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METHOD FOR CHANGING STEREOTYPED RESPONSE PATTERNS BY THE INHIBITION OF CERTAIN POSTURAL SETS[1]

FRANK PIERCE JONES

Institute for Psychological Research, Tufts University

An empirical method is described for changing habitual response patterns by inhibiting postural sets which disturb the reflex balance of the head. The procedure results in a redistribution of postural tonus which is reported by S as a decrease in the feeling of weight and in the effort needed to move. Differences in posture and movement are recorded by multiple-image photography, X-ray photography, and electromyography. Anatomical and physiological mechanisms are suggested to explain the phenomenon. The implications for behavioral science are discussed.

The problem of behavioral change becomes more important as society becomes more complex. Even if a complete set of desirable responses could be successfully taught to everyone, the necessity would still remain, in a rapidly changing world, of modifying or eliminating some of them. This is easier said than done, however, as anyone can testify who has attempted to change an unwanted habit. A well-learned response pattern continues to be elicited by appropriate stimuli long after it has lost all value for the organism. "I see the better course and approve of it," the poet says, "but I follow the worse."

This paper will describe an empirical method for changing habitual patterns of behavior by inhibiting certain postural "sets." Once understood, the method can be applied to any pattern of response. It is demonstrated most easily with a movement which involves head, neck, and trunk and which is performed against gravity.

POSTURAL SET

The term *set* is used here to mean a preliminary change in the level and distribution of tension as a preparation for movement (Jones, 1963). In preparation for a movement against gravity, the increase in tension is often sufficient to change the relation between head and trunk. This change is so much a part of the movement to come that it is seldom detected by the mover. If it is eliminated from the response pattern (i.e., inhibited), the movement itself will differ markedly from the ordinary movement in the

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This study originated in conversations with J. Dewey, who persuaded me that the sensory phenomenon described in this paper could (and should) be investigated within the framework of experimental psychology. The study was undertaken with the advice and encouragement of G. P. McCouch, J. McV. Hunt, and H. Schlosberg.

For assistance in the design and conduct of experiments and the interpretation of experimental data I wish to thank my colleagues at the Institute for Psychological Research, particularly M. and Dorothea Crook, Florence E. Gray, and J. A. Hanson.

way the weight of the body is perceived. In addition, the movement will produce a different distribution of postural tonus, against which a subsequent set can be perceived kinesthetically as a figure-ground relation. The character and significance of the phenomenon can perhaps be best understood from an introspective account.

INTROSPECTIVE REPORT

The effect on a movement pattern of changing the habitual relation between head and trunk was first demonstrated to me by the late A. R. Alexander.[2] Alexander used the movement from sitting to standing for the demonstration. The experience, which is still vivid in retrospect, was unexpected. Assuming that the demonstration would have something to do with voice production, I did not anticipate a movement of any kind. At the start, Alexander made a few slight changes in the way I was sitting. These changes seemed quite arbitrary to me, and I could not remember afterwards what they were. Then, asking me to leave my head as it was, he initiated the upward movement without further instructions. The movement (from sitting to standing) was completed before I had a chance to organize any voluntary response. The sensation was not that of either getting up or being lifted. My body seemed to be straightening reflexly against gravity. The analogy of the knee jerk suggested itself immediately. The two movements were similar kinesthetically, but this one, in an integrated fashion, involved the whole extensor system.

In addition to the reflex effect, the movement was notable for the way time and space were perceived. Though less time than usual was taken to complete the movement, the rate at which the head and other parts moved was paradoxically slower, and the trajectories which they followed were unfamiliar. The experience is difficult to describe, but the impression was that of a sudden expansion in both dimensions so that more time and space seemed available for the movement.

The sense of reduced weight which accompanied the movement persisted after it was completed. The centers of gravity of the head and trunk seemed to have shifted forward in relation to the feet, and the weight of the body to be supported by structures which previously had not been called into play. The effect of the change was to eliminate much of the fatigue which for me had been associated with standing.

What later became a clear-cut, easily recognizable kinesthetic experience of lightness and ease of movement registered at first as the absence of sensations which, though familiar, had never been consciously observed. The nature of these sensations began to be manifest, however, when an attempt was made to repeat the movement from sitting to standing. This time I got set in anticipation. There was an increase of tension in the neck, trunk, and limbs as soon as the suggestion of getting up was made. The tension had apparently always been present as a preliminary to movement, but by some process of adaptation it had passed unobserved. Now, against the remembered back-

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[2] A. R. Alexander was a brother of F. M. Alexander (1923, 1932, 1941). Alexander's teaching, which was based on a principle of conscious inhibition, had an important influence on the thinking of Dewey (1922, 1923, 1932; McCormack, 1959). Coghill (1941) and Dart (1947, 1950) gave firsthand accounts of Alexander's system. It was noted briefly but favorably by Sherrington (1946) and Herrick (1949) and discussed at various times in the British medical press (Barlow, 1945, 1954; Macdonald, 1926; Rugg-Gunn, 1940). A discerning account has recently been written by Carrington (1963).

ground of the previous movement, it stood out as a recognizable pattern. It was as if the reflex movement had eliminated some of the "noise" from the system, so that when the signal reappeared it could be perceived as a discrete pattern of spreading tension. The pattern began first in the neck, fixing the position of the head and spreading quickly to the trunk and limbs. While it was present, no movement except the habitual seemed possible.

Once this signal—this pattern of spreading tension—had been clearly perceived, I found it reappearing in a great variety of situations—in speaking, for example, in taking a deep breath, in climbing stairs, in lifting a heavy weight, in changing the fixation of the eyes. The pattern was magnified by stress, but seemed to be present in some degree a great deal of the time. It was repeatedly demonstrated to me that when this pattern was inhibited and the tension prevented from spreading, the character of the associated activity changed: it became markedly easier and was accompanied by the same kinesthetic effect of lightness I had observed before.

The kinesthetic effect of lightness was tonic and persisted long after a particular movement had been completed. With it almost from the start came certain automatic or semiautomatic changes which are probably significant for understanding the phenomenon: (*a*) a change in the rest position of the eyes and a marked reduction in the tension used in eye movements; (*b*) a change in the rest position of the jaw and a relaxation of tension in the tongue and throat; (*c*) a change in the rate and depth of breathing, associated with an increase in the excursion of the diaphragm. All of these changes were corollaries of the postural change and disappeared when I returned to my habitual pattern of posture and movement.

