

Visceral-Somatic Integration in Behavior, Cognition, and "Psychosomatic" Disease

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I. INTRODUCTION

The behavior of organisms is adapted to their internal as well as external environment. Their behavior is integrated with their own basic physiological processes (e.g., respiratory, cardiovascular, and hormonal). A major role in the integration of overt behavior with internal events is played by afferent neural activity of visceral origin, as exemplified in ingestion, excretion, copulation, and parturition. Even the timing of locomotion is coordinated with visceral (e.g., cardiac and respiratory) rhythms. In the present article, we focus on certain aspects of modulation of somatic behavior by visceral events, and the integration of visceral and somatic activity within the organism. Adequate integration of

these systems is essential to the organism's adaptation to physical and social factors in its external environment.

Traditionally, two bodily action systems have been recognized—the "voluntary" system which includes the striated muscles associated with the skeleton, and the "involuntary" system which includes the smooth muscle associated with the viscera. These two systems have also been referred to as "somatic" and "visceral," respectively. The latter is under the control of the "autonomic" nervous system, so-called because its activity is relatively autonomous of "voluntary" control. Although these two systems can operate independently of each other, they can also act in concert. This article analyzes some of the properties that emerge when the visceral and somatic systems operate in concert vs when they operate independently, and speculates on the implications for cognition and pathology. These properties are examined at several levels, starting with segmental spinal reflexes.

Local reflexes demonstrate that somatic sensory stimulation can modify local visceral motor activity, and, conversely, that visceral sensory stimulation can modify somatic motor activity. The functional significance of these basic building blocks of somatic-visceral relationships is examined, e.g., in the coordination of internal and external body muscular movements during parturition.

At a higher level of integration, such as in behavioral patterns that involve precise timing and coordination of the entire body, multiple visceral and somatic systems act in concert, e.g., when locomotor activity is coupled with cardiovascular and respiratory activity. The reflexive and central coordination of these systems is discussed and related to rhythmical activity of the brain.

Following the discussion of visceral-somatic integration in terms of motor function, this integration is then considered in terms of sensory and cognitive function. Changes in sensory threshold and perceptual effects that occur in relation to visceral activity (e.g., phasic changes of ideational imagery in relation to the cardiac cycle) are reviewed. Evidence that visceral sensory activity exerts cognitive effects is presented, based upon dream content in relation to visceral disease, and literal metaphors derived from bodily sensations (e.g., "nausea," "catching one's breath").

Finally, coordination of visceral and somatic activity is examined in symbolic expression (e.g., change in blood flow to the limbs in association with inhibition against using the limbs). The speculation is made that certain forms of somatic or visceral psychogenic pathology may be understood in terms of the metaphoric "use" of specific bodily activity. The viscera may react in the absence of concomitant somatic action, and the viscera may, through their activity, provide afferent stimulation under conditions of suboptimal somatic sensory stimulation. According to this view, an understanding of pathological aspects of visceral-somatic relationships can be aided by an understanding of the principles of visceral-somatic coordination at various levels, from reflexive to cognitive.

II. VISCERAL-SOMATIC RELATIONSHIPS

In this section we shall be concerned only with reflexes that pass *between* visceral and somatic systems, not those that occur only *within* either visceral or somatic systems. Thus, we will not consider visceral-visceral reflexes, such as peristalsis in response to gut distention, or somatic-somatic reflexes, such as the stretch reflex. We will consider somatic-visceral reflexes, i.e., those with somatic afferents and visceral efferents, and visceral-somatic reflexes, i.e., those with visceral afferents and somatic efferents.

A. SOMATOVISCERAL REFLEXES

Somatic stimulation in the form of maternal licking of the pups' anogenital or rump skin elicits the visceral responses of urinary and defecatory emptying. In rats and guinea pigs, this stimulation is essential for the survival of the young, since their endogenous visceral emptying reflexes are not operational at birth (Beach, 1966; Harper, 1972; Boling *et al.*, 1939). In adult rats, the bladder-emptying response to tactile stimulation of the anogenital skin is considered to be a spinal reflex, on the basis that it can be elicited after mid-thoracic spinal transection in adult rats (Sato, 1975).

Somatic stimulation may also elicit a vascular response. Thermal (cold) stimulation of the lower thoracic skin elicits ischemia in the duodenum and lower intestine, corresponding to the segmental level of the skin that is stimulated (Kuntz and Haselwood, 1940; Kuntz, 1945; Richins and Brizzee, 1949). A spinally mediated vascular response (dilatation) in response to somatic stimulation also occurs in the case of penile erection, resulting from stimulation of the penile skin in spinal-transected rats and dogs (see review, Hart, 1978).

In spinal-transected dogs at least 30 days postoperative, the visceral responses of erection and ejaculation of seminal fluid can be elicited by mechanical stimulation of the penile shaft. Furthermore, detumescence can be elicited in these dogs by stimulation of the glans penis. These responses are therefore somatovisceral reflexes that are organized at the spinal level. It is particularly interesting that the duration of penile engorgement is reduced by withdrawal of androgen treatment in spinal dogs, suggesting the possibility of spinal androgen sensitivity and/or peripheral androgenic effects on the target motor and sensory systems (Hart, 1978).

Somatovisceral reflexes are mediated in part at the spinal level by the sympathetic and parasympathetic divisions of the autonomic nervous system. A role of the sympathetic division was shown in the rat by the observation that noxious electrical stimulation of the thoracic skin increased the heart rate after spinal transection at the cervical level, and noxious electrical stimulation of the abdominal skin decreased gastric motility after spinal cord destruction at levels T5-T11

(Sato, 1975). This noxious cutaneous stimulation increased the firing activity in the splanchnic (sympathetic) but not the vagus (parasympathetic) nerves, and the gastric response was abolished by destruction of the splanchnic nerves (Sato, 1975). The parasympathetic division also mediates somatovisceral reflexes at the spinal level: gentle tactile stimulation of the perineal skin induced urinary bladder contractions, such as those involved in the emptying response, and increased firing activity in the pelvic (parasympathetic) but not hypogastric (sympathetic) nerves which innervate the bladder, after spinal transection at C2 in the rat (Sato, 1975).

B. VISCEROSOMATIC REFLEXES

Sensory stimulation originating in the viscera can modify somatic motor activity. This activity can be viewed in general form as postural adjustment to visceral distention, such as leg and trunk extension during voiding and parturition. Mechanical stimulation of the vagina, cervix, or rectum elicits leg extension, and blocks the leg-withdrawal response to noxious stimulation of the foot in rats in which the spinal cord has been transected at the mid-thoracic level (Komisaruk and Larsson, 1971). Electrical stimulation of the pelvic nerve, which provides afferent innervation of the urinary bladder, rectum, and genital tract (Komisaruk *et al.*, 1972), induces combined relaxation of the muscles of the perineum and contraction of the striated muscles of the abdomen and diaphragm (Kuru, 1965). This adaptive "pelvico-perineo-abdominal reflex" is utilized in urination and defecation, and is also active during parturition. Additional examples of local viscerosomatic reflexes are represented in the following cases, although their function in natural contexts is not known. Compression of the fallopian tube induces contraction of the paravertebral striated muscles in rabbits (Eble, 1960). Distention of the uterine horn, urinary bladder, or rectum inhibits polysynaptic reflexes of the hind limb in cats (Evans and McPherson, 1958). Polysynaptic reflex responses of the hind leg are suppressed during spontaneous contractions of the urinary bladder (McPherson, 1966). Stimulation of the pelvic or splanchnic nerves, or sympathetic chain inhibits polysynaptic reflexes of the hind leg (Evans and McPherson, 1960).

Pathologically, somatic muscular spasm occurs in response to visceral irritation, at the same segmental levels, e.g., in spasm of the lower abdominal muscles occurring in appendicitis, or of the thoracic muscles in tuberculosis (Ruch, 1961).

In addition to the local segmental responses described above, multisegmental somatic responses to visceral afferent stimulation also occur. One example is the lordosis mating stance of the female rat, which involves elevation of the head and rump and depression of the lumbar area. In estrous females, this posture is elicited by mechanical stimulation of the skin of the flanks and perigenital re-

gion, but it fails to occur to this stimulation in nonestrogenized females (Komisaruk and Diakow, 1973; Kow *et al.*, 1979). Vaginal or rectal mechanical stimulation added to the skin stimulation increases the lordosis intensity in estrogenized females. This visceral stimulation can facilitate lordosis even in nonestrogenized females. Vaginal or rectal stimulation without skin stimulation does not elicit lordosis (Komisaruk and Diakow, 1973). It is not known which sensory endings mediate this response. However, the vaginal epithelium is at least in part of entodermal origin (although the anal epithelium is of ectodermal origin) (Arey, 1954), and the stretch receptors of the vaginal and rectal smooth muscle are probably activated by the adequate stimulus; hence, this reflex is provisionally considered to be visceral-somatic rather than somatic-somatic. A long-lasting somatic effect of this visceral stimulus has been described. In ovariectomized rats in which perigenital skin stimulation initially does not elicit lordosis, brief (2-sec) vaginal stimulation enables subsequent perigenital skin stimulation to elicit lordosis, an effect that begins immediately and persists for 2-3 hr after the single application of the brief vaginal stimulation (Rodriguez-Sierra *et al.*, 1975).

