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# Relaxation and Muscular Tension: A Biobehavioristic Explanation

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*Relaxation and muscular tension are commonly ascribed to cohere to metaphorical principles of stimulus–response (S-R) that presumably are isomorphic with neurally based reflexive mechanisms that are not modifiable by learning. However, purely S-R principles have been progressively replaced in modern learning theory with expectancy or discrepancy models of learning that do not recognize separate neural processes that subserve operant (R-S) and respondent (S-R) conditioning. An alternative explanation for the relaxation response and muscular tension is provided that is derived from principles of modern learning theory. It is demonstrated theoretically and through practical procedure that muscular relaxation is a homeostatic resting state and muscular tension is a function of simple biopsychologic processes of incentive motivation or learning.*

*Keywords:* coverant, relaxation response, Pavlovian incentive motivation, affect

In contemporary psychology, muscle relaxation has commonly been interpreted as the end product of reflexive mechanisms that are activated by obscurely defined mechanisms of attention. These interpretations have an ancient lineage, and their psychologic representation as "meditation" has had a long and exhaustive history as a topic for empiric investigation in psychology. The fact that selective focusing on simple stimuli or cognitive precepts (e.g., mantras) correlates with relaxation is undisputed but has been historically confounded by claims of additional mental benefits (e.g., unique states of consciousness) that supersede the bounds of conservative empiric inquiry. Extensive surveys of the critical literature on meditation (Holmes, 1984, 1988) have demonstrated that the dependent variable for all meditative protocols is no more than generalized muscular relaxation. However, the correlation between focused attention and relaxation has continued to imply an underlying causal relationship. Nonetheless, the neuropsychologic con-

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nection between focused attention and relaxation has never been empirically demonstrated and has been explained instead by wholly inferred neurologic linkages between discrete attentive states and relaxation that are equivalent to Pavlovian stimulus–response (or S-R) bonds. That is, a "relaxation response" (Benson, 1974) occurs as a reflexive response to concentrated or focused attention, and it is the physiological opposite to the "flight or fight" response that is embodied as anxiety or stress.

It is the position of this article that S-R explanatory mechanisms for the somatic effects of the relaxation response and its opposite of muscular tension are untenable, and that relaxation and tension are not dependent on discrete and consciously perceived Pavlovian-like stimuli of "attention," but rather on indiscreet and nonconsciously perceived patterns of information or "expectancies" that cohere with modern neuropsychologic models of learning. This new model for the relaxation response and tension is easily testable, and suggests strong procedures for behavioral or self-control.

## THE ILLUSION OF STIMULUS–RESPONSE

Relaxation, as well as muscular tension, is traditionally said to adhere to the theoretical principle, long established in psychology, that the nonconsciously elicited somatic responses of tension and relaxation and the physiological concomitants of such responses (e.g., increased respiration, heartbeat, and so on) follow and are solely determined by initiating or stimulus events. These responses thus represent an adaptive response to environmental "demand," or allostasis. Until the last 20 years, the common view was that variances in environmental demand and how such variances correlated with changes in the rate and topography of behavior, or the psychology of learning, was bifurcated into behaviors that were initiated by stimulus or antecedent events alone (the stimulus–response [S-R] model) or were response events that had a subsequent stimulus outcome (the response–stimulus [R-S] model). These disparate principles produced the respective data languages and procedures of classic (Pavlovian) and operant (Skinnerian) conditioning. The *behavioral* metaphors of classic and operant conditioning in turn extended to a commonly accepted *physiological* metaphor that localized S-R and R-S processes in separate parts or organelles of the brain. Thus, S-R or Pavlovian processes were localized in midbrain structures that operated in an analogic manner, and R-S or Skinnerian processes were localized in cortical processes that operated in a logical or computational manner. These processes in turn acted independently of each other. Finally, S-R and R-S metaphors provided a *taxonomy* in which certain modalities of behavior could be classified. For example, operant behaviors encompassed the conscious control of the striated musculature and all voluntary or overt behavior, whereas respondent behaviors reflected the nonconscious control of the smooth musculature and all involuntary or covert behavior (e.g., emotions).

The problem with this metaphoric scheme is that it does not fit the facts of behavior. For example, the contraction of the striated musculature follows an R-S model for overt behavior such as walking and talking but is commonly attributed to S-R mechanisms when such behavior is covertly displayed as part of a stress or anxiety response. Furthermore, overt and covert striated muscular contraction initiates the activity of the smooth musculature (cardiovascular system), which, as an allostatic (S-R) response, sustains the R-S response of muscular contraction by increasing blood flow (McGuigan, 1978). The causal loop between R-S and S-R mechanisms means that such mechanisms cannot represent independent response classes (e.g., covert vs. overt, smooth vs. striated musculature) and that behavior must be understood through an understanding of their interdependencies, an S-R-S model.

This is underscored by the fact that the assumption of distinctive S-R and R-S neural processes is purely inferential and is not grounded in the realities of actual neural processes. In modern learning theory, classic and operant conditioning are distinguishable through their unique data languages and procedures (Staddon, 1993) that do not have a correlate to separate identifiable neural processes. Indeed, the opposite is the case, because neurologically both classic and operant conditioning may be derived from a common set of biobehavioral processes (Donahoe & Palmer, 1993). It may be argued, therefore, that the behavioral metaphors of distinctive S-R and R-S neural processes are wrong, because such metaphors are themselves primarily inferences from behavior rather than embodied in actual observed neural processes; moreover, such processes have no distinctive neurologic referents.

Finally, the physiological metaphor that canalizes classes of behavior into separate cerebral organelles is also untenable. "Higher" and "lower" cortical and midbrain structures are exquisitely interdependent, and behavior is informed mutually by associative learning (or thinking) and affective processes that reflect the hedonic attributes of brain and body whether they reside in neurochemical, neuromuscular, or other somatic events (Damasio, 1994; Panksepp, 1998). These changes require a new perspective on how learning works.