I have described a clear-cut sensory experience. Though kinesthetic in origin, it had the sharp and immediate reality of experience obtained through other sense modalities. It was repeatable, and it was not accompanied by any detectable form of suggestion. I was immediately struck by the implications of the experience for behavioral science. It seemed to open up to controlled investigation an area of the self which has heretofore been notoriously private and inaccessible and to provide the individual with a reliable means for changing a behavior pattern without delving into the past or having recourse to some outside authority. The inhibitory control which I found myself using in simple, everyday movements seemed capable of extending to any situation which could be expressed in terms of stimulus and response. Before speculating, however, about implications and extensions, I decided that experimental data were needed in order to define the phenomenon operationally. To this end, a series of studies have been made at the Tufts Institute for Psychological Research. I shall review them here and advance a theory of mechanism to account for the data.

PROCEDURES FOR CHANGING THE BALANCE OF THE HEAD[8]

The subject, seated in a comfortable, "relaxed" posture, is asked to straighten up into a more erect posture. As he responds, a slight change can be seen to take place in the axis of his head, which is usually rotated backward, bringing the occiput closer to the seventh cervical vertebra. If he is asked to straighten up even further

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[8] The procedures described here are adapted from procedures used by F. M. Alexander.

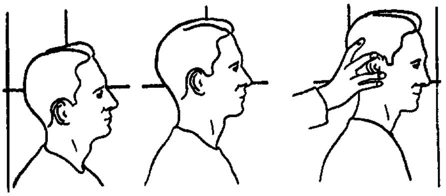


FIG. 1. Three sitting postures, traced from photographs. (From left to right: habitual relaxed, habitual erect, and experimental. In the final picture the subject has been guided into the erect posture by the experimenter, who counterbalanced the backward pull on the subject's head during the movement.)

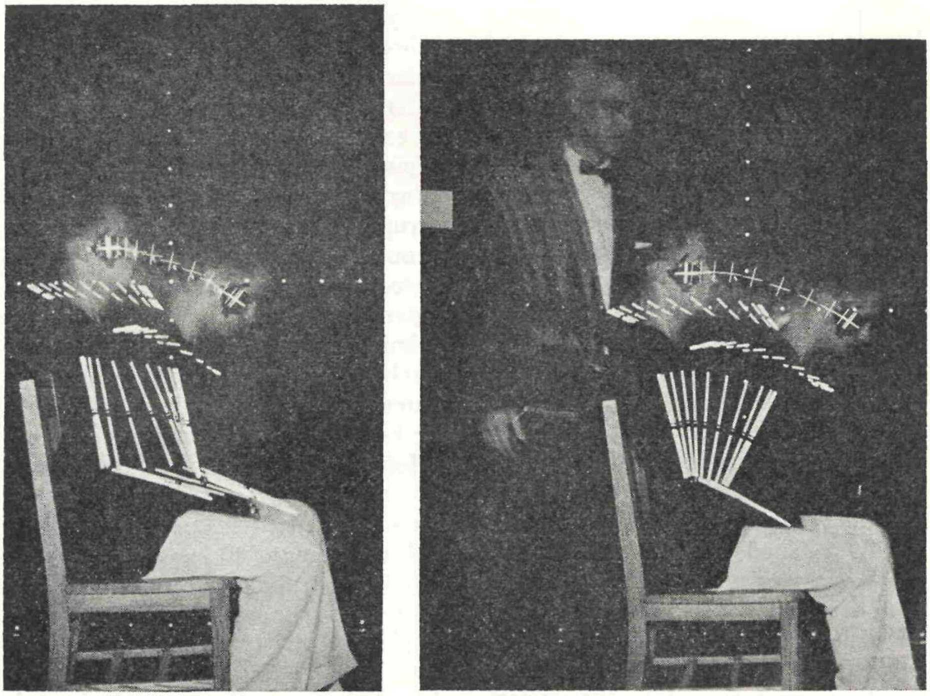
into his "greatest sitting height," the angle of head rotation will increase (Jones, Gray, Hanson, & Shoop, 1961). After the subject has returned to his relaxed posture, the experimenter applies a light pressure at the back of his head just sufficient to counterbalance the backward rotation. The subject is then guided in a series of small movements, while the experimenter continues to prevent the backward rotation of his head, taking care not to evoke stretch reflexes in neck muscles by applying unnecessary pressure. At the end of the procedure, the subject will again be in a more erect posture, but the relation of head to trunk will be different from that observed in the habitual posture (see Figure 1).

If these procedures are carefully followed, the subject's weight will seem to the experimenter to be progressively reduced until little effort is needed to move him passively. Any movement carried out after the change will follow a different course from the corresponding habitual movement.

EFFECT OF HEAD BALANCE ON MOVEMENT PATTERN

The effect of a change in head balance on movement pattern was first demonstrated by Jones and Narva (1955) with multiple-image photography. Small electric lights were attached to the subject's head, trunk, and limbs and connected with wires to a battery. The subject moved with profile to the camera, which was left open throughout the movement while an episcotister (or "Marey wheel") interrupted the moving image 10 times a second. The images of the interrupted lights provided a time-space pattern of the movement. Though the technique lacked precision, the photographs showed convincingly that the pattern of a movement is altered when the head balance is changed.

Jones and O'Connell (1956) refined the method by attaching strips of Scotchlite reflecting tape to the subject and recording the moving image by repetitive strobe at rates of 5, 10, and 20 flashes per second. The stroboscopic method is highly flexible and allows the subject a maximum of freedom to move. Patterns obtained in this way are sharp and clear-cut and contain a vast amount of information that can be quantified. An example of the method is shown in Figure 2. The subject wears a black jacket to cut down reflectance. A small cross, which is centered in the Frankfort plane (Howells, 1937) halfway between the tragion of the ear and the lowest point of the orbit, marks the position of the subject's head and its angle of rotation. Other markers are attached over the seventh cervical vertebra and the sternal notch and to the upper and lower arms. In the picture on the left, the subject sits leaning forward in the chair and moves back into an upright sitting posture. The strobe is pulsed at 5 flashes per second. In the picture on the right, the movement is repeated after the experimenter has changed the relation between the subject's head and trunk. In the experimental movement, the trajectory of the head is higher, the



2a. Habitual. 2b. Guided.

