and yellow, but they *differ* in the sequence blue and green in that the best effect was produced by blue. In my patients, where the biologic effect of colors was tested with regard to the deviation of the arm as well as to the inclination of the body, the effect of colors on the subjective feeling of the patients became apparent too. Without being aware of the resulting postural changes the patients felt very bad when looking at red, a feeling which was accompanied by nausea, pallor, accelerated pulse and breathing. However, under the influence of blue the patient felt extremely well.

This effect of blue on the correction of the postural disturbances was now evaluated therapeutically. The homolateral eye was closed, and blue spectacles were put before the contralateral eye. The expected therapeutic effect took place: the patients felt better subjectively and a visible amelioration of the disturbed functions occurred. In the second patient, after prolonged use of the blue spectacles, the spontaneous spasmatic attacks gradually disappeared too.

As has been discussed elsewhere, in dissolution of color perception, which is found in the homolateral eye of patients with the sensorimotor induction syndrome, the perception of various shades of blue was most impaired. These were perceived as being dark or even black, while perception of red was preserved best. This finding was also confirmed without exception in these two patients as well as in all other patients of this kind. This extraordinary position of red in the secondary dissolution of color perception is of special interest as it is fundamentally contrary to the position of red in color dissolution caused by an anatomical lesion of the optic nerve, where red disappears first. Therefore, it is worth mentioning that red, which from the biologic point of view is preserved best, had subjectively and objectively the most annoying and disturbing effect.

In contrast to the remarkable influence of optic stimuli on postural attitude, no influence of sound on the existing conditions was noted in either patient. This fact is certainly based on the more dominant position and deeper integration of the optic functions in the neurobiologic organization of the organism as compared with the other sensory functions. The same feature is obtained in the sphere of electrical activity of the brain, where photic stimulation activates the pathological tendencies much more frequently and more strongly than acoustic stimuli.

Conclusive Remarks

The sensorimotor induction syndrome in unilateral disequilibrium represents clinically a well-defined entity which should be observed carefully. Knowledge of the abundant symptomatology is a preliminary condition for the recognition of the picture of the disease which occurs more frequently than is generally supposed and should not be neglected any longer.

But apart from the significance of this syndrome for clinical practice the underlying neurobiological mechanisms open up interesting theoretical aspects. The significance of postural functioning with regard to sensory perception revealed here should be recalled as well as the special phenomenology and dynamics of the secondary, in contrast to the generally known primary disturbances of perception caused by lesions of the sensory organs themselves. Further the abundant phenomenology of the mutual influence of various functions should be mentioned in this connection. However, in order to understand these proceedings correctly it is necessary to know from the first that they take effect in a *secluded separate functional system* and obey rules of their own which are entirely *different* from the principles of activity valid for the pyramidal or the sensory system. The functional rules of these systems cannot by any means be applied to the theory and practice of sensorimotor induction as, on the other hand, the functional rules of this system cannot be generalized. The facts and findings revealed above justify decidedly placing the little noticed equilibratory system in a line with the most important human nervous systems. In this connection the consecutive stratification of the function and the substratum of the equilibrium in the ascending line of evolution should be recalled as well as the extraordinarily complicated conditions on which, as Magnus and his pupils demonstrated, regulation of body posture is based. With regard to localization, the disclosure made by them of the relation of the various reflexes of body posture to the cervical cord, the brainstem, mesencephalon and nucleus ruber indicates the participation of additional anatomical areas in the regulation of the equilibrium. Further mention should be made of the special tasks of the human equilibratory system with respect to the erection of the human body and the liberation of the human hand from a supporting extremity to a creative organ in connection with the phylogenetic and ontogenetic development of the human frontal brain. Through this successive functional stratification it can be explained easily that the human equilibratory system is not based on uninterrupted long tracts but on the uniform and purposive cooperation of several relay connections, one interlocking with the other. As is well known, this system includes the vestibular nerve which is connected with the cerebellum via the vestibulocerebellar tract and by means of its nuclei also with the spinal cord and the midbrain. In addition there are reciprocal corticopontocerebellar connections and among them with some parts of the contralateral frontal brain. In this system, the nature of which has only been dealt with in a general way, the cerebellum seems to occupy a central position. Of special interest in this connection and particularly with regard to the symptomatology and localization of the sensorimotor induction syndrome are the electroanatomic studies of Snider (22) and his co-workers who discovered visual, tactile and auditory areas in the cerebellum. As a result of these investigations, Snider stated that the cerebellum acts both in motor and sensory spheres, and that these sensory spheres do not subserve any known conscious function. On the basis of these findings, Snider demands a new and broader concept of cerebellar function and even states that workers in this field have been entirely too lethargic about recognizing this sensory action. As will be recalled, Snider's findings, obtained by electroanatomic means, correspond very well with our clinical investigations on primary sensorimotor symptoms of deviation, which manifest themselves in the motor, visual, tactile, haptic and acoustic spheres, unknown to the individual. These new electroanatomic findings can, therefore, add support to the anatomic and physiologic foundation of the syndrome of sensorimotor induction.

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