Other examples of multisegmental somatic effects of visceral stimulation are as follows. A posture in neonatal rats which strongly resembles lordosis is elicited by milk entering the throat as pups suckle (Drewett *et al.*, 1974; Hall and Rosenblatt, 1977; Martin and Alberts, 1979). Characteristic extensor postures occur during defecation and urination in cats (Hess, 1954) and parturition in *Antilocapra* (Müller-Schwarze, 1974), probably in response to visceral distention. And in pigeons, an effect has been described that is dependent on afferent activity generated in spinal afferents by movement of the viscera as the axis of the body shifts (Delius and Vollrath, 1973). In response to passive body tilt or rotation, pigeons show postural compensatory reflexes of the wings, tail, and neck even after labyrinthectomy (Biederman-Thorson and Thorson, 1973). The former authors suggest that this visceral afferent postural control mechanism provides an initial rapid, albeit gross, compensation before the slower vestibular reflexes come into play to provide the fine correction for passive body rotations. Diakow (1978) has shown that intraabdominal pressure affects behavior in female frogs. If a nonreceptive female is clasped by a male, she emits a "release call," but this call is inhibited in receptive females, in which there is a developed egg mass, thereby facilitating oviposition and spawning. Intraabdominal distention produced normally by vasotocin-induced fluid accumulation, or artificially by injection of fluid or inflation of an implanted balloon, inhibits this release call.

C. NEUROENDOCRINE REFLEXES

There is another class of smooth (nonskeletal) muscle response to afferent somatic stimulation—it comprises responses that are mediated by the endocrine

system. The milk-ejection reflex is a somatovisceral reflex in which the effector is activated indirectly via the systemic circulation, rather than directly via efferent neurons. In this reflex, in response to suckling stimulation, the posterior lobe of the pituitary gland releases oxytocin into the systemic circulation (Cross, 1959). The oxytocin stimulates contractions of the smooth muscle myoepithelium of the mammary gland, thereby ejecting the milk into the mammary ducts from which it is expelled into the nursing young (Zaks, 1958). A related example is stimulation of uterine smooth muscle by oxytocin released reflexively in response to nuzzling of the genital skin in cattle (Vandemark and Hays, 1952). (For further discussion, see Komisaruk *et al.*, 1981.) A similar type of somatovisceral response mediated by the neuroendocrine system is the increase in cardiac output and rate in response to epinephrine and norepinephrine which are released into the systemic circulation from the adrenal medulla following noxious somatic stimulation (see Koizumi and Brooks, 1974, for review).

III. HIGHER ORDER INTEGRATION OF VISCERAL AND SOMATIC ACTIVITY

A. INTEGRATION VIA COUPLING OF ACTIVITY CYCLES

Higher order integration of visceral and somatic activity is exemplified by the coupling among locomotor, respiratory, and cardiac activity cycles. In this section, the occurrence, possible underlying mechanisms, and possible adaptive significance of such integration are presented.

Bechbache and Duffin (1977) showed that during exercise in humans, the respiration cycle becomes entrained to the locomotion cycle. Volunteers were instructed to pedal on a bicycle ergometer, timing their leg movements to a metronome at 50 cycles per minute. When their respiration rate was recorded, it was found that respiration rate was entrained to the pedaling rhythm in 53% of 15 individuals. That is, they showed one respiratory cycle per pedal revolution. When the individuals were instructed to run on a motorized treadmill at a comfortable speed, the proportion showing entrainment of respiration to leg movement was even greater (80% of 15 individuals). The oxygen uptake in 6 of 8 subjects who showed respiratory-locomotor entrainment on the bicycle ergometer was lower (i.e., oxygen was used more efficiently) than predicted independently of entrainment. Therefore, a natural tendency exists to couple respiration with the locomotor cycle; this increases the efficiency of oxygen utilization (Bechbache and Duffin, 1977), which in turn increases stamina in locomotion. This appears to be an expression of a biological "Conservation of Energy Law" (Ralston, 1976) which states: "In freely chosen rate of activity, a rate is chosen

that represents minimal energy expenditure per unit task." Ralston's law is based on his findings that a person in a natural walk tends to adopt a speed close to that of minimal energy expenditure per unit distance walked. These findings taken together suggest that a locomotor speed is most comfortable and energy efficient when the timing of the locomotion cycle coincides with that of the respiratory cycle. It would be of interest to determine the range of locomotor and respiratory frequencies over which this relationship holds.

The cardiac cycle can become entrained to the respiration-locomotion cycle. Pessenhofer and Kenner (1975) showed that there is a marked tendency for individual respiratory movements to start at a constant phase of the cardiac cycle, in humans. The evolutionary origin of respiratory-cardiac entrainment may be found in a primitive vertebrate—the dogfish shark, in which the timing of the heart beat is synchronized with the gulping contraction of the jaw muscles, which send surges of oxygenated water across the gill surfaces. There is usually one respiratory beat for each heartbeat (Satchell, 1968). The significance of this process is that as the oxygenated water surges across the gill surfaces, the blood surges through the gills, thereby optimizing the exchange of gases.

One function of the coupling of cardiac, respiratory, and locomotor cycles may be to enable optimal efficiency of energy exchange among these systems, thereby maximizing stamina and strength. Furthermore, since such coupling exists in sharks and humans, it is likely to be phylogenetically widespread.

B. NEURAL MECHANISMS OF VISCERAL-SOMATIC INTEGRATION UNDERLYING CARDIOVASCULAR, RESPIRATORY, AND LOCOMOTOR ACTIVITY

1. *Reflexive Mechanisms*

Let us examine some of the ways in which visceral-somatic integration occurs in the cardiac, respiratory, and locomotor systems. Spinal motor neurons (at the lumbosacral level) fire in a phase-coupled relationship with respiration in decorticate cats (Frankstein *et al.*, 1974), demonstrating a fundamental linkage between locomotion and respiration. With each respiratory cycle, bursts of neuronal discharges are recorded in the sympathetic nerve bundles innervating the leg in humans (Hagbarth and Vallbo, 1968) and also in the splanchnic nerves in cats (Preiss *et al.*, 1975; Gootman *et al.*, 1975). Furthermore, the timing of blood pressure rises and falls coincides with that of the respiratory cycle in lightly anesthetized cats (Borgdorff, 1975). This coupling could provide rhythmical modulation of blood flow to the limbs. Particularly when the locomotion cycle is coupled with the respiratory cycle (Bechbach and Duffin, 1977), it could maximize the efficiency of delivery of blood to the muscles of locomotion.

Coupling of these visceral and somatic activity cycles depends, at least in part, upon reflexive peripheral feedback mechanisms. Several reflexive mechanisms which utilize musculoskeletal body movements (Shepherd and Vanhoutte, 1979) are involved in cardiac-respiratory-locomotor entrainment. First, in the "respiratory sinus arrhythmia" reflex, deep inspiration stimulates sympathetic fibers and inhibits vagal inhibitory fibers to the heart, thereby quickening the heartbeat and coupling its rhythm to that of the respiratory cycle (Porges *et al.*, 1980). Second, deep inspiration also produces a negative pressure in the thoracic cavity relative to the peripheral circulation. This suction forces the blood back to the heart in a surge, thereby abruptly stimulating the mechanoreceptors at the venal-atrial junction, and quickening the heartbeat via the cardioacceleratory system in the medulla. This respiration-linked cyclical heart stimulation could also help to entrain the cardiac cycle to the respiratory cycle. Third, a "muscle pump" effect exists in which rhythmical muscular contractions occurring in locomotion force blood back into the venous system, thereby rhythmically activating the mechanoreceptors at the venal-atrial junction. These reflexes phasically increase heart stroke volume in response to returning blood flow (Shepherd and Vanhoutte, 1979), which surges in time with rhythmical locomotor and respiratory movements. They provide an entraining rhythm to the heart, which adjusts its rate, timing, and stroke volume to the changing demand of the peripheral musculature.

