The Operant of Tension

Arthur J. Marr

A description of the covert behavior of muscular tension through a formal theory of learning has never been attempted in psychology, as tension has been attributed instead to obscure S-R mechanisms, or so called 'flight or fight' responses that are independent of learning. These responses are described and modified through the complex metaphors of literal language that are employed in the psychological and psychotherapeutic analysis and treatment of anxiety and tension. An alternative explanation of muscular tension is provided using the data language of operant conditioning rather than literal language. Muscular tension and its sustaining physiological concomitants are demonstrated to co-vary with perceived moment to moment variances in response contingencies, and tension is reinforced due its mediation of the experiential avoidance of the pain of perceived loss. It is concluded that tension is an operant behavior, and may be manipulated through testable procedure that is not derivative from the complex metaphorical structure of declarative reasoning.

Keywords- somatic marker, choice tyranny, behavioral contrast, allostasis, experiential avoidance

Learning and the Non-conscious

In learning theory, the mapping of fundamental conditioning processes does not require literal language or declarative reasoning, and can only be imperfectly described *by* language. Indeed, almost all learning is non-conscious (Lewicki, 1992, Kihlstrom, 1987, Bargh & Chartrand, 1999), or in other words is non-verbally constructed. Conditioning processes are therefore described not by literal language, but through conceptual metaphors derived from formal data languages such as classical and operant conditioning. These metaphors can specify or describe non-consciously perceived moment to moment co-variances between stimuli and behavior that are difficult or impossible to account through consciously explicated declarative reasoning. The advantage of these data languages is that they can describe and predict the elementary components of behavior with a simplicity and economy of terms that map to behavioral events that are easy to

measure and replicate. In addition, complex biological responses may also be dependent upon the perception of these co-variances, and these responses can be described as their indirect products.

For operant conditioning, the processes that underscore the response of muscular tension and the attendant neuro-biological response of anxiety are a case in point. If tension and anxiety are initiated by abstract perceptual elements of experience rather than literal reasoning, then these abstract properties can be described and manipulated without recourse to the complex metaphorical constructions of language. It is proposed that tension and anxiety are due to moment to moment co-variations between subtle features of contingencies that cannot be revealed by common language, but only through empirical investigations that are interpreted by conceptual metaphor that controls *for or limits* language. In other words, a formal and concise data language such as provided in the language of operant conditioning is necessary and sufficient to understand anxiety and suggest procedures for its management and control.

Tension and Anxiety

Anxiety has not been a topic of interest in a formal learning theory because anxiety has no essential or non-reducible component (Friman, Hayes, & Wilson, 1996). This conclusion may prove to be premature, as characteristics of decision making and its relationship to anxiety have yet to be systematically examined (Ernst & Paulus, 2005). Indeed, although the somatic components of anxiety are well established (Antony et al. 2001), the process components, or the working interdependencies of the components of anxiety, are not (Marr, 2006). The content of anxiety is broad, and encompasses a wide range of behavioral and physiological events. However, the *causal* or initiating components of anxiety are narrow, and are generally reduced to specific stimuli that can reflexively elicit emotional responses, as in fear (Ledoux, 1997) that trigger these responses sub-cortically without input from cortically instantiated processes of conditioning. This affective primacy reflects a non semantic activation process (Zajonc, 1984). However, this 'low level' pathway for fear and anxiety may not exist or be active among primates or humans (Clore et al., 2005), and semantic processing may consistently precede the retrieval of affect (Storbeck & Robinson, 2004, Storbeck, Robinson & McCourt, 2006). Assuming that the experience of affect necessarily follows the appraisal of information, appraisal may occur because of consciously enabled rule based declarative reasoning or through nonconscious associative reasoning (Sloman, 1996). If not affective but semantic primacy (Clore & Ortony, 2000) is necessary for the elicitation of affect, then it follows that appraisal must also be necessary

for the somatic event of muscular tension, which as a painful or aversive event also represents affect.

If tension is caused by a stimulus like event that bypasses conditioning or learning, then tension must be defined through process components that are indicated by *homeostatic* mechanisms (e.g. hunger, thirst) that occur independently of conditioned behavior. However, if tension is initiated by information or appraisal, then it is necessarily modulated by subsequent changes *in* information. That is, it must have the properties of a conditioned response. Furthermore, since sustained generalized muscular contraction elicits the activation of autonomic processes(e.g. hormonal release, increased blood pressure, etc.) that sustain ongoing tension (Gellhorn, 1967, 1972), then those processes must represent *allostatic* processes that are dependent *upon* the behavior of muscular tension. These processes along with tension will be defined *behaviorally* as anxiety, and conform with the general operationalization (Loewenstein et al., 2001)of anxiety in studies of affect and choice. That is, in contrast to literal definitions of anxiety that may define anxiety independently of or uncertainly related to underlying neuromuscular activity, a behavioral definition of anxiety is always coextensive with specifically defined behavior, thus eliminating the problem of the verifiability of private events (Zuriff, 1985, Lamal, 1998). Thus, in the former case anxiety occurs as a reaction to a stimulus event, and in the latter case the physiological events comprising anxiety sustain the ongoing behavior of muscular tension. Allostatic events refer to internal changes in the individual that maintain 'stability through change', and represent biological processes that sustain behavior (or in this case behavioral change) and are initiated *by* behavior (Schulkin, 2005).