FIG. 2. Stroboscopic multiple-image photographs, from leaning forward to sitting erect. (Reflecting markers are placed on: head; neck, at seventh cervical vertebra; chest, at sternal notch; upper and lower arm. Strobe at 5 flashes per second.)

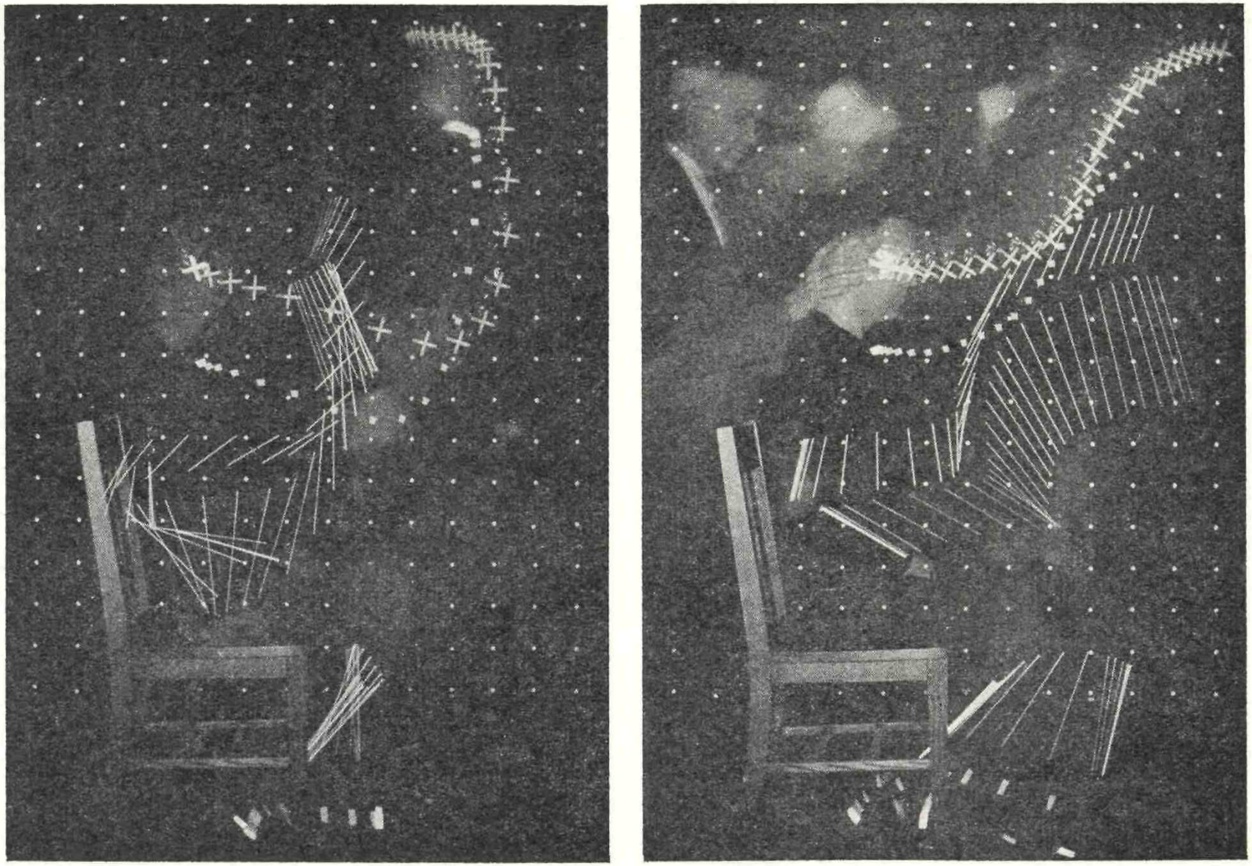
curve is smoother and more regular, and the change in head pattern is accompanied by changes in the patterns of the trunk and arm.

Other everyday movements which have been recorded in this way are walking, stair-climbing, stooping down to pick up an object from the floor, straightening up from a slump, and the movements from sitting to standing, from standing to sitting, and from lying down to sitting up. In each of these movements, the pattern is characteristically altered when the relation of head to trunk has been changed.

MOVEMENT FROM SITTING TO STANDING

The most striking differences in pattern are seen in the movement from sitting to standing (see Figure 3). In the picture on the left, the subject, with markers on head, neck, upper and lower arm, leg, and foot moves from sitting to standing in his habitual way. In the picture on the right, the movement is guided by the experimenter, who has changed the relation between head and trunk in the manner described above.

In the movement from sitting to standing, habitual patterns show individual differences which remain remarkably constant from trial to trial (Jones & Hanson, 1961, 1962). When the movement is guided, individual differences tend to disappear so that the guided patterns are much more uniform than the habitual. Quantitative methods of pattern analysis (Jones &



3a. Habitual. 3b. Guided.

FIG. 3. Stroboscopic multiple-image photographs, from sitting to standing. (Reflecting markers are placed on head, sternal notch, right upper and lower arm, right leg, right foot, and left foot. Strobe at 10 flashes per second.)

O'Connell, 1958) were used to compare guided with habitual movements. In an analysis of 36 patterns from six subjects, indexes were found that distinguished the guided from the habitual at a confidence level of .01 or better (Jones, Gray, Hanson, & O'Connell, 1959). The three indexes which have proved most useful in subsequent studies are: (*a*) head thrust, which measures the forward thrust of the head during movement; (*b*) trajectory ratio, which measures the extent to which the head trajectory departs from a straight line; and (*c*) rise time, which measures the time needed to bring the head above the starting level. In the guided movement, head thrust decreased, rise time was shorter, and head trajectory approached more closely a straight line.

The value of the three indexes was tested by applying them to patterns which could be judged "better" or "poorer" on the basis of some external criterion. Jones and Hanson (1961) analyzed the movement from sitting to standing as it was performed by "well-coordinated" and "poorly coordinated" subjects. Jones, Hanson, Miller, and Bossom (1963) compared the same movement in a group of normals and a group of patients with neurological diseases. The three indexes which had distinguished guided movements from habitual distinguished (again at a confidence level of .01 or better) well coordinated from poorly coordinated and normal from abnormal movements. By these criteria, then, the guided movements are not only different from the habitual, they are better.