Another component of the neuromuscular system which regulates cyclical blood flow to the skeletal muscles is afferent activity generated by muscular contraction, such as that which could occur during walking. Coote (1975) found that, in cats, muscular contraction (generated by electrical stimulation of the lumbosacral ventral roots) was followed by increases in arterial blood pressure, heart rate, and pulmonary ventilation, but these effects were abolished when the muscle afferent activity was blocked by cutting the dorsal roots or by blocking muscle contraction with gallamine. Rhythmical muscular contraction utilizing this reflex in locomotion would therefore tend to entrain these systems to its rhythm.

The reflexive relationships among the systems reviewed above facilitate the phase-coupling of their activity cycles. This may serve to optimize the efficiency of energy exchange among the systems, thereby optimizing the organism's strength and stamina. This optimal condition may represent the simplest relationship among the cardiovascular, respiratory, and locomotor systems. That is, in the state of synchrony among these activity cycles, the variability in their timing is minimized, i.e., their relationship is least differentiated, and this may be the most "primitive" and efficient way in which they operate. This may be virtually the only way in which the most primitive vertebrates (e.g., shark) function (hence, by necessity, the most efficient means of functioning), and also the most efficient means of functioning in higher vertebrates.

2. *Central Mechanisms: The Role of Brain Rhythms in Visceral-Somatic Coordination*

Coordination of respiratory, cardiovascular, and motor systems is also based upon the phasic entrainment of their activity cycles to delta-theta, and alpha EEG rhythms of the brain. The following studies describe phasic correlations between brain rhythms and bodily activity rhythms. Langhorst *et al.* (1975) found that medullary reticular formation neurons that respond to stimulation of the aortic baroreceptors, by rapid phasic increases in blood pressure, fire in phasic relation with the theta-delta rhythm in chloralose-urethane anesthetized cats. Similarly, during exploratory sniffing behavior in rats, cardiac and respiratory cycles (including muscular contraction cycles of the face, neck, and thorax), and respiratory cycles in hamsters (Macrides, 1975), are coupled with theta waves recorded as hippocampal and/or hypothalamic EEG, at a frequency centered near 7 Hz (Komisaruk, 1970, 1977).

In humans, the cardiac cycle can also become phase-coupled with the alpha rhythm (Callaway and Buchsbaum, 1965; Birren *et al.*, 1963; Buchsbaum and Callaway, 1965; Callaway and Layne, 1964; Callaway, 1965). Therefore, the three major rhythmical brain systems (lower brain stem: delta; limbic system: theta; thalamocortical: alpha) can be phase-coupled to the cardiac cycle.

We can speculate that different kinds of motor activities are entrained to brain rhythms of different rates. Perhaps rapid-movement rhythmical muscular systems are coupled primarily with the high frequency brain systems (e.g., thalamoneocortical alpha rhythm; 8–12 Hz, related to physiological finger tremor (Jasper and Andrews, 1938) and eye saccades (Gaardner *et al.*, 1966), whereas slower-movement, rhythmical muscular systems (respiratory, cardiovascular, locomotor) are coupled primarily with lower frequency brain rhythms [e.g., limbic system theta rhythm (3–8 Hz) and lower brain stem delta rhythm (less than 1–3 Hz)]. One form of integration among the systems that could occur is that in which a rapid movement is timed to occur at an optimal moment during a slower movement (e.g., the respiratory, hand, and arm movements involved in throwing a curve ball or cracking a whip).

It is tempting to speculate that when brain rhythms overlap in frequency (e.g., the low end of the alpha rhythm range and the upper end of the theta rhythm range overlap at 8 Hz) they share coupling with the neuromuscular systems that may ordinarily be coupled with only one of the brain rhythms when it is active at a different rate. This may be involved in the establishment of fine control over large-mass systems, e.g., eye-finger precision of movement brought to bear on trunk and leg orientation as in dancing and athletics.

Thus far we have focused on the performance aspects of visceral-somatic integration, noting that respiration, cardiovascular, and locomotor activities are interrelated at spinal and supraspinal levels of the central nervous system. This

integration is based in part upon afferent stimuli which provide feedback information that coordinates the activity. The temporal patterning of this activity suggests that somatic movement is adapted to, and integrated with, the cardiovascular and respiratory supply systems and with the visceral components of the movements, as in mating, parturition, defecation, and urination. The rates and rhythms of movements, the segmental level of a movement, the muscles employed in the movement, and the duration of the movement may be understood in terms of the underlying visceral process with which they are neurally integrated, and to which they are functionally related. Evidence in humans will be presented that we sense the various kinds of somatic-visceral integrations, assess their "quality," and utilize this perception in our behavior and language.

C. PERCEPTUAL-MOTOR ASPECTS OF VISCERAL-SOMATIC INTEGRATION: RESPONSES TO EXTEROCEPTIVE STIMULATION

Visceral-somatic integration operates in two directions: in one direction it incorporates internal sources of stimulation, as discussed earlier. In the other, discussed in the present section, it deals with exteroceptive stimulation and adapts the organism's behavior to its external environment. Over the past decade it has become clear that sensory input is regulated by brain processes that exhibit wave-forms. Thus continuous sensory stimulation at the periphery may be "gated" to affect behavior only at certain times, in relation to the brain wave activity with which the stimulation interacts (Komisaruk, 1977). We have seen that these wave patterns of neural activity are related to visceral-somatic integration. Let us now examine ways in which these may be involved in exteroceptive perception and in the timing of motor responses.

In the following section, evidence is reviewed that when visceral and somatic activity cycles become coupled with each other, they may jointly or singly become entrained to brain rhythms; consequently, perceptual sensitivity and motor activity fluctuate in time with these rhythms. When coupling of these systems occurs, it is likely that unique perceptual and motor properties emerge.

The existence of entrainment of neuromuscular excitation cycles to brain rhythms implies that the activity (e.g., excitation level, responsivity) of the neuromuscular systems and their associated sensory input does not remain constant, but instead varies over time. There is extensive evidence that brain rhythms do in fact represent fluctuating levels of sensory and neuromuscular excitability. Evidence for this has been presented in an analysis of sniffing in the rat.

In the rhythmical oscillatory pattern of the rat's exploratory sniffing behavior, the vibrissae are whisked to and fro in synchrony with discrete rhythmical sniffs, head-neck-thorax movements, and individual theta waves. This sequence can be viewed as a chain of individual cycles during each of which the state of excitation of limbic system neurons and the associated neuromuscular system varies cycli-

cally over time. This suggests that there may exist specifiable phases of the cycle during which perceptual processes associated with the movements can be performed optimally. In other words, the underlying neural system may perform different operations (i.e., sensory and motor) at specific phases of the cycle (Komisaruk, 1977).

It was these considerations that led us to predict that in rats a self-initiated act (e.g., a lever press which delivers a food pellet) would be initiated nonrandomly in time and in phasic relation to an individual theta cycle. In a test of this hypothesis (Semba and Komisaruk, 1978) we found that, indeed, bar *presses* were most likely to occur at wave peaks during the theta cycle (recorded as, hippocampal EEG), whereas bar *releases* were most likely to occur at theta-wave valleys. The difference in the behavioral movements involved in pressing vs releasing the bar suggests that the flexor and extensor forelimb systems are preferentially activated at different phases of the theta cycle.

A "gating" effect related to the theta cycle was also observed by Buzsaki *et al.* (1982) who found that the amplitude of evoked potentials recorded in the dentate gyrus of the hippocampus, which were generated by electrical stimulation of the perforant path, was greater when the stimulus was delivered during the negative-going phase of the theta wave cycle than during the positive-going phase. It is not known whether this effect is more closely related to sensory or motor systems.

The theta cycle is not unique in its relationship to sensorimotor excitability cycles; the higher frequency alpha cycle and lower frequency cardiac cycle have been shown to be related phasically to cycles of visual and auditory sensitivity and reaction time. For example, the subjective intensity of a constant-intensity light flash varied as a function of the phase of the alpha wave during which the flash was presented (Callaway, 1965). Using a different approach, Harter and White (1967) showed that there was a marked tendency for a light flashing at 33.3 times per second to be perceived as flashing only as many times as the cortical alpha wave (10 Hz) peaked during the flash train. That is, when a train of three flashes occurred during which only one alpha wave peak occurred, the subjects reported that only one flash had occurred. When a train of six flashes was presented, only two flashes were reported (only two alpha peaks had occurred). Thus, the alpha wave apparently modulates or "gates" the visual input cyclically.

In related experiments, the galvanic skin response was measured when the word "danger" was presented, and the magnitude of the response varied as a function of the phase of the alpha-rhythm cycle during which the word was presented (Nunn and Osselson, 1974). The authors concluded: "it seems likely that the alpha rhythm is indeed a correlate of the activity of a 'neuronic shutter' which periodically prevents the reception or processing of visual information by the cortex." Similarly, the probability of eye opening in response to an auditory

stimulus varied in relation to the phase of the alpha rhythm (Boreham *et al.*, 1949). The amplitude of the visual evoked cortical response has been shown to vary as a function of the phase of the alpha rhythm at which the light flash occurs (Callaway and Layne, 1964; Remond and Lesevre, 1967).