In its rudiments, a learning theory describes how experience shapes behavior and, as a matter of principle, must account for the antecedent and consequential events that shape behavior as well as for *all* behavior from the molar to the molecular. The elimination of the metaphors that command a blinkered perspective on learning provide for new metaphors of learning and reinforcement that integrate these pictures in a unified view of learning. Present-day single-factor or unified theories of reinforcement or reward (Berridge, 2001; Donahoe & Palmer, 1993) are distinguished from S-R and

R-S models by the ways they integrate antecedent and consequential events with the behavior they frame. Consequential events are also termed *contiguous* or *contingent* events. In particular, for every behavioral response, whether overt or covert, a resulting environmental or behavioral event is present and will influence behavior. For example, if a student is tense, he or she may postpone taking a test, or if an individual is tense while deciding whether to buy a new car, he or she may make a decision quickly to relieve the tension of indecision. In both cases, the somatic behavior of tension will tend to recur because it historically led to a contingent or "reinforcing" outcome like when an individual after rumination fixed by tension settles on, or perhaps rationalizes, an appropriate choice. Likewise, a lack of contingent outcomes for behavior may also influence behavior. For example, avoidance behavior is reduced if an individual has no historical opportunity for escaping in similar circumstances, as the classic phenomenon of "learned helplessness" demonstrates (Seligman, 1972), or test anxiety may be reduced by a "time out" procedure that withholds potentially reinforcing responses such as escape (Gresham & Kern, 2004).

Given this new perspective, one that postulates a universal role for contingency or contiguity in learning that we might term an "S-R-S" model, all behavioral aspects of brain and body from molar to molecular become subject to a new unifying metaphoric vision. However, in the case of the ubiquitous somatic states of muscular tension and relaxation, this perspective also requires a clarification of exactly what constitutes their related behaviors.

## THE NONRESPONSE OF RELAXATION

The first empiric appraisal of muscular relaxation and tension dates from the work of the psychologist Edmund Jacobson (1938) and his colleague and student F. J. McGuigan (1976, 1997), both of whom postulated that muscular tension is a behavioral response that nonverbally modulates discriminative or contingent outcomes, namely patterns of thinking and the action patterns they entail. The covert behavior of generalized muscular tension increases emotionality by activating neuromuscular circuits that excite the central and autonomic nervous systems. The latter's physiological representation (e.g., increased gastric motility, hormonal activity, heart rate) combined with tension represents anxiety or stress. In turn, relaxation does not modulate such outcomes and thus is not a behavioral response per se. Rather, relaxation denotes the relative inactivity of the striated musculature. Relaxation merely entails that the musculature, which is comprised of more than 1000 groups of muscular fibers, is for the most part doing nothing. Moreover, such inactivity is not mediated by other cognitive or proprioceptive stimuli, like in the conscious and nonconscious events that permit one to get relaxed and stay relaxed. Finally, because relaxation provides no input leading to the activation of the central and autonomic nervous systems, anxiety cannot otherwise occur. Thus, the paradigm for controlling tension and anxiety is to control the skeletal musculature. That is, to avoid anxiety, muscular tension must be controlled.

The Jacobson-McGuigan hypothesis for relaxation and tension has never been directly challenged but nonetheless was overshadowed by biologic models of emotion (Cannon, 1927) and stress (Selye, 1956), which incorporated tension as one of a constellation of physiological events that were not at root behavioral, but that represented instinctive or reflexive responses to environmental "demands." A similar S-R model was later provided by Benson (1974), who postulated that relaxation is a reflexive response to attentional focusing, and because it is not influenced by contingencies, it is also not behavioral.

The problem, however, with S-R (reflexive) linkages of demand–tension and attention–relaxation is that the independent variables of demand and attention have mutually exclusive definitions. Thus, "demand" may represent a surprising or threatening event that elicits muscular tension as a priming response leading to "flight" or "fight"; or demand may represent nonsurprising and nonthreatening choices that will elicit tension not to prime flight or fight, but to differentially influence thinking and thus choice, as the Jacobson-McGuigan model would predict. However, in common explanations of stress, muscular tension in all circumstances is subsumed under the fight or flight response, thus marginalizing the Jacobson-McGuigan model as a complimentary definition of demand and leading to the somewhat awkward conclusion that the tension elicited while choosing between the myriad unthreatening choices of a workaday existence reflect a mere species of fear or anger or of flight or fight.

A more complicated issue in the case of the relaxation response is whether attention can be defined as an indivisible stimulus event. The critical issue underlying the S-R mechanisms that are implied by meditative protocols is whether selective or focused attention is a necessary independent variable that covaries with a dependent state of relaxation. In his survey of the meditation literature, Holmes (1984, 1988) concluded that it does not and that relaxation can occur just as surely and effectively by simply avoiding thought while sitting in a quiet place or, in other words, resting. Moreover, "attention" is not an indivisible process nor can it be used as such but is rather a taxonomy for the distinctive neural processes, consciously or nonconsciously perceived, that underlie choice between reinforcing events, or "incentive motivation" (Kruschke, 2001), that represent distinctive independent variables in themselves. Specifically, attention may represent the perception

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of *abstract* properties of information that may be ordered or relational (like in paying attention to a move in chess, or repeating a simple word or phrase) or disordered and unrelated (like in sitting alone while avoiding thought and simply observing dissimilar stimuli or resting); or attention may represent the nonconscious gating of information or orientation resulting from stimuli that represent *affective* properties of information (like when attention is directed to a novel, discrepant, or ambiguous event or distraction). The bifurcation of attention into two independent variables leads to the observation that the relaxation response hypothesis encompasses not one but *two* different independent measures that correlate with muscular relaxation: passively attending to simple patterns of stimuli (e.g., repeating a nonsense word, looking at an object) and avoiding distractions. These variables, of course, are embedded in the formal definition of Benson's original relaxation response hypothesis (1974). Yet a characteristic of research on the relaxation response or on meditation is that passive attention to orderly versus disorderly stimuli (i.e., meditation vs. rest) have not been adequately controlled (Holmes, 1984, 1988), and in the case of 'distraction,' neither controlled nor defined.