SUBJECTIVE EXPERIENCE

For the great majority of subjects, the guided movements are accompanied by a kinesthetic experience of lightness and ease of movement, which tends to persist after the experimental session is concluded (Jones, 1954). By some, this kinesthetic effect is observed immediately, i.e., after the first guided movement. Others observe it only after the movements have been repeated a number of times. When asked to describe the experience, subjects are apt to find it difficult to put their feelings into words. To make the task easier, a check list of 18 adjectives was constructed, 16 of them paired opposites (Jones, 1964). The subject is first asked if the guided movements felt different in any respect from his ordinary movements. If the answer is "yes," he is given the list of adjectives and asked to check those that best describe the difference.

Data from 39 subjects are presented in Table 1. All of the subjects were normal young adults without previous knowledge of the phenomenon under study. The responses were obtained after a brief demonstration of 10 or 15 minutes.

The adjectives most frequently checked (i.e., lighter, less familiar, higher, and smoother) seem to give the core of the sensory experience. Other adjectives reflect individual differences in the attempt to describe the unfamiliar. A feeling of "unreality" which some subjects observed was variously identified by "brighter," "duller," or "softer." The fact that some subjects checked "slower," while others checked "faster," seems related to the paradoxical character of some of the guided movements (e.g., sitting to standing) which may be completed in a shorter time than the corresponding habitual movements, but which reach a lower maximum velocity. Sometimes the experimenter failed to convey the kinesthetic effect of lightness. When this was the case, a different constellation of adjectives was checked with "heavier" and "more difficult" replacing "lighter" and "easier." Some sub-

TABLE 1

PERCENTAGE OF RESPONSES OF 39 SUBJECTS TO THE ADJECTIVE CHECK LIST

Adjective	%	Adjective	%
Lighter	72	Tenser	20
Less familiar	62	Brighter	15
Higher	59	More difficult	15
Smoother	54	Less steady	13
Slower	44	Heavier	13
More relaxed	44	Faster	10
Easier	41	Jerkier	10
Softer	38	Duller	8
Steadier	36	Lower	3

jects reported that the feeling of lightness was confined to the upper part of the body at the start and did not extend below the waist until a later stage in the demonstration, or until a later session. The spread of the kinesthetic effect from the head downwards (it is never reported the other way around) is undoubtedly important for understanding the phenomenon.

To measure the subjective feeling of reduced weight, the method of magnitude estimation has been used. The subject is asked to put a value of 10 on the effort he ordinarily exerts in a movement against gravity; then, on the same basis, he is asked to estimate the effort involved in the experimental movements. Measured in this way, the feeling of weight may be reduced anywhere from 20 to 80%, with some subjects reporting that all sense of effort has disappeared.

X-RAY STUDY OF THE HEAD-NECK RELATION

X-ray photography was used by Jones and Gilley (1960) to obtain a better definition of the three postures—habitual relaxed, habitual erect, and experimental—shown in Figure 1. The subjects were 20 students at the Tufts University School of Dental Medicine who were taking part in a study of dental occlusion. X-ray photographs were taken of each of them in the three postures. To analyze the photographs, planes were constructed through the head and neck, and the angles which these planes made with the horizontal and with each other were measured. Additional measures were taken of the distance between the spines of the first two vertebrae and of the distance between *sella turcica* (which corresponds roughly to the center of gravity of the head) and a horizontal line drawn through the second vertebra. When the three postures were compared, it was found that both of the erect postures differed from the habitual relaxed in the angle between horizon and neck. They differed from each other in the angle between horizon and head, and in the angle between head and neck. In the experimental posture, the distance between the first two vertebrae was greater, and the distance between *sella turcica* and the second vertebra was smaller, than in the habitual erect. These differences are significant at the .01 level or better.

X-ray photographs of the two erect postures are shown in Figure 4. In the experimental posture (on the right) the neck has lengthened, the head has rotated forward on the atlas, the distances between the spines of the vertebrae and between the vertebrae and the occiput have increased. Though the head is slightly higher in the experimental posture than in the habitual, its center of gravity relative to the vertebrae is lower.

ROLE OF THE STERNOMASTOID MUSCLE

In the light of the X-ray findings, it seemed reasonable to expect a difference in the activity of neck muscles in the two erect postures. Preliminary investigation pointed to the sternomastoids (the prominent diagonal muscles on either side of the neck) as the muscles which distinguished most sharply between the two postures. Later, the postural activity of these muscles was systematically studied in seven male subjects between the ages of 16 and 21 (Jones, Gray, Hanson, & Shoop, 1961; Jones, Hanson, & Gray, 1961). Surface electrodes were placed over the right sternal head halfway between origin and insertion. The activity of the muscle was recorded as the subject sat in his "most comfortable" posture, in his "best" posture, and at his "greatest height." It was recorded again when he was guided into the "experimental" posture. Mean potential for the seven subjects increased from 7 microvolts for most comfortable to 10 microvolts for best and to 26 microvolts for greatest sitting height. In the experimental posture it dropped back to 6 microvolts. The difference in the behavior of the sternomastoid appeared not only in the postures themselves but also in the movements which led into them. All differences (which are illustrated by bar graphs in Figure 5) are significant at a confidence level of .05 or better.

ANATOMICAL MECHANISMS

The head can be rotated, tilted, or lowered by contracting the muscles attached to it; but it cannot be lifted. It can be lifted only by straightening and

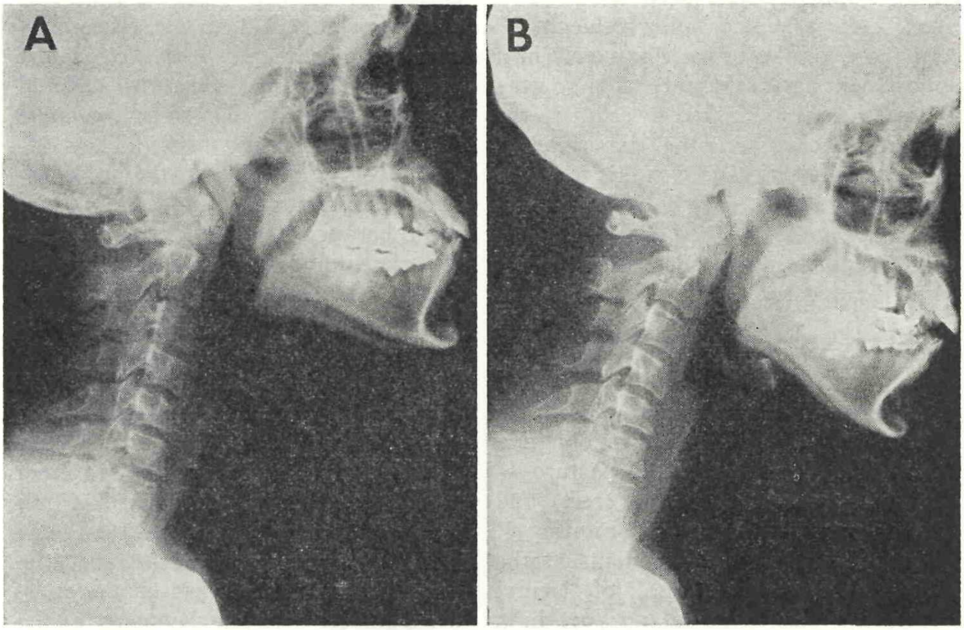


FIG. 4. X-ray photographs of two erect sitting postures. (A, habitual; B, experimental.)