Muscular movements have also been shown to occur in phasic relation to the alpha wave. Thus, Jasper and Andrews (1938) found that normal physiological tremor of the fingers is at times synchronized with the alpha rhythm recorded from the motor cortex. In rats, tremor of the vibrissae and jaw at a frequency of approximately 10 Hz occurs normally when the rats are crouched and showing no gross motor activity. These movements are precisely coupled with individual waves of a characteristic neocortical alpha rhythm and with bursts of thalamic neuronal activity (Semba *et al.*, 1980). The tremor activity can in most cases be abolished by surgical ablation of the contralateral sensorimotor cortex (Semba and Komisaruk, submitted for publication).

In humans, saccadic eye fixations are phase-locked with the alpha wave cycle (Gaardner *et al.*, 1966). These authors suggested that "each saccade results in a packet of information being presented for storage . . . a single alpha component cycle may reflect a basic unit of storage." This is of particular interest when considered in conjunction with the findings of Lansing (1957), who showed that reaction time measured as a finger response to a flash of light presented at various phases of the alpha-wave cycle was shortest at a particular phase of the cycle. That is, the neuromuscular actions involving eye fixation, visual perception, and behavioral response may be performed in basic units, rather than continuously, like individual "stills" of a motion picture.

Sensorimotor modulation occurs in phasic relation to cardiac cycles as well as brain rhythms. Reaction times are longer during the heart systole than during the diastole (Birren *et al.*, 1963; Callaway and Layne, 1964). This was suggested as being due to response inhibition generated by the pulsatile increase in blood pressure during systole, since a similar slowing of reaction time during systole was reported in patients with transistorized pacemakers (Callaway and Layne, 1964). As an example of another visceral-somatic pacing mechanism, Pesenhoffer and Kenner (1975) showed that there is a marked tendency for inspiratory movements to start at a constant phase of the cardiac cycle. An analysis of this phenomenon, described later, indicates that this effect may be related to motor inhibition induced by increased afferent activity from the baroreceptors and lung afferents.

In dogs, Heymans (cited in Liljestrang, 1965) separated the circulation of the head from that of the trunk, but left the vagus and aortic nerves intact. Administration of adrenaline to the trunk increased the blood pressure, and inhibited facial motor activity that was associated with respiratory movements. In addition, expansion of the lungs inhibited facial respiratory movements. Both inhibitory effects were abolished by cutting the vagus and aortic nerves. These

studies demonstrate that afferent impulses from stretch receptors in the lungs and chemo- and/or baroreceptors in the cardioaortic vascular area can inhibit motor activity of the face.

The studies described above suggest a neurological basis for the coupled activity of cardiovascular, respiratory, autonomic, and musculoskeletal systems. This mode of activity can be viewed as a relatively undifferentiated and, hence, primitive condition. When it occurs, certain properties emerge, which are probably perceived as "peak experiences." Lowen has expressed some of the properties of such integrated visceral-somatic activity as follows:

The body's involuntary movements are the essence of its life. The beat of the heart, the cycle of respiration, the peristaltic movements of the intestines—all are involuntary actions. But even on the total body level, these involuntary movements are the most meaningful! We convulse with laughter, cry for pain or sorrow, tremble with anger, jump for joy, leap with excitement and smile with pleasure. Because these are spontaneous, un-willed or involuntary actions, they *move* us in a deep, meaningful way. And most fulfilling, most satisfying and most meaningful of these involuntary responses is the orgasm in which the pelvis moves spontaneously and the whole body convulses with ecstasy of release (Lowen, 1976, p. 244).

The following section examines some other cognitive aspects of integrated visceral-somatic activity.

D. SUBJECTIVE ASPECTS OF VISCERAL-SOMATIC INTEGRATION

Not all of the manifestations of visceral-somatic integration have been measured objectively as yet, but humans are apparently finely tuned subjectively to sensations of comfort and discomfort during locomotion, to the sensations which accompany great effort or relative ease in movement, to the pressures arising from contact between internal organs and from blood engorgement of the extremities, as well as to many other internally based sensations. Humans make use of these sensations to adjust their movements, their posture, and their effort to minimize discomfort, and also to maximize the force of their actions when this is required. In this section I shall discuss the visceral-somatic integrations in humans that underlie the subjective sensations of comfort and discomfort, forcefulness or lack of force, ease or difficulty in movement, and the sense of harmony or its absence during activity.

During locomotion, the thorax, shoulders, and arm form a subsystem whose components are jointed mechanically such that swinging the arms outward and upward forces the rib cage to increase its internal volume. Conversely, during locomotion, expanding the thorax from within can be felt mechanically to lift the shoulders and arms outward and upward, against gravity. The activity rhythm of this subsystem is synchronized with that of the legs in comfortable, energy-

efficient locomotion (Bechbache and Duffin, 1977). This is a form of structural resonance: the arms help the thorax to move, that inertia helps the legs to swing, and inertia of the legs in turn helps the arms to swing. Thus, when the limbs and thorax are in resonance, whole-body forward momentum is increased, thereby mechanically increasing the speed of locomotion.

When running at a comfortable gait, the lung expansion-contraction cycle can be adjusted to the limb cycle and this respiration cycle duration can be adjusted, in turn, to the heartbeat cycle. When such coupling is achieved, a minimum of pressure is felt at the boundary between the expanding-contracting heart and lungs (which are contiguous with each other) within the thoracic cavity. If the coupled activity is suddenly disrupted, physical clashing is felt at the boundaries between lungs and heart, which is reduced again if coupling is reestablished.

During locomotion, as the arms move back and forth, pulse pressure, felt at the fingertips, is increased by the mechanical pumping action of the arms casting the blood toward the periphery. If the phases of arm movement and heartbeat are adjusted such that this pulse pressure is minimized in the fingertips, a feeling of ease of arm movement results. In other words, when the forward thrust of the arm is timed to coincide with the time of the surge of blood to the fingertips, there is a feeling of minimal pulse pressure at the fingertips and, consequently, minimal effort of arm motion. Coleman (1921) made the following interesting observation: "One who always became breathless when halfway up a hill felt his pulse and began the climb breathing and stepping in unison with the pulse and climbed the hill without breathlessness, and the rise in blood pressure was only half as great." A one-to-one correspondence between heartbeats and leg kicks has also been described in diving tufted ducks during the underwater descent and ascent phases of the dive (P. Butler and T. Woakes, cited in MacDonald and Amlaner, 1981). This is likely to be a situation in which energy utilization is of necessity highly efficient, and thereby indicates the adaptive significance of this coordination pattern.

Schlant (1978) noted the mechanical effect of musculoskeletal activity on cardiovascular activity: the lungs expand to fill the increased volume of the thorax as it expands while the diaphragm contracts synchronously. Inspiration and expansion of the lungs exerts a compressive force against the heart, which is surrounded by, and in contact with, the lungs. Hence, there is a mechanical advantage of having limb, trunk, respiration, and cardiovascular cycles the same length and phase-coupled. This pumping action varies the filling rate of the heart and the blood pressure, thereby cyclically modulating neural reflex activity via mechano- and baroreceptors, thus influencing atrial and ventricular contractility and vasomotor tone via the autonomic nervous system (Schlant, 1978; Shepherd and Vanhoutte, 1979). We may speculate that the sense of ease of movement corresponds, therefore, to a state of synchrony among the activity cycles of the respiratory, cardiovascular, and locomotor systems.

1. *Linguistic, Interpersonal, and Aesthetic Expressions of Visceral-Somatic Rhythmic Integration*

Visceral-somatic sensations and their rhythms permeate our linguistic, interpersonal, and aesthetic expressions as the reference for temporally ordering our activities. In music, the sense of timing (i.e., "tactus," literally "time beating") was originally based on the natural rhythm of the pulse, rather than an absolute external standard (Sachs, 1948). The interval between pulse beats during quiet respiration was used to define the duration of the semibreve (i.e., whole note). Natural rhythms of movement occur in a variety of contexts in humans in relation to biological rhythms. Lourie (1949) claims that in a pediatric clinic population, 15–20% of 130 children showed rhythmical body movements. Furthermore, "In the great majority of the children who rock, roll, bang, or sway the pacemaker is the heartbeat.... In a minority of the children in this series the pacemaker is the breathing rate" (p. 657).