To illustrate, the primary variable of "focused attention" is based on the postulate that relaxation will follow attending to orderly patterns of stimuli (e.g., repeating a nonsense word or phrase), yet the secondary variable, namely attending to disorderly stimuli (i.e., clearing your mind of thought or just sitting and observing dissimilar stimuli without rumination or thinking), also correlates with relaxation as well as does being in a stimulus-deprived environment such as flotation rest (Fine & Turner, 1985). In other words, **AQ:1** relaxation correlates with attending regardless of the relatedness, complexity, or even existence of the stimulus events that comprises one's field of attention. Indeed, attending to disordered patterns of information is core to the practice of "mindfulness meditation" (Davidson, Kabat-Zinn, Schumacher, et al., 2003; Dunn, Hartigan, & Mikulas, 1999) that also has been empirically demonstrated to correlate with relaxation, thus expanding the definition of meditation to what common sense would term "inattentive states"!

Thus, attention to orderly stimuli does not have any greater causal efficacy in eliciting a relaxation "response" than attention to disorderly stimuli or resting. Finally, it may be argued that even the much vaunted correlation between attending to or rehearsing simple chains of verbal or perceptual information and relaxation does not exist. In particular, individuals in a resting or relaxed state demonstrate an increased capability to simultaneously perform complex reasoning (Greicius, Krasnow, Reiss, & Menon, 2003; Raichle, MacLeod, Snyder, Powers, Gusnard, & Shulman, 2001). In other words, complex thinking or reasoning is not only compatible with relaxation, but may be *dependent* on relaxation. If this latter observation is true, it would invalidate not only the main premise of the relaxation response hypothesis, that relaxation uniquely correlates with a species of attention, namely the rehearsal of simple perceptual or verbal behavior, but also McGuigan's position that muscular tension is necessary for complex thinking. As later postulated, this would require a revision of McGuigan's hypothesis.

Finally, stimuli may possess abstract properties (novelty, discrepancy) that instigate attending independently of declarative thought. These "distractions" are not at root cognitive states but "affective" states and, because they are conflated with cognitive behaviors, are not considered to represent a class of variables that should be separately controlled, although a reduction in distraction is crucial for all relaxation protocols. That is, an individual who is resting or meditating may clear his mind of thoughts, but nonetheless be aware of the need to avoid distracting events to be and stay relaxed; thus, this individual meditates in a quiet place free from distraction. Indeed, attending is correlated with relaxation, but relaxation is also correlated with a reduction of distraction.

The conclusion follows that attending to (or rehearsing) simple ordered or relational patterns of stimuli (e.g., repeating a nonsense word), because such activity cannot be shown to have greater correlation with the initiation and maintenance of relaxation when compared with attending to disordered or complexly ordered stimuli, is of no more value as an explanatory variable than the element of phlogiston, an imaginary ingredient of ancient times that enabled fire. Because relaxation or resting does not require the presence of distinctive eliciting or contingent stimuli and thus cannot be considered an adaptive response to stimulus input, it also cannot be considered an example of allostasis, but is rather a steady homeostatic state representing the nonactivity of the musculature and its accompanying physiology.

## MEDITATION AS METAPHOR

As a homeostatic state, resting does not represent mere muscular relaxation, but rather is a taxonomy for the default regulatory mechanisms of brain and body that are integrated with relaxation. These mechanisms share attributes that are neurologically and phenomenologically the same as meditation such as increased self-awareness or knowledge of self (Wicker, Ruby, Royet, & Fonlupt, 2003), pain reduction (Fine & Turner, 1982), increased endogenous opioid production, and reduction of adrenaline, noradrenaline, and cortisol (Turner & Fine, 1983), and neural activation patterns (Greicius, Krasnow, Reiss, & Menon, 2003; Raichle, MacLeod, Snyder, Powers, Gusnard, & Shulman, 2001). Nonetheless, the neurophysiology of resting states is not compared with the physiology of meditative states in current repre-

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sentative studies on the neurophysiology of meditation (e.g., Newberg & Iverson, 2003). Indeed, since Holmes' (1984, 1988) original review of the literature comparing rest and meditative states, there have been no systematic comparisons of the physiological correlates of rest with the physiological correlates of meditation. Rather, definitions of meditation are commonly broadened in the literature to extend to resting protocols that do not involve the concentration or focused attention (e.g., mindfulness meditation) that is generally imputed to the formal definition of meditation itself. Thus, through the broadening of the semantics of meditation, all resting protocols become *de facto* meditation! Although no evidence has been provided that can demonstrate that the somatic and neural correlates of resting are any different from meditation states, the question is effectively avoided if resting is subsumed under meditation.

It may be postulated, therefore, that given the evidence for the biobehavioral equivalence of the dependent and independent variables that describe meditative and resting states, the historic disputation of whether meditation is different from rest (Holmes, 1984, 1988) is moot. That is, meditative states often are no different from resting states. Nonetheless, meditation and rest can be differentiated through the different roles each imputes for the independent variables that correlate with rest. This results in the interpretation of rest as either a state of allostasis or homeostasis. As an allostatic state, "attention" acts as a "demand" or causal element for rest and, as a homeostatic state attention, acts as an "enabling" or noncausal element for rest. Thus, just as "counting sheep" or quiet seclusion enables but does not cause sleep homeostasis, focusing or attenuating attention enables but does not cause resting homeostasis.