In the literature of anxiety and stress, the longstanding assumption has been that anxiety occurs independently of behavior, namely that anxiety reflects a reflexive response to the stimulus of 'demand'(Selye, 1980). As an incidental component of anxiety, muscular tension was one of a host of somatic events that occurred with near simultaneity as a reaction to a broadly defined stressful stimulus or demand. The appearance of simultaneity was prima facie evidence of a lack of causality, hence tension and anxiety were not subject to information or contingency, and were non-behavioral events that represented the body's reflexive attempt to return to stability, or homeostasis. Tension represented not a behavior, but an aspect of the cumulative 'wear and tear' on the mind and body due to demand. But the appearance of simultaneity does not logically demonstrate the *fact* of simultaneity, as the operant may simply be hidden from casual observation.

This argument may be illustrated through the consideration of the very perceptible operant of running. Consider an animal chasing after prey. The initiating neuro-biological event

of hunger initiates and precedes the emission of the operant of seeking and eating food, which brings the body back to a homeostatic set point of satiation. Alternatively, the repeated flexion of the musculature that occurs while chasing prey elicits an array of somatic behaviors from hormonal release to increased heart rate that stabilize the animal and sustain the altered topography of its behavior, or in other words allow it to keep running. The operant of running is incidental to the homeostatic mechanisms supporting hunger, as hunger occurs no matter what the animal 'does'. On the other hand, running is essential to the occurrence of the allostatic mechanisms that support it, hence the activation of those mechanisms is *dependent upon* the operant. Because the allostatic responses elicited by running are indirectly controlled by running, modifying the response contingencies that necessitate running allow one to control for the painful or pleasurable effects that are concomitant with running. However, if running occurred without the perceptible markers signified by overt movement, then it could easily be conflated with the allostatic responses that mediate it. That is, if the repeated tension and flexion of the striated musculature in running occurred covertly rather than overtly, its influence on behavior would be difficult to ascertain, and would most likely be overlooked. But is this the case with anxiety?

The key question is ultimately what comes first. If tension reliably precedes and causes the somatic responses that comprise anxiety, or in other words if anxiety responses are an example of allostasis rather than homeostasis, then anxiety may be controlled through the simple behavior modification of muscular tension. The questions raised are twofold. One, does substantive research on the biology of anxiety support this position? Secondly, can tension be reliably correlated with specific aspects of response contingencies, and if so, can those contingencies be controlled?

The fact that tension control is key to the management of stress is incontrovertible. Indeed, all remedies for stress from meditation to massage emphasize muscular relaxation as both necessary and sufficient to eliminating anxiety or stress. Thus, the component neurobiological markers of stress from blood pressure to cortisol return to normal levels with the onset of muscular relaxation, and cannot be reduced independently of muscular relaxation. Furthermore, the argument that muscular tension instigates somatic responses that are subsumed under the label 'anxiety' is amply confirmed in the research literature. It has been repeatedly demonstrated (Gellhorn, 1967, 1972, Jacobson, 1970, Malmo, 1975) that because of a bi-directional connection between the reticular arousal system and muscle efferents, a dramatic decrease or increase in muscle activity throughout the body can respectively stimulate decreases or increases in sympathetic arousal. The behaviorist F. J. McGuigan (1991) took this concept further and speculated that every bodily tension has

both meaning and effect. That is, tension occurs because it does something, namely modulating thought, which in turn modulates tension. This presumptive bi-directional link between thought and relaxation is implicit in relaxation protocols such as meditation that induce relaxation by eliminating or parsing thought. Nonetheless, thinking per se has no positive correlation with tension, and indeed can be demonstrated to have a negative correlation with tension. For example, declarative reasoning is enhanced during states of rest (Grecius et al. , 2003, Raichle et al., 2001), thus leading to the opposite conclusion that tension is deleterious to effective thinking. Moreover, proprioceptive feedback from the musculature is not required for problem solving (Taub et al. 1966, Teuber, 1972). Finally, peripheral feedback does not reliably influence decision making accuracy, and may reflect the end product of decision making rather than a key feature in its development (Dunn et al., 2006). This suggests that tension occurs for reasons apart from enhancing declarative reasoning, and that reasoning or decision making per se does not cause tension. But if tension occurs because of a non-verbal aspect of experience, what is the content of that experience?