Byers (1979), on the basis of cinegraphic analysis, has found that people in small groups perform gestural movements toward each other in what appears to be a common rhythm, the intermovement interval of which is approximately 0.4 sec. He states, "This duration of 0.4 sec is the same (recognizing that 'same' embraces a small range of possible variation) as that of the military march rate, is half that of the accepted heart rate at rest, and is equivalent to four cycles of the familiar "alpha" rhythm of encephalography." Byers (1977) further points out "some form of this synchronizing process is used everywhere in the world. It is familiar in church ceremonies, cheerleading at sports events, rock concerts, dances."

Perhaps the cycles of systole-diastole, adduction-abduction, and inspiration-expiration provide a body-based sensory input which underlies our concepts of the beginning, duration, and end of movements, i.e., phrasing. The modulation of expenditure of effort in relation to time during each such movement cycle or phrase provides "expression" in the musical sense (Byers, 1977, 1979). With regard to expression in the motoric sense, Clynes (1979) points out

An expressive movement is an entity in time; it has a beginning, middle, and end. The first step in studying such entities is to realize that it takes a certain amount of time to execute an expression of joy, of anger, of sadness, of love and so on, and these times differ for different emotions...we have called these elemental chunks of entities of expression *essentic forms*...the expressive quality is recognized from the dynamic contour of the motion, rather than the particular part of the body used.

Clynes (1979) has shown that when human subjects press a pressure transducer on hearing a click, expressing the quality of anger, hate, love, etc. as precisely as they can with single, expressive pressure actions, the change in pressure over time generates, on a polygraph, "sentic forms" which differ markedly from each other in characteristic ways. For example, the sentic form for "hate" has a more

abrupt onset than that for "love." Biological movement cycles of exertion and relaxation (e.g., cardiac, respiratory, locomotor) may therefore provide the basic building blocks out of which more complex behavior patterns (e.g., vocalization, gesturing) are differentiated, the more primitive biological rhythmicity nevertheless being retained.

2. *Physiological Consequences of Rhythmic Visceral-Somatic Activity*

Rhythmical repetition of somatic sensory stimulation in the genital system leads to an increase in the intensity of visceral and somatic muscular contraction leading to an efferent excitation peak, i.e., orgasm. In mammalian male orgasm, there is a sudden surpassing of the contraction threshold of the visceral muscles of the seminal vesicles and prostate, thereby producing ejaculation (Monnier, 1968). Perhaps it is the intense but nonaversive sensory input generated by synchronous, peak visceral and somatic muscular contraction in genital orgasm that is perceived as intensely pleasurable. The "organ pleasure" that occurs in the performance of sucking and retention of excreta in addition to genital stimulation (Freud, 1924) may be based at least in part upon this property of afferent visceral-somatic excitation.

The orgasmic process as described above need not be restricted to the genital system. Indeed, sensations with orgasmic qualities have been described to occur during breathing (Scott, 1948), crying (Hite, 1976), and vomiting (Dodson, 1974). A sneeze may be described as a respiratory orgasm. Masters and Johnson (1979) claim that "the total body is a potentially erotic organ... There can be back-of-the-neck orgasm, bottom-of-the-foot orgasm and palm-of-the-hand orgasms" (p. 110). Genital orgasmic response has been described in response to breast stimulation alone (Masters and Johnson, 1979), and to other forms of nongenital stimulation (Hollander, 1981). A similar statement was made in popular literature: "It is possible to generate an orgasm at any spot on the human body" (Alther, 1974, p. 43).

We may speculate that orgasm is generated by a process of increasingly synchronous afferent discharge (at least in part generated by muscular contraction) which generates a peak of sensory excitation. Synchrony of discharge among different systems implies undifferentiated activity, i.e., unity among otherwise differentiated elements. Hypersynchrony is characteristic of epileptiform seizure discharges in the EEG, and reports of pleasurable sensations occurring during epileptic seizures, sometimes bordering on orgasm, have been described (Myslobodsky, 1976).

The following analogy may be considered to be a model of orgasm which depicts the relationships among rhythmicity, synchronicity, and intensity of excitation. At times, in a noisy sports stadium, some individuals start clapping in a slow steady rhythm, then others join them (i.e., are "recruited") in the same

rhythm, and there develops a steadily increasing contrast between peaks and valleys of sound intensity. Thus, a relatively undifferentiated (i.e., simple, "primitive") synchronized pattern of alternating bursts of sounds and silences emerges out of a more differentiated (i.e., complex) continuous din, reaching a climax of intensity. In orgasm, perhaps the activity cycles of somatic and visceral systems are entrained by rhythmical stimulation, peak efferent activity generates undifferentiated peak afferent stimulation, and at a cognitive level this is described as intensely pleasurable.

IV. VISCERAL ACTIVITY AND IDEATIONAL IMAGERY

The findings we have reviewed concerning the integration of cardiovascular activity, respiration, and somatic motor activity have subjective counterparts in feelings of well-being, comfort, ease of movement, or the opposites of these. Highly specific ideational imagery has also been reported to be related to visceral activity.

A. IDEATIONAL IMAGERY ASSOCIATED WITH THE CARDIAC CYCLE

An individual using marijuana has been described (see Komisaruk, 1977) in whom visceral, visual, and somatic imagery fluctuated in synchrony with the heartbeat. The individual described an experience that was as if one were suddenly thrown high into the sky, soaring like a bird, looking down, feeling warm, light, yellow, free, limbs extended, strong, good, and hearing a high-pitched ringing hum; then suddenly being plunged deep down into a small, cramped, blue-black dark hole, hearing a low-pitched hum, feeling cold, terrified, and minuscule in size and importance. Then the upsurge occurred again, followed by the plunge; up and down, over and over again in a steady rhythm which was precisely that of the heartbeat.

This kind of "synesthesia," e.g., between a sense of bodily motion and visual image, may be based in part upon specific neuronal circuitry. For example, Dauntton and Thomsen (1976) have shown that in cats suspended in a harness, neurons in the vestibular nucleus that respond to linear acceleration of the cat in a given direction also respond to a visual stimulus which simulates actual movement of the cat in the same direction: a cell excited by movement of the cat to the left was also excited by movement of the visual stimulus to the right.

Perceptions similar to those described earlier were reported by Castaneda under the influence of peyote.

At moments everything was so clear it seemed to be early morning or dusk. Then it would get dark; then it would clear again. Soon I realized that the brightness corresponded to my heart's diastole, and the darkness to its systole. The world changed from bright to dark to

bright again with every beat of my heart I was able to detect a definite melody. It was a composite of high-pitched sounds like human voices, accompanied by a deep bass drum. I focused all my attention on the melody, and again noticed that the systole and diastole of my heart coincided with the sound of the bass drum, and with the pattern of the music (Castaneda, 1974, pp. 98-99).

These perceptions are also similar to those described by Custance (1964) in a psychotic patient: "The great male and female organs of love hung there in mid-air ... pulsing rhythmically in a circular clockwise motion, each revolution taking approximately the time of a human pulse or heartbeat, as though the vision was associated in some way with the circulation of the blood."

Since these perceptions fluctuate along the gradients of warm-cold, rising-falling, light-dark, extension-flexion, yellow-blue-black, expansion-contraction, and free-confined, cyclically in time with the heartbeat, it seems likely that they would be temporarily associated with fluctuations in autonomic tone. Hagbarth and Vallbo (1968) have shown autonomic nerve activity to be phase-coupled with the heartbeat in humans. Sympathetic tone increases suddenly in response to changing from a reclining to an upright posture, providing increased blood pressure necessary to maintain the blood supply to the head (McLaughlin *et al.*, 1978). Conversely, increased parasympathetic tone has been termed "gravity-submissive" (Kempf, 1953). Therefore, perhaps the feelings which accompany the sympathetic-dominant phase of the cardiac cycle are those related to accelerating upward against gravity, feeling strong, expansive, and good, whereas those associated with the parasympathetic-dominant phase are perhaps those related to falling with gravity, feeling weak, contractive, and bad. At first, this formulation may seem to be at odds with that of Reich (1942) who proposed that the parasympathetic system is "operative wherever there is expansion...out of the self—toward the world ... and pleasure. Conversely, the sympathetic is found functioning wherever the organism contracts...away from the world—back into the self ... [in] anxiety ... sorrow, and pain" (p. 257). But in this formulation, Reich does not take into account the sympathetic activation that occurs at orgasm (Wenger *et al.*, 1968; Zuckerman, 1971) and during exercise (e.g., Shepherd and Vanhoutte, 1979). Resolution of the issue would require assessment of the covariation between spontaneous mood and autonomic tone.

B. BODY IMAGERY AND METAPHORIC LANGUAGE

The previous section provided evidence suggesting that visceral activity can influence ideational imagery of the position and appearance of the body. The present section provides evidence suggesting that body imagery is used extensively in the formation of words and idioms. Since many words and idioms are metaphors of bodily sensations, an understanding of the metaphors that refer to bodily sensations may provide insight into our perception of such sensations.