A final distinction between meditation and rest derives from purely linguistic causes. Meditation and meditative states are commonly self-described through metaphoric language that, by definition (Lakoff & Johnson, 1999), imposes meaning from other perceptual domains that are not logically derivative from the experience itself. For example, requesting an individual to rest infers passively attending to a stimulus event or multiple events and to avoid thoughtful rumination on events present or past, in other words, clearing the mind of thought and avoiding distractions. This of course duplicates meditative protocols. Yet meditative states are further differentiated through their metaphorical aspects (e.g., transcendence, pure consciousness, self-actualization, etc.) rather than somatic or neural entailments, and these are dependent on cultural and contextual cues that have nothing to do with independent and dependent measures of the act of resting. Moreover, these metaphoric representations are an impairment to scientific explanation because they confuse and confound the independent and dependent variables that represent resting states.

This importation of meaning through metaphor confuses the literal with

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the alliterative and bestows meaning through poetic language rather through a direct reference to the facts of behavior. The result of this is the proliferation of a pseudoscientific "nonspeak" that is not only circular, but is detached from the empiric facts of behavior. For example, why is a person relaxed? Because he or she is meditating. How do you know he or she is meditating? Because he or she is relaxed. If "transcendence" replaces "relaxation" in this example, this circular reasoning becomes confounded reasoning, because all reference to the empiric facts of behavior is lost. When misused in this way, the term "meditation" deludes us into believing we have explained behavior when we have merely classified it or, worse, obfuscated it. It follows that metaphoric representations of the independent (meditation procedure) and dependent measures of rest (transcendence, meditative state) impede rather than further scientific explanation and have limited, if any, place in the empiric study of relaxation.

Given the fact that relaxation or resting is a nonbehavioral or nonallostatic event that has no unique correlation with antecedent or contingent stimulus events, the concept of meditation, as a preeminent example of allostasis, must be abandoned. The question reverts to whether the converse of relaxation, namely muscular tension, can be explained by a neurally informed theory of learning. As demonstrated, the introduction of neurally based motivational concepts to the understanding of somatic bodily states has growing experimental and theoretical precedent and can provide relatively simple and testable hypotheses for the understanding of muscular tension and its control.

## PARSING REWARD

In modern biobehavioral models of learning (Berridge, 2001; Donahoe & Palmer, 1993), contiguity and contingency influence nearly *all* behavior, including covert responses commonly subsumed under the rubric "emotion," and are presently incorporated into the data languages of behaviorism—whether Pavlovian, Skinnerian, or the molar expectancy theories derived from Tolman. The problem and challenge for theorists of covert behavioral states that include muscular tension such as fear, anxiety, or the more encompassing "stress" is that contiguous or contingent factors are not well integrated into models of stress or, more commonly, are ignored altogether. This can be attributed largely to the fact that covert emotional states that include muscular tension are measured by self-reports (Wilhelm & Roth, 2001) that cannot be dissociated into separate somatic components, thus making the causes of these components easily conflated, and the contiguous and contingent events that follow them are rendered difficult to determine.

This has resulted in the incorrect parsing of all somatic components of the stress response from muscular contractions to glandular activity to represent simple S-R linkages, ignoring the effects of contiguity and contingency that are now implicit even in the ostensibly S-R data language of Pavlovian conditioning. However, although learning principles may be unified to include antecedent and consequential events, incentive motivational principles are not so unified. In other words, although behavior may occur through unitary principles that incorporate past and future events, the antecedent and consequential events that drive behavior are themselves bifurcated into very separate processes.

In the folkways of common sense, reward is something that is appraised logically, and pleasurable or painful events are pivot points that fit in an overall rational calculus of utility. Thus, we appraise "goods" because of logical measures of their utilitarian and hedonic value. Moreover, our often pleasurable anticipation of attaining goods that have hedonic and/or utilitarian value, that is, our "wants," are inextricable aspects of the things we desire or "like." Because of this common sense or heuristic principle, behavior is a function of how we manipulate the contents or inventory of the things we desire. Thus, our workaday strategies (as well as the psychotherapeutic strategies, like suppression, that we turn to when we fail) revolve about an economic calculus of value, in which motivation and emotion are relative to real and metaphorical *objects* of desire. By managing the *content* of cognition, namely what we want and how we will get it, we manage our behavior and, implicitly, our emotions. The problem is that we can never get all we want or get what we want in the time and fashion we choose. This, of course, is the basis of stress, a confluence of choices or demands that we are continually juggling, and more often than not failing to manage, as we proverbially drop the ball at home and at work. Thus, poor decision-making, and hence stress, becomes an endemic and seemingly inescapable aspect of our lives. However, what if mismanaging the objects of desire is not the primary cause of muscular tension, but rather the *style* of desire, or how we anticipate the objects we value? To know how we anticipate, we must first define what anticipation is.