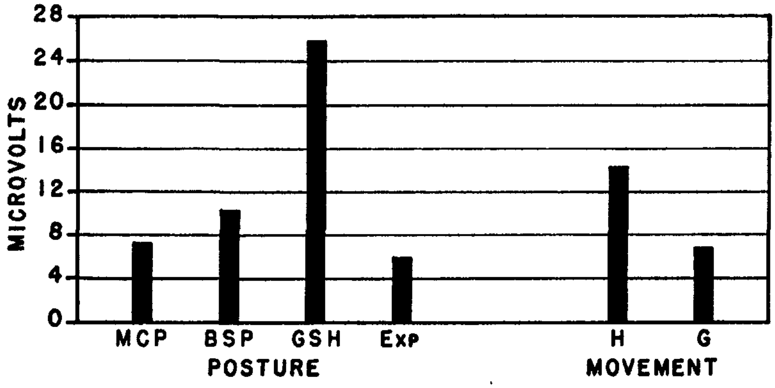


FIG. 5. Postural activity in right sternomastoid muscle. (Means for seven subjects. Abbreviations are: MCP, most comfortable sitting posture; BSP, best sitting posture; GSH, greatest sitting height; Exp, experimental; H, habitual movement into erect sitting posture; G, guided movement into erect sitting posture.)

lengthening the cervical spine. Between the vertebrae and the skin there are four structures whose joint action determines the height of the head and its angle of tilt and rotation. They are shown schematically in Figure 6.

Intervertebral Discs

The cartilaginous discs between the bodies of the vertebrae contain fluid and are capable of exerting hydraulic force on the bony structures around them (Gray, 1942, p. 281). The discs are kept under pressure by ligaments and by various muscles, including the small muscles which run from one vertebra to the next. If these muscles shorten, the distance between the vertebral bodies will be lessened, and the discs will be further compressed. Conversely, if they lengthen, the distance will increase as a result of the released pressure of the discs. In the intervertebral discs, then, is a mechanism by which the height of the head can be altered a small but significant amount.

Flexors and Extensors of the Neck

Both convexity (extension) of the cervical curve and its forward inclination (flexion) are countered by the tension of ligaments and muscles whose origins and insertions are on the vertebrae themselves (Gray, 1942, pp. 390, 394–395). Acting together, the flexors and extensors of the neck straighten and strengthen the cervical spine, turning it into a column of support and, in so doing, increase the height of the head.[4]

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[4] In standard textbooks of anatomy, the extensors of the head and the extensors of the neck are treated under a single heading and illustrated with the same plates so that it is sometimes difficult to distinguish one group of muscles from the other. They have similar names (*splenius*, *longissimus*, etc.) and similar origins on the spinal column. They differ, however, in their insertions and in the functions which they perform. When the neck is flexed, the head is brought forward and down. If, then, the neck extensors contract, the spine will be straightened (extended), and in the process the head will be brought to a higher level, even though the head extensors remain relaxed. Contracting the head extensors, on the other hand, will not lift the head, but will only tilt it backward so that the occiput approaches the seventh cervical vertebra. Duchenne (1959, p. 534) first pointed out in 1867 the difference of function between the two sets of extensor muscles. He had observed that patients whose neck extensors were paralyzed could not lift their heads, though they still had the full use of their head extensors.

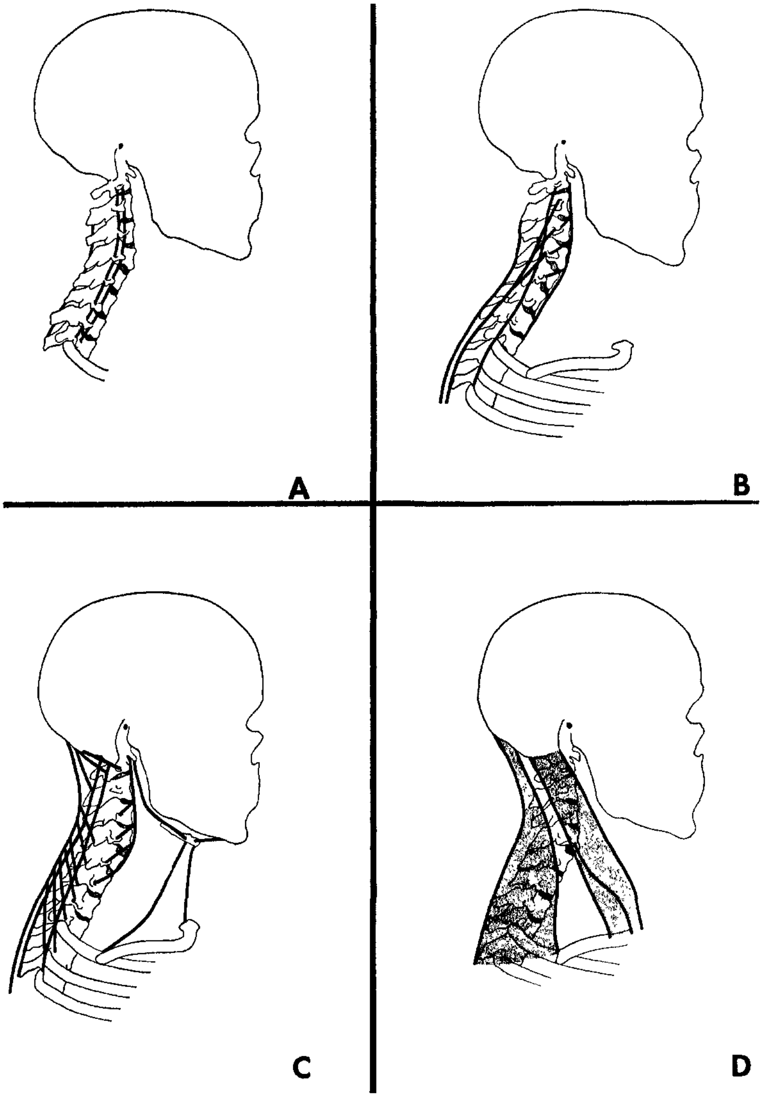

FIG. 6. Anatomical structures affecting the height and angle of the head. (A, intervertebral disks with *interspinales* and *intertransversarii* muscles. B, flexors and extensors of the neck. C, flexors and extensors of the head. D, *upper trapezius* and *sternocleidomastoid* muscles.)