The physical body is used as a point of reference in forming word meanings, by which an identity with an external object is established. For example, as compiled by Swadesh (1971), 'number' = 'digit' = 'finger or toe' (English; 'five' = 'hand' (Sumerian); 'ten' = 'belonging to the hands' (Chukchee); 'twenty' = 'man' (Mayan).

Thass-Thienemann (1968) points out that expressions such as 'I have a sinking feeling in the pit of my stomach' or 'my heart goes out' are literally absurd, yet such words describe true subjective sensations. Similarly, abstract feelings are communicated by expressions which describe the bodily sensations by which they are accompanied; for example: hair-raising, skin- (or flesh-) crawling, spine-chilling (or -tingling), cold feet, no sweat (Sperling, 1981). Such viscerally based metaphors are common in language and provide meaning to words. For example, 'nausea' has the same origin as 'nautical'; the bodily sensation of nausea feels similar to the sensation that is produced by being on a ship in an undulating sea. According to Freud (1924), 'The name *Angst* (anxiety)—*angustiae*, Enge, a narrow place, a strait—accentuates the characteristic tightening in the breathing which was then the consequence of a real situation and is subsequently repeated almost invariably with an affect' (p. 404). Similarly, in onomatopoeia, the meaning of a particular word is congruent with the sound produced when pronouncing the word. These are forms of 'iconic signals,' i.e., 'literal images,' as are hand signals in American Sign Language (see Green and Marler, 1979). An example of such iconicity is seen in the following quote from Thass-Thienemann (1968).

Considering such words as *psychē*, *pneuma*, and *spiritus* phonemically, it is difficult to deny...that some sound symbolism is also operative in their meanings. The combined explosive and sibilant consonant cluster in the initial *psy-*, *pneu-*, *spi-*, suggests the explosive exit of air (pneumatic). The implication of the odor perception of the outflowing air may explain how this sound cluster became expressive of anal fantasies connected with disgust, loathing and contempt. Such are some interjections in English as *pooh*, *pshaw*, *pish*, *fie*. The same sound complex is present in the German *pfui* or the French *fi...* The phonemic equivalent of the Greek *pneuma*, 'spirit,' is the Old English *fneo-san*, Dutch *fniezen*, and Old Nordic *fnysa*, all meaning 'sneeze.'

Hinde (personal communication) has pointed out that many 'sn-' words are also related to the nose (e.g., snort, snore, snuffle, snivel, sniff, snout, snorkel) (Onions, 1966).

Similarly, Swadesh (1971) suggests that many of our words originate from sound utterances and facial-tongue movements which imitate or metaphorically represent certain objects. For example, the dental 't' sound is produced by, and thus provides the effect (meaning) of the contact of a point, whereas the 'k' sound provides that of a blunt object. Sounded together, they iconically represent 'pointed to blunt' as in 'tack.' Although the many exceptions to this line of reasoning restrict its generality, they do not necessarily deny its heuristic value.

There may exist a "bodily geometry" to feeling good or bad; falling and shrinking feel bad, whereas soaring up and expanding feel good. G. Lakoff and M. Johnson in an unpublished manuscript ("Toward an experimentalist philosophy: The case from literal metaphor") have catalogued the English phrases which describe feelings of good and bad in the form of physical metaphors based on body geometry. For example: "Happy is up; sad is down. I'm feeling up. That boosted my spirits. My spirits rose. You're in high spirits. Thinking about her always gives me a lift. I'm feeling down. I'm depressed. He's really low these days. I fell into a depression. My spirits sank." They relate these metaphors to body imagery by pointing out that droopy posture typically goes along with sadness and depression, and erect posture with a positive emotional state. As noted in the previous section, these postures are associated with parasympathetic and sympathetic dominance, respectively. The words and idiomatic expressions may be based on specific feelings which are related to specific moods, postures, and autonomic tone.

Other examples of body-based metaphor are as follows.

The head in its role of standing for the entire body also has a tendency to exhibit its own dichotomy of front and back. Unwelcome thoughts are pushed to the back of the mind, whereas other ideas are accepted into the forefront of consciousness. What is in front is known, what is in back is unknown. Also, what is in back is held back, whereas what is in front is faced. We look to the future and push the past behind us. These metaphorical expressions may actually refer to physical sensations, and perhaps to physiological processes. (Reprinted by permission of the publisher from Kepecs, *Psychosomatic Medicine* 15, p. 427. Copyright 1953 by The American Gastroenterological Association.)

Kepecs (1953, p. 426) also points out that the expression "keep a stiff upper lip" refers "to the employment of muscle tension as a defense against vegetative discharge of feeling." This is similar to Reich's (1942) identification of "character armor" with "muscular armor" and Dunbar's (1943, p. 86) notion of the "relationship that exists between muscle tension and the keeping of important emotional material in repression," indicating that "muscle tension is a general defense against expression of vegetative energies."

Similarly, Schwartz *et al.* (1976), on the basis of their findings that specific facial muscles are differentially active during mental imagery associated with happiness, sadness, and anger, and that the profiles of muscular activity differ between normal and depressed persons, postulate that "peripheral feedback from discrete, innate patterns of facial muscle activity provides an important component underlying the subjective experience of emotion." This conclusion is similar to that of Gellhorn (1964), who suggested that "mood depends to an important degree on posture ... the inner attitude may be induced through the external posture, and vice versa" (p. 413). These statements are consistent with the notion of William James (1884) that "we feel sorry because we cry, angry because we strike, afraid because we tremble, and not that we cry, strike, or

tremble, because we are sorry, angry, or fearful..." Lowen provides support for this point of view in the following quote from one of his patients during a "falling exercise" in which the patient is encouraged to stand on one leg with bent knee until she falls to a cushion on the floor: "'I am not going to fall. I am not going to fail. I've always failed.' And with that remark she fell and began to cry deeply" (Lowen, 1976, p. 205).

A link between the form of body expression and specific types of psychosomatic disease was demonstrated experimentally by Williams and Krasnoff (1964). They found that peptic ulcer patients gave significantly more Rohrschach responses emphasizing "penetration of (bodily) boundary" (e.g., mashed bug, person bleeding, soft mud) than did rheumatoid arthritis (RA) patients. The RA patients tended to give more "barrier" responses (e.g., "bottle," "knight in armor," "turtle with a hard shell") than the peptic ulcer patients. Patients in both groups who had "high barrier" scores showed significantly higher muscle tension during an emotionally stressful test than patients with "low barrier" scores, indicating a relationship between body image (i.e., projecting the body as having a barrier or being penetrated) and bodily muscular expression.

The generation of dream imagery by bodily sensations was suggested by Freud (1900) in the sixth chapter of "The Interpretation of Dreams." He pointed out that Hippocrates had noted that disorders of the bladder were associated with dreams of fountains and springs, and disorders of the intestine, Freud believed, are associated with dream symbols of buried treasure, gold, and feces. Similarly, in a hypnagogic state between waking and sleep, Silberer (1951) observed visual imagery of body pantomimes which were metaphors of his thoughts. For example, a thought of his was "I am to improve a halting passage in an essay," and his imagery was "I see myself planing a piece of wood... the position of the piece of wood I am planing is that of my lower arm; I really feel that my lower arm represents this piece of wood" (p. 206).

Since dream or dreamlike imagery can apparently be generated by visceral afferent activity, it is likely that visceral motor activity would generate reafferent activity and thereby induce such imagery. A vivid example in support of this notion occurred in an instance when my auto skidded on an icy road and I could feel my stomach contract suddenly as I turned the steering wheel. I had the distinct imagery of my stomach feeling as if it was an auxiliary hand that reached out and gripped the wheel, helping me steer. The motor and sensory components of this process may well represent what Freud characterized as "primary process," which creates unconsciously generated, wish-fulfilling dream imagery (Mack and Semrad, 1967). In the present context, the visceral motor activity "acts out" an ineffectual but comprehensible response to a perceived situation (i.e., the stomach "helps" as an auxiliary hand) and that motor activity generates afferent activity which is perceived as an auxiliary hand in a dreamlike manner.

Another kind of transformation of body imagery, that occurs in organic disease was described by Schilder.

Every protrusion can take the place of another. We have possibilities of transformation between phallus, nose, ear, hands, feet, fingers, toes, nipples and breasts; every round part can represent another—head, breasts, buttocks; every hole can be interchanged with another—mouth, ears (in some respects, eyes and pupils), openings of the nose and anus.... Actions may create artificial caves in the body; the inside of the hand and the inside of the mouth and the inside of the genital region may be substituted for each other (Schilder, 1950, pp. 182-183).