Anticipation can be appraised as a singular motivational or incentive event elicited by an object of desire that merges expectation with arousal. However, according to modern neuroscience, cognitive expectations are different behaviorally and neurologically from the affective salience or felt state of arousal that is present when we are anticipating an object of value (Balleine & Dickinson, 1998; Dickinson, Smith, & Mirenowicz, 2000). Indeed, affective or incentive salience has nothing to do with the normative properties of an object of desire, but rather has to do with abstract properties of information that are mediated by the relationship of a performance and the object itself. This information is enfolded in "discrepancy" theories of reward that identify reinforcement or reward with our perception of positive discrepancies (Donahoe & Palmer, 1993; Schultz, 1998), positive events or turns of events that are unexpected. More formally called Pavlovian incentive motivation (Berridge, 2001), decision-making is influenced by knowledge derived natively or instinctively from abstract properties of information as represented by its relative predictability. This knowledge is represented nonverbally by the affective or hedonic value that derives from the release of neurochemicals or neuromodulators (dopamine) that modulate global areas of the brain. This process mediates the predictive expectation of a reward signaled by a stimulus and teaches new predictions by signaling deviations from the expected (Montague, Dayan, & Sejnowski, 1996, Schultz, 1998). However, like cognitive expectancies, dopamine systems also instigate behavior. Neurologically, dopamine systems (DA) interact with the prefrontal cortex (PFC) and induce motor (i.e., behavioral) responses that suppress the DA systems, reset the PFC, and return activity to baseline levels (Cohen, Braver, & Brown, 2002). Restated in behavioral terms, human beings will respond or orient to surprises or discrepancies in their environment that represent variances from what they have come to predict, and acquire this interest not through logical processes of thought, but through nativistic analogic processes rooted in the structure of the human brain.

Ultimately, anticipation, or more specifically incentive motivation, is a product of separate but interactive processes that are different behaviorally and neurologically (Berridge, 2001). However, this observation leads to a conundrum. If incentive or value is also rooted to abstract and analog principles that are psychologically and biologically separate from the logical objects of desire, they must invariably integrate or clash with the concrete and logical principles that we commonly believe informs value. Indeed, common sense heuristics tells us as much. Affective events cohere with rational events when we pursue an interesting project at work, enjoy a healthy meal, or pursue an artistic endeavor that will achieve the applause of our peers. However, affective events may also be incoherent with rational events. Choosing between raiding the refrigerator and staying with a diet, stopping in a hallway to chat or going about one's business at work, or watching television rather than doing household chores all represent choices between rational and "affective" choices, providing us with choices that derive from different sources of value that cannot be logically compared. In common sense terms, a day filled with such choices is a day full of "distractions," endless choices that we cannot resolve logically, but perhaps do so somatically through muscular tension. However, the question is, can muscular tension act covertly to force decision where logic cannot?

## SOMATIC MARKERS

For cognitive associative learning, or thinking, decision-making derives from procedural knowledge that represents act–outcome expectancies. This knowledge may be represented verbally or consciously, but it may also be latent or nonconscious, and may be mediated nonverbally by the nonoral musculature (McGuigan, 1978). Muscular tension has been hypothesized to provide a nonconscious, "allographic code" (McGuigan, 1976) that is linguistically interpreted in the brain and conforms to associative learning principles. Thus, we literally, albeit nonconsciously, "think" with our musculature, a notion that has achieved common currency in contemporary theories of emotion (Damasio, 1994). Applying this model to muscular tension, it follows therefore that relaxation will occur when conscious or nonconscious information is not available that would otherwise be embodied by muscular contraction, or when such conscious or nonconscious information is suppressed or inhibited. For example, a student would sit still if there were no distractions that would otherwise cause him or her to move, or he or she may sit still because a teacher's threat of punishment may cause him or her to ignore or suppress such distractions. Similarly, relaxation may occur through the avoidance of distractions (like in taking a vacation to a remote beach resort), or it may occur through the alteration or suppression of distractions (like in ignoring, reframing, or suppressing distracting thoughts and perceptions).

Associative learning is a critical explanatory component for the widely accepted notion of the "somatic marker" (Damasio, 1994). A somatic marker is an automatic somatic signal influenced by the laws of learning (or more specifically, neocortical processes) that enables an individual to parse between alternatives before their rational or conscious consideration. As such, it centers the modulation of somatic or affective states to the activity of the somatosensory cortices that map the body. Somatic markers encompass affective events such as hormonal (hunger, thirst) or neuromodulator (excitement, depression) activity or the activity of the viscera (gut feelings) or musculature (muscular tension). For example, desire may be mediated by semantic or act–outcome expectancies (i.e., rational behavior), or it may be accentuated or "marked" somatically by the prior association of such expectancies with an "affective" source of value such as a feeling of arousal marked by dopamine release or a literal "gut" feeling. Thus, a new car is valued because it has functional properties, but also because of its novel appearance, sense of comfort, anticipated positive reactions of peers, and the like, which represent affective events.

Somatic markers represent different somatic activation states that, as recent research suggests, are specific to different *types* of choices. For

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example, for semantic or procedural reasoning, the gating of attention through the release of the neuromodulator dopamine provides incentive or affective value to the appraisal of the myriad choices that in critical thinking implicitly involves novel or unpredictable outcomes and is core to neurobiologic definitions of reinforcement (Donahoe & Palmer, 1993; Schultz, 1998). However, semantic reasoning is markedly accentuated during states of rest in which the musculature is in an inactive or relaxed state (Greicius, Krasnow, Reiss, & Menon, 2003; Raichle, MacLeod, Snyder, Powers, Gusnard, & Shulman, 2001), and peripheral feedback in sensory and motor function is not required for complex reasoning and behavior (Taub, Ellman, & Berman, 1966; Teuber, 1972). Thus, for an individual pondering a problem in science, a move in a chess game, or what item to choose from a restaurant menu, decision-making is more effectively mediated neurologically without the need to include the afferent input from the musculature.