Flexors and Extensors of the Head: I

In the upright posture, the head is in unstable equilibrium, its center of gravity forward of the base of support (the atlas), and its weight balanced by the tension of ligaments and muscles which run from insertion points at the base of the skull to various origins along the spinal column. These muscles, the extensors of the head, are designed to balance, in addition to the weight of the head, the tension in a smaller group of flexor muscles in front. By the lengthening and shortening of the various muscles in these two groups the head can be moved in many directions without destroying the equilibrium of forces (Gray, 1942, pp. 386–395).

Flexors and Extensors of the Head: II. Sternomastoid and Upper Trapezius

There are two pairs of flexors and extensors which connect the head directly with the shoulder girdle. They are the *sternocleidomastoids* (Gray, 1942, p. 384) and the *upper trapezii,* which form a blunted isosceles triangle at the back of the neck (Gray, 1942, p. 428). Simultaneous contraction of the two pairs of muscles will bring the head closer to the shoulder girdle and increase the curve of the cervical spine, the sternomastoid drawing the head forward and down, the *upper trapezius* preventing forward rotation by retracting the occiput.[5] In the process, the origins and insertions of the muscles and ligaments which maintain the weight of the head against gravity will be brought closer together.

STARTLE PATTERN

An example of the joint action of the sternomastoid and *upper trapezius* can be seen in the "startle pattern" of Figure 7. Surface electrodes have been attached to the subject's skin over the right sternomastoid and right *upper trapezius.* In Figure 7A he is standing in his "most comfortable posture." In Figure 7B he has been startled by the sudden slamming of a door. The two sets of muscles have contracted simultaneously. The head is thrust forward, but the Frankfort plane remains horizontal. The postural change does not stop with the head and neck. As in one of the "attitudinal reflexes" described below, the shoulders are lifted, the chest is flattened, the legs are flexed, and the arms are extended.

The startle pattern, which was studied with high-speed photography by Landis and Hunt (1939), provides a vivid example of how "good" posture can change to "bad" in a very brief time. The pattern itself is typical of bad posture in general, whether it is the result of age, disease, or lack of exercise (Jones, Hanson, & Gray, 1964). In the startle pattern, the active character of malposture and the sequence of events by which it comes about can be clearly observed. The response is not instantaneous. It begins in the head and neck, passing down the trunk and legs to be completed in about ½ second. The neck muscles are central in the organization of the response. Jones and Kennedy (1951), who studied the startle pattern by multiple-channel electromyography, placed surface electrodes in various locations on the subject's neck, trunk, and limbs, with one pair always over the *upper trapezius.* The intensity of the stimulus was varied from the sound of a dropped book to the sound of a .32 caliber revolver. Sixty patterns were obtained from eight subjects. In all cases when the stimulus was strong enough to elicit a response, it appeared in the neck muscles; in many cases, the response appeared nowhere else.

PHYSIOLOGICAL MECHANISMS

I have described two reciprocal sets of structures in the neck, one designed to straighten the cervical spine and move the head out from the trunk, the other designed to bring head and

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[5] It may be significant that the two muscles have the same phylogenetic origin (Romer, 1949, p. 285) and that, unlike other neck muscles, they receive their principal innervation from a cranial nerve (the accessory). Duchenne (1959, p. 5) commented on their extreme sensitivity to electrical stimulation, which he attributed to the peculiar character of their nerve supply.