This transformation is also evident in more prosaic examples, such as the facial and tongue movements of a child trying to copy a figure by hand, or of a mother trying to coax a spoonful of food into her baby's mouth. If some food drops off the spoon as the baby opens its mouth, the mother might suddenly drop the edge of her own mouth as if to catch it. She might use the edge of her mouth as she would her hand or her shoulder and arm in that situation. The expression "down at the mouth" refers to an attitude in which everything is drooping, as if the shoulders are bearing heavy weights. A related example is the facial grimace accompanying lifting a heavy weight. Perhaps the mouth corners are used as metaphors of the wrists. A contrast, with respect to gravity, is arms extended up in victory and a victory smile with the edges of the mouth raised high.

The face apparently can mimic what the hand does. Significantly, the facial and scalp muscles are derived embryonically from the visceral branchial arches, and are innervated by the fifth and seventh cranial nerves, which are "visceral" nerves (Romer, 1962; see Komisaruk, 1977). Since the face performs actions directed at the environment which are metaphors of what the hands do, but the facial muscles are of "visceral" origin, face-hand coordination may represent a form of visceral-somatic integration. Perhaps the face-scalp can act as a "hollow" viscus representing both the stomach and the hand. For example, when one is nauseated and feels a vomiting-like movement in the stomach, a characteristic movement of the face appears, in which the lips are pursed and the cheeks are billowed out. Thus, the face may adaptively "act out" a pantomime, i.e., create a physical metaphor, of a specific movement of the stomach or of the hand.

In this section I have speculated on some ways in which somatic and visceral integrated activity gives rise to expressive imagery, metaphor, language, and symbolic behavior. It should be emphasized that the gradients of sadness-happiness, and droopy-erect posture appear to parallel the parasympathetic-sympathetic and gravity submissive-gravity opposing gradients described in the previous section. These also parallel the trophotropic-ergotropic gradients described by Hess (1954). It is thus tempting to speculate that skeletal postures, visceral tone, and mood, feelings, and body-metaphor-based language are all integrated along congruent physiological and cognitive gradients.

V. TOWARD A CONCEPT OF PSYCHOGENIC ORGANIC ("PSYCHOSOMATIC") DISEASE

The visceral system can act out the primary process without the participation of the usually associated somatic system, as in the report of increased blood flow to an arm when one thinks of moving the arm (Dunbar, 1946). This is a form of "motoric thinking."

In the somatic system, L. W. Max (see Crafts *et al.*, 1938) found that when subjects were told to imagine acts such as holding a wriggling snake behind the head, holding a squirming fish in the hands, telegraphing an SOS signal, and typewriting the subjective experience of kinesthetic image was usually accompanied by contractions of the muscles which would be active in the performance of the acts imagined, although the contractions themselves were not perceived by the subjects.

In the realm of the visceral system, motoric thinking can be viewed as, e.g., the activity of the cardiovascular system being adjusted appropriately to the holistic attitude of the body. Kempf (1953) vividly contrasts its activity in panic and rage.

In panic, when unable to escape from deadly force, the pulse grows extremely fast and small, accompanied by cutaneous pallor and visceral vasodilation, with fall in blood pressure and great general weakness, trembling and fumbling, and even fainting of submission.

In rage or hate, when the offended person feels stronger than the offensive force, the heart develops slower, stronger and larger contractions than in fear. This sustains a greater volume of blood at high pressure, and supports violent somatic compulsions to destroy the cause (Kempf, 1953, p. 316).

If we propose that the motor activities of the viscera enact our fantasies, then we can assume that the visceral sensations that result from the enactment bear some relationship to those that would occur if we actually enacted the specific fantasy with our entire body. Perhaps individuals who eventually develop gastric ulcers use their stomach as they would their hand, the stomach contracting as a sphere when the hand, face, and thorax-abdomen do so. Perhaps the pain that these actions of the stomach create gives them the feeling that they would get from a powerful crush, pinch, or twist. This implies that the symptoms in psychogenic organic disease may be unconsciously created bodily representations of the way in which the individual deals with a given situation at a primary process level. Wright (1976) in referring to phobic symptoms proposes that "the symptom is a wordless presentation of an unnameable dilemma—an abortive metaphor that stops below the level of speech... the undoing of a symptom is in part the creation of (conscious) metaphor from symptom."

By performing viscerally a metaphor of what we feel like doing but refrain from doing somatically, we may generate a cognitive representation of our fan-

tasied response. That is, we may provide ourselves with the visceral equivalent feelings that fulfill our wish, e.g., by acting out an angry punch, using the stomach but not the arms. If the blood vessels to the arm persevere in acting out the punch, but we prevent the arm from actually doing so, this could, perhaps, eventually lead to pathological changes in the muscles of the arm. Indeed, Travell (1960) has described a process of muscle contracture and eventual locking of skeletal joints in cases of prolonged conversion reactions, the musculo-skeletal system eventually becoming physically incapable of performing the actions which were previously inhibited hysterically. According to Weiner (1977, pp. 457-458) "physical diseases such as rheumatoid arthritis are often accompanied by conversion symptoms.... The hypothesis that psychological tension is translated into tension in muscles and tendons around joints is central to many past formulations about the initiation of rheumatoid arthritis." For example, Reich (1942, p. 267) stated, "Every muscular rigidity contains the history and the meaning of its origin." Weiner (1977) has raised the question of whether psychological factors could be mediated through autonomic outflow channels to produce vasoconstriction in the arterioles that supply the joints, cartilage, or synovial cells. Thus, the overriding wish not to perform some act would eventually be fulfilled by the body's becoming incapable of performing it.

According to Dunbar (1946), "somatic symptoms appear as safety valves against the appearance of repressed material." Following are some examples, in the case of rheumatoid arthritis, of what is interpreted to be metaphoric use of body parts in expressing conflicts arising from repressed desires.

The close relationship between the psychological life history of the patient and arthritic process receives additional emphasis from the fact that the localization of the disease seems to be in the joint or joints in which the conflict is focussed.... The joints play an important part in an activity that is disliked, and which, as the ultimate result of the disease, cannot be continued. Thus, in 12 cases, the joint was strained in an occupation which the patient hated, and in nine cases the sacro-iliac joints were particularly involved, where repression of the sexual act constituted an integral part of the patient's dilemma. The joint is essential to the assumption of an attitude which is expressive, in a symbolical way, of the patient's general demeanor or conduct. Thus, in seven cases of primary stiffening of the spine, conceited haughtiness was very evident (Booth, 1937, p. 144).

Booth (1937, p. 645) concluded that, "The arthritic process tends to localize in joints which the patient, for conscious and/or unconscious reasons, desires immobilized rather than active." Similarly, Lowen (1976, p. 86) stated, "Tensions in the small muscles of the hand are the result of repressed impulses to grasp or seize, to claw or to strangle. I believe such tensions are responsible for rheumatoid arthritis in the hands."

The use of specific bodily parts to express specific conflicts led Engel (1968) to consider rheumatoid arthritis as a form of conversion reaction. He stated that

a complication of the conversion ultimately results in local tissue damage...involving...joints and even parts of the vascular system. For example, we have seen Reynaud's

phenomenon appear first in the index finger of a woman about to dial the phone and "tell off" her mother, and rheumatoid arthritis first in the ankle of a man upon impulse to kick down the door of a rejecting girlfriend (Engel, 1968, p. 321).

Deutsch (1959) has developed a concept of somatic disorders based upon the conversion process.

External objects are perceived as if severed from the body and lost. This separation leads to the continual wish to restore the loss of the bodily wholeness.... The child reacts to this loss of an object with the attempt to regain it, to retrieve this part of himself, by imagining it. Attempts of this nature continue throughout life and can be considered as the origin of the conversion process.... The objects outside become reunited with the body by way of symbolization...the source of the symptom is the wish for, and the flight from, a symbolized object which stirs up an emotional process aimed at undoing the loss. ...However, if no surrogate object is available, conversion symptoms are formed. This can lead to partial or complete inhibition or to hyperactivity of a bodily function. The organic symptom is the protective device against an impending loss of the object (Deutsch, 1959, pp. 76-77).

We may speculate that visceral disease may develop when we do not perceive, understand, or act out responses to, our visceral afferent messages. This notion is supported by the following quote from Dunbar (1946).

Important in the psychic situation of organic heart patients is the absence of a definite correlation between the seriousness of the illness and the subjective experience of it. In striking contrast to the objective findings, these patients show little or no consciousness of disease, and consequently, no insight; complaints (shortness of breath on exertion, etc.) are minimized or dissimulated. This situation is peculiarly characteristic of a majority of serious organic heart patients (p. 208).