In contrast, for forced-choice reasoning in which a decision has to be made rapidly between alternatives that cannot by time or circumstance be logically compared, effectiveness in decision-making is a function of the *speed* whereby decisions are made; hence, muscular tension or "stress" may occur to force decision before its effective appraisal. In particular, muscular tension as a somatic marker may develop through learning and be construed to be functionally similar to a covert operant, or "coverant" (Homme, 1965) in that it indirectly operates on behavior by directing choice and is governed by nonconscious information. According to this model, muscular tension occurs as a somatic marker that expedites decisions between two choices before their conscious consideration. Thus, tension occurs because it is critical to rapid decision-making between rational alternatives. The question is, can tension also occur to mediate decisions between alternatives that are rational and affective? As presently conceived, the somatic marker hypothesis cannot provide an answer. This is because by situating the origin of experienced somatic or affective states in associational learning processes centered in the neocortex, Damasio ignored the many subcortical sources of emotional feelings or affective value (Panksepp, 2003) and how they, like in the case of Pavlovian incentive motivation, may indirectly influence behavior and the elicitation of the somatic marker of muscular tension. Thus, there is no way to test the somatic marker hypothesis within Damasio's theory because affective processes are outside its theoretical range.

Associative learning and Pavlovian incentive motivation represent entirely different yet continually present neurologic sources of value that result in ends that may be additive or be at cross-purposes. For example, the act–outcome expectancies that fill our workaday lives generally entail predictable relationships between means (work) and ends (a paycheck). However, the relative predictability of work may be interspersed with unexpected or "discrepant" events that may cohere with and enhance the aims of work

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(e.g., praise from a boss, completing a work task more quickly than expected) or be incoherent (e.g., checking e-mail, reading a newspaper, gossiping) with doing a good job. Moreover, an individual may be stimulated or "primed" by the mere modeling of such events such as expecting an imminent raise or coffee break. In other words, the cognitive representation of positive future events will also stimulate by virtue of the continuing virtual uncertainty of those events.

When conscious or nonconscious procedural decision rules governing alternative means–ends expectancies (i.e., applying logic or reason to make a decision or resolve a problem) are not known or are partially known in situations that require quick choice, then in keeping with a somatic marker hypothesis, muscular tension may occur to drive decision in one direction or another. Thus, we may become "on edge" when making critical life decisions. However, another and more prevalent source of tension or stress occurs when one must choose between two different and incommensurable neural sources of value. In other words, the priming of behavior (pleasurable alertness) as measured in the affective or hedonic value of certain choices may covary with the procedural or cognitive rules for decision-making.

In our daily lives, priming occurs continually to influence choices that covary with the procedural rules of behavior. That is, we know that diverting or discrepant behaviors are available at any time. Thus, we are often diverted or "tempted" to engage in idle conversation, check e-mail, read the newspaper, and the like because of the novelty or discrepancy these events entail. The continuous "choice–choice" between decisions mediated by different incentive factors signals muscular tension that ultimately expedites decision. However, if an individual chooses an end that has affective or discrepant value, or in other words, "surrenders to temptation," then that temptation will recur as a continuous prime for future behavior. So, by taking a time out to converse about the weather or sports, the option to engage in such diversions remains present throughout the day and will continue to arouse attention, divert behavior, and elicit other somatic events (i.e., muscular tension) that will expedite that diversion. In other words, by surrendering to temptation, the temptation remains constant and so do the discomforting somatic events that we call muscular tension or "stress." So ironically, by taking time out in a stressful day to perform some diversion, we actually accentuate tension.

Finally, the postulation of tension as a covert operant that occurs and is reinforced within the discriminative or stimulus control of a specific *type* of choice resolves the ambiguity associated with findings of McGuigan and Damasio that implicate the musculature in decision-making and findings (Taub, Ellman, & Berman, 1966; Teuber, 1972) that do not. Rather, tension influences not decision-making per se, but rather decisions that cannot be expeditiously resolved through declarative reasoning. In other words, tension does not indirectly effect decisions, but it resolves dilemmas.

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## THE PRAGMATIC SCIENCE OF STRESS

In summary, contemporary neuropsychologic models of incentive motivation posit separate neurologic *sources* of incentive value, whereas the somatic marker of muscular tension occurs through associative learning to expedite choices *between* sources of incentive value. Following this logic, the somatic marker of muscular tension occurs not because of a discrete stimulus event or "S," but as a interoceptive, psychosomatic, and *operant* behavior that helps to mediate decisions between different stimulus event–stimulus outcome expectancies (S-S*) or, in a molecular behavioral language, response contingencies. These S-S* expectancies or response contingencies denote the weighing of separate but exclusive means–end relationships (e.g., which fork on the road to take) *or* they may denote different sources of neurologic value. Thus, by deciding between the road to God (logical goals) or mammon (temptation), one must weigh different "logical" and "affective" sources of value that at root cannot be logically compared.

The fact that human incentives do not have a unitary neurologic source is ironically not contrary to the common sense heuristics that humans have always used to explain their behavior as well as control stress. Indeed, to master stress is to master the skills that enable one to predict with much greater reliability the proper course of action. Thus, one becomes less nervous about driving cars, dating, or doing income taxes when the skill sets are mastered that enable one to predict outcomes like a good night kiss or avoiding an IRS audit. Humans are also well aware of the unreasoning power of "affective" events and reduce the "priming" or temptation to perform them by circumscribing in time the events that they can or cannot do. Thus, we set aside certain times where we can eat, gossip, watch television, and the like, knowing full well that tension would surely occur if we were continually primed to veer from our present, more constructive behavior.

If we take this pattern of behavior—setting time aside for certain events—to an extreme, when nearly all priming variables or "primes" are sharply reduced, we have *meditation*. Thus, by avoiding all conflicting cognitive alternatives, a resting state or state of inactivity follows because we are not deciding between alternatives (i.e., thinking) with our minds *or* with our musculature. By crowding out other conflicting cognitive activity, repeating a nonsense word coopts the need to think or the awareness of thought, and by not thinking, relaxation necessarily follows.