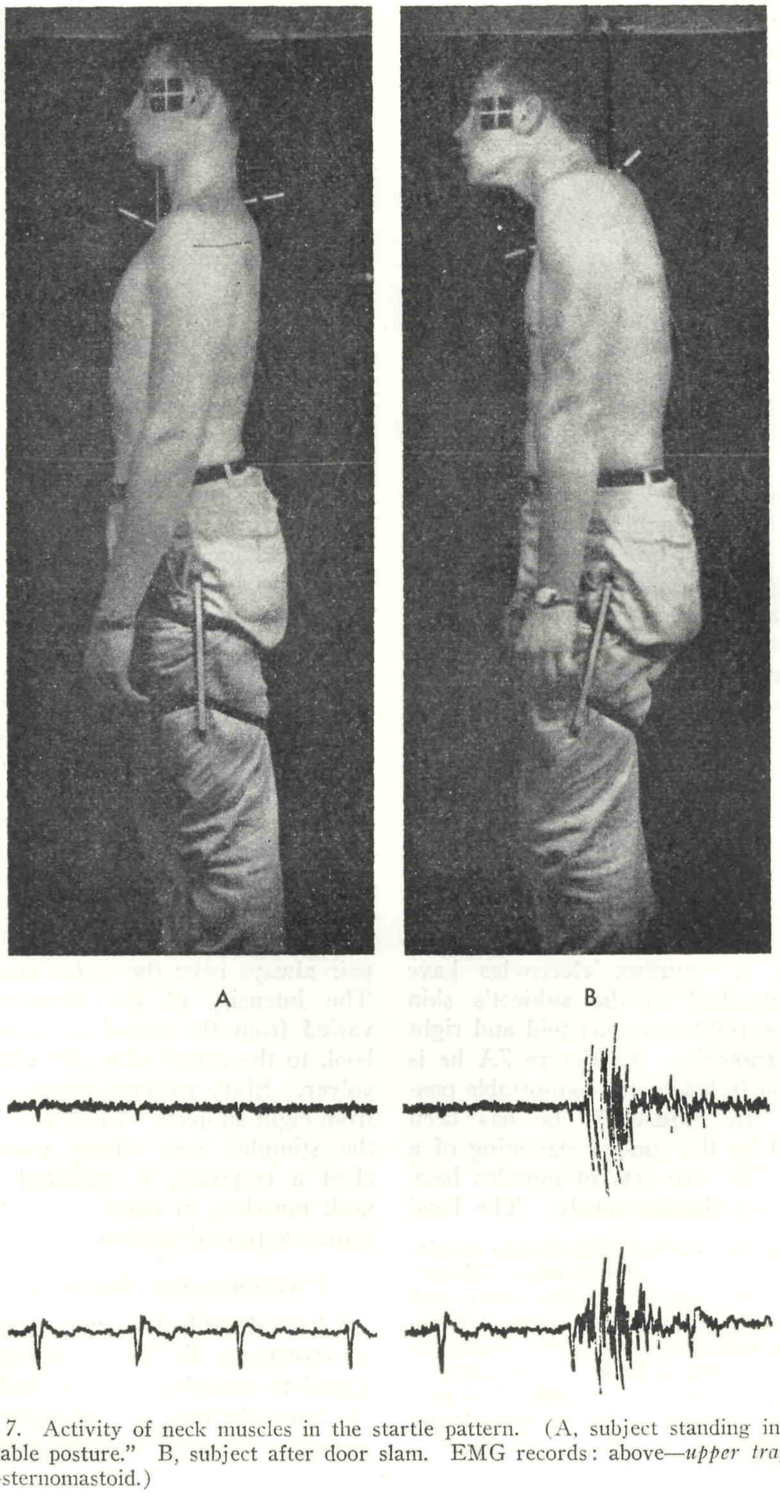

FIG. 7. Activity of neck muscles in the startle pattern. (A, subject standing in "most comfortable posture." B, subject after door slam. EMG records: above—*upper trapezius;* below—sternomastoid.)

trunk closer together and increase the spinal curvature. In the procedure described earlier in this paper, the downward pull of the sternomastoid and *upper trapezius* was counterbalanced by the experimenter while the subject moved. It is conjectured that in the process, the pressure on the discs was reduced, the flexors and extensors of the neck shortened, and a lengthening took place in the flexors and extensors of the head and in the small muscles between the vertebrae. During movement, the lengthening which appeared in the neck could be expected by purely mechanical means to extend along the rest of the spine, with the force being transmitted by muscle and ligament from one vertebra to the next.

Stretch Reflexes

The mechanical effect of stretch on muscle is modified by the action of the nervous system. When a muscle is stretched, it contracts reflexly, and the strength of the contraction is proportional to the stretch. Though stretch reflexes occur at the spinal level, they are under the influence of higher centers in the nervous system. This influence is transmitted directly to the muscles through the system of small motoneurons, the gamma efferents. As the level of activity in the gamma efferents rises or falls, the sensitivity of a muscle to stretch increases or decreases. Whether a contracting muscle shortens or lengthens (as in lowering a weight), the stretch reflex persists as long as the stretch stimulus is applied. Though the range of lengths over which muscles can contract is considerable, there is an optimal "resting length" at which a particular muscle exerts maximum tension.

It seems reasonable to suppose that one effect of the experimental procedures is to reorganize stretch reflexes in the neck and back so that more muscle fibers take part in the antigravity response, and that the muscles in contracting remain closer to their optimal resting length. This effect would account for the subjective feeling of reduced weight while maintaining a position as well as for the apparent lack of effort in movements performed against gravity.

Head-Neck Reflexes

The kinesthetic phenomenon and the change in the movement pattern cannot be explained entirely by the behavior of individual muscles. Such an explanation does not account for the major role which the head and neck appear to play in facilitating the movement, nor for the secondary changes, e.g., in breathing, reported by subjects.

In the posture of animals, it is well established that the most important mechanism of control is the head-neck relation. Magnus and his associates (Magnus, 1924; Magnus & de Kleijn, 1912; Rademaker, 1931), in a long series of carefully controlled experiments, showed that the position of an animal's head in space or its position relative to the body can affect the distribution of tonus in its neck, back, and limbs. Magnus summed up the principle by saying that in posture and movement the head leads and the body follows.

In classifying his material, Magnus used two categories—the "attitudinal reflexes" and the "righting reflexes."

The *attitudinal* reflexes with receptors in the labyrinths and in the joints of the neck (McCouch, Deering, & Ling, 1951) are used by an animal to maintain a position that is assumed for some special purpose, like that of a cat drinking from a saucer or looking up at a piece of meat held high. The position taken by the head imposes on the rest of the body an attitude which is maintained as long as it is functional. These attitudes are quite stereotyped and follow regular rules. According to Magnus, they are the most enduring and untiring of reflexes.

The *righting* reflexes take over when an animal is ready to return to the normal upright posture. The fixed position of the head is released; the imbalance of parts, registering at a postural center in the brain, initiates the righting response; as in the attitudinal reflexes, the head leads and the body follows. The mechanism is most strikingly demonstrated when a cat is held on its back in the air and then dropped. The instant it is let go it begins to right itself. The head turns first. As it turns, the tensions in the neck, back, and limbs are progressively altered. The body is twisted around, and the cat lands on its feet. (Marey's photographs of the phenomenon are reproduced by Chatfield, 1957, p. 205.)

Secondary effects of the head-neck reflexes on respiration, circulation, and eye position have also been demonstrated. In diving birds and mammals there is a highly developed set of reflexes which stops breathing and slows down the heart in order to conserve oxygen (Irving, 1939; Scholander, 1963). In ducks, this reflex is strongly reinforced by the change in the relation of head, neck, and body that takes place in diving. Huxley (1913) found that without immersing a duck in water, breathing could be stopped by bringing the head and neck into the diving position or by placing the duck on its back and dorsiflexing the head. Conversely, breathing was at once restored if the head was brought back to the normal posture. A similar postural mechanism to stop breathing and slow the heart was later demonstrated in diving mammals (Koppányi, 1929). A. de Kleijn (1920) used monkeys to demonstrate the effect of head-neck reflexes on the position of the eye in the orbit. He showed that the eyes moved down when the head was dorsiflexed and up when it was ventriflexed, and that the same shift in eye position took place when the head remained fixed and the trunk was rotated so as to bring the back closer to the occiput or the chest closer to the chin.