Perhaps the intensity of the sensory activity generated by visceral efferent activity continues to increase until one responds to it consciously. If one does not respond to it, it persists and/or intensifies, leading eventually to organic disorder. In other words, the viscera may act out our fantasies and in so doing, provide us with some, but not all, of the components of the stimulation which we would receive from the body if we acted out our fantasies. What is missing is the stimulation provided by reality. Thus, in the visceral, but not the somatic, realm we act out our primary process.

Perhaps stomach spasm is a visceral pantomime which resembles the feeling of stomach fullness, and which the primary process might initiate if one felt abandoned, as a means of recreating the feeling of being fed, thereby mitigating the feeling of abandonment. The stomach spasm pantomime could also provide the feeling of a hand grasping a desired object. In both cases, the stomach can be viewed as performing a wish-fulfilling pantomime, in which one "gets what one wants" in a dreamlike, but not a real, sense.

If one feels lonely, the primary process might create the feeling of pressure in the chest which one would obtain from a hug. Lung congestion against which we

strain to breathe creates a feeling of pressure. Perhaps asthmatic attacks which are precipitated by anxiety could be understood as an attempt by the body to generate this specific sensory stimulation. This "visceral strategy" would operate when one feels unable to obtain appropriate desired sensory stimulation from the external world. If specific *somatic* stimulation (e.g., a hug from a loved one) is impossible or thwarted, the closest substitute may be *visceral* stimulation originating in a body region whose sensory input is convergent with the desired somatic stimulation. Examples of such convergence are seen in referred sensation, e.g., forearm cutaneous input converging with cardiac input to the same spinal neurons (Foreman, 1977) or urinary bladder and cutaneous thigh afferents converging on the same spinal neurons (Fields *et al.*, 1970). Thus, cigarette smoke may stimulate visceral spinal afferents whose spinal projection fields overlap with those of somatic afferents that are stimulated by a hug. If the smoking strategy is not used, perhaps production of lung congestion would be the body's next resort. In other words, a "strategy" of generating lung congestion as a substitute for thoracic contact stimulation (hugging) might characterize certain forms of asthma.

This notion is supported by Weiner's (1977, p. 297) characterization of some asthmatic patients.

In about one-half of asthmatic patients the dependency conflicts take the form of the unconscious wish to be engulfed and protected. The threat or actuality of separation may then mobilize the cry for the mother which may not be fully expressed, and which is associated with the asthmatic attack.

Perhaps the cry generates sensory stimulation via increased muscular tension in limbs, trunk, and throat as a compensatory substitute for a perceived inadequate level of sensory stimulation. When the stimulation is provided by an external source (e.g., holding, hugging, rocking) or the symbolic equivalent, it is no longer necessary to generate the stimulation by crying.

A similar process of trying to provide a form of sensory stimulation which compensates or substitutes for that which is lost, could account for the series of events leading to the development of a peptic ulcer in a patient described by Savitt (1977, p. 609).

In the course of the analysis, the patient revealed a striking example of an earlier somatization of the oral zone. At sixteen, about a year before he developed his stomach ulcer, he had experienced an overpowering need to suck. It was as persistent a desire as his earlier wish to suck his thumb, which had lasted until he was twelve. This need to suck seemed beyond his control; while sucking, he pulled at the buccal mucosa of his right cheek until a buccal papilloma developed. He had "created" in this papilloma a breast-nipple equivalent which he could mouth and suck at will. This constituted an internal maternal breast that could not be taken away. But it was a "dry breast" which gave no nourishment; it was as nongiving as his mother had been. Consistent biting, chewing, and

sucking enlarged and macerated the papilloma; ultimately it had to be removed surgically. With the loss of this part-object breast substitute, he sustained another oral deprivation, which may have been a factor in the original somatization of his oral conflicts that led to the peptic ulcer at age seventeen.

Similarly, Weiner (1977, p. 83) concluded that "many adult male patients are indeed predisposed to peptic duodenal ulcer by long-standing and unconscious wishes to be loved, cared for, and fed, and given that they also have the anatomical and physiological predispositions to the illness." It is also relevant to note that Fenichel (1945) called attention to the permanent hunger for love and its frustration as a factor in the etiology of stomach ulcer.

Anxiety has been considered to provide a common basis for psychosomatic disease. Fromm (1956) considered anxiety to be the expectation of isolation in some form, such as separation, abandonment, or ostracism. This notion is supported in instances of essential hypertension and rheumatoid arthritis, as well as asthma and ulcer which have been discussed. Thus, in the case of rheumatoid arthritis, Weiner (1977, p. 477) stated, "separation from another person, especially from someone who had previously been submissive to the patient, and felt trapped in the relationship, are common onset conditions." And in the case of essential hypertension, "separation may antecede the malignant phase."

The implication of these conclusions regarding a common basis for psychogenic organic disorders is that visceral activation occurs when the individual perceives that he is receiving inadequate sensory stimulation. As Kaufman (1960, pp. 321-325) pointed out, "Most gratifications are in fact derived from stimulation, not the lack of it; people deprived of sensory experience hallucinate it; ... Freud ... said that the child sought this experience (nursing) again for the pleasurable state it produced, which it should be noted is a state of stimulation..." McCray (1978) reports that compulsive excessive masturbation in children (10-15 times per day) has a common theme of withdrawal of affectionate parental tactile stimulation, and is reversed by reinstatement of affectionate non-sexual tactile contact by the parents. The pleasurable aspect of the various types of orgasm may be due to the nonaversively intense sensory stimulation that is generated by movement of visceral and somatic structures. This implies that the lack of adequate sensory stimulation may induce the organism to generate sensory stimulation "homeostatically."

Perhaps psychogenic organic disorders arise if the self- or other-generated somatic stimulation, or its symbolic equivalent, is inadequate or thwarted. The individual might then seek compensatory physical stimulation by organizing his or her behavior to generate stimulation of the viscera at the equivalent segmental level, such as by eating, drinking, or smoking. If this visceral self-stimulation is perceived as being an inadequate substitute for somatic stimulation, the visceral efferent system (e.g., parasympathetic, controlling gastric secretion or lung congestion) may compensate by becoming hyperactive, thereby generating visceral

sensory activity. If this inadequate compensatory input persists for an extended period, the results could be organic disorder represented by intestinal ulceration, asthma, etc. Although the autonomic system is characterized by negative feedback leading to homeostasis (Gellhorn, 1957), it is likely that cognitive factors (not necessarily "conscious" or "voluntary") affect the "set-point" of the system, so that certain levels of sensory input are perceived as being inadequate, thus allowing the activation of compensatory processes. When visceral afferent activity is generated by compensatory efferent visceral hyperactivity, it may tend toward providing the calming, reassuring effect that the thwarted somatic input that was previously experienced had provided. Even visceral discomfort or pain might actually be reassuring: it may be perceived as preferable to the absence of stimulation, which is equivalent to being isolated.

Therapeutically, this formulation implies that fulfilling the wish somatically or viscerally might reverse the necessity to perpetuate the compensatory visceral efferent activity, thereby perhaps reversing the organic pathology.

VI. CONCLUSION

A major function of the visceral system is to provide metabolic support for the somatic (musculoskeletal) system. It prepares the organism for, and enacts, basic energetic adaptations to the environment. Therefore, the "language" of covert visceral activity can be understood in terms of the overt somatic activity which the visceral activity normally supports. The visceral system can be viewed as enacting the "primary process" level of thinking (i.e., wish fulfillment) with, and even without, the participation of the somatic system.

Pathological states may develop under chronic conditions of dissonance between the activity of the two systems. Specifically, during conflict situations the activity of the cardiovascular system may not match that of the musculoskeletal system. As an example, Reynaud's disease may develop out of chronic unresolved conflict represented by the body metaphor expressed in the extremities and referred to idiomatically as "cold feet or hands." As the primary process is enacted by the visceral effector organs, afferent activity emanates from them. A state of dissonance exists when the visceral system provides such afferent activity in the absence of either matched somatic motor activity or appropriate sensory stimulation, a consequence of which may be organic pathology.

In contrast to the condition of dissonance, consonance between the activity patterns of the visceral and somatic systems probably provides optimal strength and stamina, energy efficiency, and ease of movement. The temporal coordination between these systems is probably facilitated by the existence of rhythmical activity cycles of the cardiovascular, respiratory, and locomotor system, which under certain conditions are coupled to each other and to several rhythmical brain

activity systems. Maximum consonance may be represented by orgasm and other "peak experiences."

In this contribution, emphasis has been placed on the integration between visceral and somatic activity at various levels of the neuraxis from high-order symbolic activity to simpler segmental reflexes. This approach views the visceral system as both a psychological and a physiological entity, to which common principles of operation may apply.

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