## THE CONFLATION OF AFFECT AND ATTENTION

Although relaxation is the main dependent measure for focused attention, relaxation is generally felt as an affective or pleasurable state, and affective states such as reported ecstasy or pleasure are also commonly assumed to be inherent in or caused by attention itself (Csikszentmihalyi, 1990). Indeed, the release of endogenous opioids or endorphins are correlated with resting or relaxed states (Infante, 1998; Maclean, 1997; Turner & Fine, 1983), thus likely accounting for the common attribution or felt presence of a hedonic state to the inactivity of the musculature. However, the stimulus–response model that attributes affective states to focused attention is incorrect because it conflates the separate neural processes governing affect and attentional focus. If focus is conservatively defined through the modulatory or activating processes for global states of the brain, then rehearsing a nonsense word or mantra will cause less neural activity than rehearsing, say, a role from "Hamlet." However, the *degree* of cortical activation does not in any way covary with affective experience and indeed cannot do so because affective experience is not rooted in a neocortex that is in fact enervated (Panksepp, 1998). Rather, it is the *content* or computational quality of that activation that matters and how that content interfaces with lower or midbrain systems that *do* modulate affective experience. Thus, one may be focusing on a stimulus or narrow range of stimuli and report a range of affective experiences from panic to ecstasy. For example, an individual running from a predator or engaged in completing an income tax return on time may be acutely focused on a means of avoiding the bite of a lion or the IRS, yet would feel anxious rather than relaxed. Contrariwise, an individual may be focused on creating art, scaling a mountain, or performing a delicate surgery and feel ecstatic. This final example bears witness to the fact that tasks that challenge an individual to the limits (but not surpassing those limits) of his or her capability, or a matching or demand to skill, will result in a high degree of prediction error that reflects the moment-to-moment uncertainty that a critical goal (e.g., artistic inspiration, staying on the mountain, losing the patient) will be attained or lost. Indeed, these "flow" states (Csikszentmihalyi, 1990), which are also incorrectly attributed to focused attention, are actually instantiated by high levels of dopamine release derived from continuously perceived positive prediction error. This fact has been confirmed by functional magnetic resonance imaging studies (brain scans) of individuals in flow-producing situations such as gambling, creative pursuits, and the like (Fried, Wilson, Morrow, et al., 2001; Koepp, Gunn, Lawrence, et al., 1998).

Attentional focus is often conflated with nonconsciously perceived cognitions or expectations that, in turn, elicit affective states. Cognitive expectations of relief, relaxation, or other somatic or "psychic" events influence response persistence, content, and its subsequent interpretation. This "placebo" effect can also influence brain function on a biologic level (de la Fuente-Fernández, Ruth, Sossi, Schulzer, Calne, & Stoessl, 2001; Leuchter, Cook, Witte, Morgan, & Abrams, 2002) with an attendant increase in affective tone that can be subsequently and incorrectly interpreted as a result of attentional focusing alone. Specifically, dopamine levels may also increase as an individual is "primed" to respond to anticipated positive outcomes as well as positive discrepancies (Martin-Soelch & Leenders, 2001). Nonetheless, like with the perception of cognitive discrepancies, conscious or nonconscious expectations are generally not experimentally controlled in studies on the efficacy of meditative protocols.

## POPULAR PSYCHOLOGY AND THERAPEUTIC METHOD

As these examples attest, the substitution of a neuropsychology of affect with a psychology of metaphoric inferred processes ungrounded to the actual workings of the brain in "action" has resulted in widely accepted psychologic constructs (flow, meditation, etc.) that account for human behavior unrealistically. In particular, in popular psychology, neuropsychologic accounts of behavior are noticeably absent and are replaced by discrete mental events (e.g., pride, willpower, self-esteem, focused attention) or metaphors for causality that follow hydraulic, computational, or other vitalistic schemes. That this mentalistic thinking scarcely coheres to how the mind actually works has been an impediment to a true understanding of behavior (Panksepp, 2000) and, as it must logically follow, to the development of effective procedures that predict and control behavior realistically.

The explanatory principles of meditation are cases in point. Meditation, whether transcendental meditation or the "relaxation response," is said to be effective because of causal relationships between relaxation and a mode of thinking that is nearly eliminative of thinking (i.e., nonsense words, mantras). However, this premise is false for it is not thinking, but *conflicted* thinking that is at the root of muscular tension. Thus, the result of meditation, namely relaxation, can occur by changing the *style* (how we think) rather than reducing the *content* (what we think) of cognition and may be demonstrated through easily replicated procedures.

Tension, of course, cannot be eliminated in our daily lives because we live in an uncertain world. Thus, informational sources of conflict cannot be absolutely avoided, because we must all anxiously face the uncertainties of death and taxes. However, conflicts between "affective" and "logical" choices *can* be avoided, but in our workaday worlds, they are generally not because we often cannot conceive of how they may lead to stress. Indeed, taking a time out to check e-mail, gossip, read magazines, watch television, and the like is looked as a palliative for stress rather than a cause. Ironically, by doing the opposite, and avoiding for preset hours during the day all *possibilities* of engaging in events that are primarily or exclusively selected because of some novel, discrepant, or otherwise affective value, relaxation will naturally follow because a major source of conflicted thinking is eliminated. So if the alternative for doing logical acts is doing nothing at all, or in other words "a time out," one has only to weigh the logical alternatives of doing something or doing nothing, choices that are far easier and less stressful to make because affective value is left out of the equation. Because effecting a change in cognitive style can be made without withdrawing from workaday behavior, as would be the case with meditation, this procedure can hypothetically provide for a state of relaxation throughout a working day, represent a far more effective method for emotional control, and demonstrate conclusively the homeostatic nature of rest.