Head-Neck Reflexes in Man

In human beings, the influence of the head-neck reflexes is masked by patterns of voluntary activity. The mechanisms are clearly present, however. They have been frequently demonstrated in infants (Gesell, 1954; Peiper, 1963),[6] young children (Landau, 1923; Schaltenbrand, 1925), patients with neurological diseases (Simons, 1923; Walshe, 1923), and in normal adults (Hellebrandt, Schade, & Cairns, 1962; Tokizane, 1951; Wells, 1944). A large number of drawings and photographs to illustrate the patterns of head-neck reflexes as they manifest themselves in dancing, sport, and everyday activity were brought together by Fukuda (1957).

Various specific reflexes, both attitudinal and righting, have been defined in the literature. Rather than describe them in detail, I should like here to emphasize what each set of reflexes has in common. In the attitudinal reflexes, the head is drawn into a fixed position and tonus is redistributed in the trunk and limbs. In the righting reflexes, again under the influence of the head, the normal distribution of tonus is restored. These two mechanisms will account most

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[6] The secondary effect of differences in the trunk-to-head relation on the position of the eyes, which was demonstrated in monkeys by de Kleijn (1920), was demonstrated in human infants by Voss (1927).

economically for the phenomena which have been described in this paper. The sitting or standing posture of the average person functions like an "attitude" which has been imposed on the body by the head. The procedures employed in the experimental movements, by releasing the head from its habitual attitude, facilitate the righting reflexes and bring the subject into a different orientation within the gravitational field. The changes in breathing, in circulation, and in the use of the eyes, which are sometimes reported, take place automatically by reflex facilitation when the head moves into its new relationship to the trunk.

PSYCHOLOGICAL CONSIDERATIONS

I have described a mechanism by which the antigravity response can be facilitated. It is a mechanism which ordinarily operates below the level of consciousness. Magnus was emphatic that the righting reflexes are subcortical and inaccessible to direct conscious control.[7] An indirect control can be established, however, if the subject learns to recognize and inhibit maladaptive postural sets which interfere with the response of the organism to gravity.

In the course of motor learning, sets may be developed which are not the best preparation for the movement to come. They may, in fact, hamper the execution of the movement. Unfortunately, like some of the "superstitious" responses which appear during conditioning experiments, such sets do not extinguish readily. The organism adapts to them quickly; they come to "feel right"; and they remain undetected, because once the stimulus to move has been received, attention becomes focused on the goal to be reached.

One of these inappropriate sets is the tendency to shorten certain neck muscles as a preparation for a movement against gravity. It has been demonstrated that such a movement is facilitated when the preparatory shortening of muscles is prevented by the experimenter. If the subject becomes aware of the tendency, he can learn to prevent it and thus establish an indirect control over the postural mechanism. In my experience, the only satisfactory way to achieve such a control is to reorganize the field of attention, so that when a stimulus to move is received, the focus of attention remains within the organism. This does not mean that the goal is excluded from attention; it means that the goal is not allowed to dominate the field. Attention is organized around the head-trunk relation, with extension in time and space so that both the stimulus and the response can be comprised within the same field.

Ordinarily, attention is directed either outward to the environment or inward to the organism itself. The central nervous system, however, is receiving information about movements

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[7] Magnus (1925):

> It seems to be of the greatest importance that the whole central apparatus for the righting function (with the only exception of the optical righting reflexes) is placed subcortically in the brain stem and by this means withdrawn from voluntary action. The cortex cerebri evokes during ordinary life a succession of phasic movements, which tend to *disturb* the normal resting posture. The brain-stem centres will in the meantime *restore* the disturbance and bring the body back into the normal posture, so that the next cortical impulse will find the body prepared to start again [p. 349].

Magnus (1930):

> We have . . . a subcortically acting apparatus which controls and adjusts the position of our body, whether erect or recumbent, in relation to space. This unconsciously acting mechanism, by the cooperation of complicated reflexes, restores our body to the normal position whenever it is displaced [p. 103].

and positions of the body and its parts at the same time that it receives information about events in the world outside. There is no reason why the field of attention cannot be organized in the same way. In such a field, the relation of the head, neck, and trunk, kinesthetically perceived, forms the background against which events outside and inside the organism take place. Thus it is possible to perceive an object simultaneously with the organism's reaction to it, since both are comprised within the same field.

Perceptually, objects are known to vary with the psychological context in which they are perceived. A staircase, for example, is perceived differently depending on whether it is to be climbed or merely to be looked at. The difference, of course, lies within the perceiving organism. If it is a staircase to be climbed, it may elicit a postural set which is so marked that it can be detected by an outside observer. The set can be detected by the climber himself only if he reorganizes his field of attention so as to take in both the staircase and his reaction to it as he approaches and climbs it. With this shift in the focus of attention, he can perceive the cause-and-effect relation between the stimulus (the staircase) and his immediate response (the postural set). If he takes an experimental approach, he can devise a means to inhibit the set while continuing to make the specific response (climbing the stairs). In the process, the antigravity response will be facilitated in the same way as in the guided movements which were described above.

Climbing a staircase was used to illustrate a principle. Any activity—reaching for a pencil or making a speech—would have done as well. The principle of inhibition can be applied to any movement. A movement pattern is a complex whole which, for convenience, may be thought of as having two aspects or parts: a specific, goal-directed part, and a tonic or postural part, by which the integrity of the organism is maintained while the specific response is being carried out. The tonic or postural part of a movement is not ordinarily perceived. Tensional patterns which interfere with the smooth performance of movement can be perceived, however. If they are inhibited, postural tonus is redistributed, and the specific, goal-directed response becomes easier. In contrast to the ease of the facilitated movement, old ways of moving come to feel wrong, and a new sensory standard is gradually established.

In the paradigm of postural change which I have just outlined, inhibition is the basic principle. Inhibition is a term which has been used by psychologists and physiologists in a variety of meanings (Diamond, Balvin, & Diamond, 1963). I have used it here to describe a process by which a person consciously refrains from making a response which he could make if he chose. In this sense inhibition is the central function of

> a nervous system which, when it functions well, is able to exclude maladaptive conflict *without suppressing spontaneity* [Diamond et al., p. 395].

In the presence of inhibition, a stimulus should elicit only a generalized increase of alertness, leaving the organism free to respond or not respond.

The principle of inhibition, as it has been developed here, offers a new approach to the problem of behavioral change. In the close connection between inhibition and postural tonus is a mechanism which not only reveals the inner pattern of a stereotyped response but brings it under conscious control. In so doing, it greatly enlarges the area of behavior where free choice can operate.

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