## DISCUSSION

The 20th century has been labeled the "Age of Anxiety," yet for the affluent classes of the modern world, the number and severity of threats to life and limb are far less than the dire events from pestilence to war that confronted our ancestors. A more persuasive case may be made that the modern age is not characterized by more pernicious threats to life and property, but rather by more pervasive choices, bad and good, that continually impact every facet of our lives. Indeed, the significant increase in modern times of depression, anxiety, and stress-related disorders has been far more cogently related to an increase in choices (Schwartz, 2004) than to threats. Nonetheless, the mere apprehension of choice, from the availability of flavors of ice cream to styles of cars to cell phone plans, is itself a reinforcing thing, because choices denote positive and novel (or positively discrepant) outcomes that are pleasurably arousing. The problem is that, unlike in decades past, choices are no longer constrained by time or circumstance, because a person may make phone calls, watch television, play games, and so forth at any place and any time. Because the circumstances in which we can make choices are massively expanded today, choices are multiplied as well. The *portability* of choice therefore transforms a world of hopes into a world of distractions, because we must continually choose between options that may be difficult or incommensurable. Thus, the "stressors" of a distraction-filled life are not characterized by more real or perceived threats, but by options that multiply because they are unconstrained by time or circumstance.

Perceived threats of course are different in kind from perceived choices, and so too it may be argued are the somatic events they elicit. For example, strong emotional *reactions* such as fear, rage, panic, and the like are the significant and separately distinctive emotional components of the "flight or fight" response that do engage reflexive mechanisms (LeDoux, 1997; Panksepp, 1998), because individuals must be able to immediately prime their behavior to respond to threatening circumstances. Specifically, the attribution of tension to subcortical processes is rooted to organelles just as the amygdala links tension to novel, surprising, threatening, or ambiguous stimuli that are not characteristic to the cortically mediated choices that comprise the great majority of the stressors in our daily lives. In these latter cases, muscular tension may precede "fight" (anger) or "flight" (fear) responses, or tension may not be associated with such primary affective states at all. That is, the somatic responses that may be elicited from such choice–choice options, namely muscular contractions, do not necessarily include the hormonal and neural responses that are characteristic of more primal emotions such as anger and fear. More specifically, it may be argued that choice–choice options between simple alternatives (e.g., what hat to wear to go to church) initiate response classes that are different not only in magnitude but also in *type* from similar options that involve much more severe outcomes for a poor choice.

Furthermore, a case may be made that muscular contraction does not represent an emotion at all, because it does not differ in *kind* from voluntary muscular activity (running, talking), but only in terms of its microbehavioral characteristics that render it intractable to conscious observation. That is, just as voluntary movement of the gross musculature is not emotional in itself, the same conclusion must be applied to subtler muscular activity that is controlled as well (albeit nonconsciously) by the same perceptual events. Because the transition from low to high levels of stress represents changes in classes of responses as well as a gradations of similar responses (e.g., getting more and more tense), the "flight or fight" response so commonly identified by psychologists with stress is inapplicable to the type of stress reaction (i.e., muscular tension) that is elicited by nonthreatening situations. Thus, for low-level stressors, muscular tension may be presumed to be the dominant physiological response (McGuigan, 1978) and may be understood through processes of human conditioning or learning.

A learning-based perspective on stress has the benefit of significantly simplifying stress control procedures by providing an explanatory model for everyday muscular tension that engages observable conditioned behavior rather than reflexive, metaphoric, or otherwise inferred events. Thus, muscular relaxation may be controlled by avoiding information (meditation, time outs, vacations), changing or suppressing information (reframing, positive thinking, psychotherapy, coping skills), and learning how to perceive information. The last example implicates progressive relaxation (Jacobson, 1938), which entails the progressive relaxation of different parts of the body as a means of learning how to perceive the proprioceptive stimuli that permit the discrimination and control of relaxed states.

This new taxonomy for muscular tension engages modern biobehavioral learning theory (or less strictly, a radical behaviorism) because it defines tension and the mediating biologic sources of incentive value as behavioral and not just physiological events (Barnes-Holmes, 2003; Moore, 2001). That is, the somatic responses that underscore incentive motivation (e.g., dopamine release, muscular tension) are dependent on discriminative and contingent events that may be consciously or nonconsciously perceived. Specifically, it expands Damasio's somatic marker hypothesis by postulating that the *somatic event of muscular tension occurs not just to expedite decisions between rational values that are cortically instantiated, but also to speed decision-making between disparate and often conflicting axes of rational and affective values that respectively derive from cortical and subcortical structures.*

Nonetheless, because neuropsychologically informed models for stress, and indeed for all psychologic phenomena, are new, they have not been persuasive or even of passing interest to the vast majority of psychologists. The reason is simple. It is much too easy to conflate the causes with the components of stress and make muscular tension incidental to anxiety rather than a proximal cause of anxiety. By obscuring the role of contingency, a behavioral analysis of muscular tension is more easily supplanted by reflexive or S-R mechanisms under which all stress responses are subsumed. If this is to change, ultimately, it must be through reasons pragmatic as well as theoretical or empiric. In other words, the explanatory schemes that we accept are forced on us not only because of the simplicity of their logic and the empiric evidence that supports that logic, but also because of the effectiveness of the methods those schemes entail. Thus, we must accept and understand biologic theories of disease, of quantum mechanical explanations of the universe, or of the evolution of the human genome not just because the empiric facts point to them, but also because the technologic features of our world *depend* on them. The studied ignorance of biobehavioral psychologic accounts of human nature near universally displayed by present-day psychologists is no different from that displayed by the clergy who rejected Galileo's offer to look through his telescope at the true nature of our solar system. However, this unreasoned stubbornness will disappear not with the plaintive logic that a despairing Galileo offered to his critics, but with the unstoppable power of method that is entailed by the truth.

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