Affective Decisions

Behavior can be directly emitted through the perception of means-ends relationships denoted by response contingencies, by homeostatic events that pertain to stimulus deprivation or 'drive', or indirectly emitted through the perception of allostatic changes in somatic states that occur because of performance *under* response contingencies. For example, running may be emitted due to perception of contingencies of reward (i.e. a trophy, obtaining food, etc.), but running may also be modulated due to painful or pleasurable somatic events (e.g. muscle fatigue, endorphin production) that are a product of that behavior.

Allostatic changes also occur through the very act of deciding between response options. Unpredicted positive or negative changes in the discriminative function of a response will elicit bio-chemical changes in the brain that will accentuate or attenuate attention, increase or decrease the ability to attend and hence the ability to optimize decision, and be subjectively rendered as either painful or pleasurable. The role of unpredicted positive changes in discriminative stimuli is reflected in discrepancy theories of reward or reinforcement (Donahoe & Palmer, 1993, Berridge, 2001) that demonstrate how positive unexpected variances co-vary with changes in the activity of dopamine neurons, and code the difference between the expected and actual value of outcomes (Schultz, 1998). Unpredicted negative changes or counterfactual changes in the discriminative function of

a stimulus (Camille et al. 2004, Zeelenberg, 1998) perform a similar function by also coding a difference between actual and expected values. Behaviorally, unpredicted positive and negative changes (Shepperd & McNulty, 2002) respectively result in self reports of elation or regret, and the anticipation of discrepant events will also elicit affective responses and corresponding approach or avoidance behavior (Mellers & McGraw, 2001).

The affective events of elation and regret and their respective neurological representation code for the valence or 'goodness' or 'badness' of molecular choices that successively occur during the moment to moment responses that from a molar perspective are required in sum to achieve some discrete result, *but they do not specifically code for the goodness of that end result*, and can have a positive or negative relationship to the normative results of decision making. This is because the affective events that guide molecular choice are dependent upon unpredicted variances of the schedule of reinforcement that are unrelated to the goodness of the response set that is in turn dependent upon logically derived measures of utility. In fact, these affective events occur even when the utility of a chain of behaviors cannot be ascertained. For example, a gambler knows full well that the end result of a day spent at the slot machine will almost certainly result in a net loss, yet will find individual pulls on the lever attractive because of the anticipated positive discrepancy of an immediate pay off. Similarly, when the logical utility of a behavior cannot be ascertained, as when one is forced to choose between multiple alternatives that cannot be logically compared due to lack of information, behavior will still have discrepant outcomes that will be affectively perceived, but can have no capability determining the relative utility of alternative choices because this determination is impossible to ascertain.

Damasio's Error

Affective events as mapped to the activity of dopamine systems are teaching signals that determine the relative 'goodness' of individual moment to moment behaviors under a contingency, but these same events cannot determine the goodness of the results of those behaviors when considered as a whole. These affective events correlate with and parallel the somatic event of muscular tension, which is an element of systemic autonomic arousal that has been hypothesized as instrumental in determining the overall goodness of a specific course of action. In Antonio Damasio's (1994) widely influential theory of the somatic marker, muscular tension and associated autonomic arousal occur because of previous socialization or learning, and occur prior to the consideration of response options to alert one to or pre-determine the 'goodness' of a particular response set. In other words, tension and arousal allow one to make a proper choice between response options prior to

their rational consideration. However, although somatic events comprise arousal, Damasio did not specify what sequence of cognitive and somatic events *lead to* arousal (Rolls, 1999). Specifically, the existence and form of non-conscious or pre-conscious cognition (i.e. non-consciously perceived response contingencies) as a precursor to tension was not considered in the somatic marker hypothesis, and tension itself was a-priori assumed to be a non-salient corollary event *to* arousal, ignoring the abundant empirical evidence for tension's role as an initiating cause *for* arousal.

This somatic marker hypothesis derived from a now classic experiment surnamed the Iowa Gambling Task, or IGT (Damasio,1994). As described by Tomb (2002) "A subject was presented with four decks of cards. After turning over a card, participants either win or lose varying amounts of play money. Unknown to the participants, picking from two of the decks ('good' decks) will result in eventual gain, whereas picking from the other two decks ('bad' decks) will result in eventual loss. The task ends after the selection of the 100th card, when most normal individuals have picked more cards from the good than the bad decks." After several rounds of picking cards, it was found that 'anticipatory' muscular tension and associated arousal, as measured indirectly by the skin conductance response or SCR, was significantly higher for bad decks rather than good."

These experiments demonstrated that human performance on variable ratio or VR schedules of reinforcement (characteristic of variable outcomes implicit during the course of the card game) is consistently marked by measurable fluctuations in skin conductance (Bechara et al., 1997), an indirect indicator of autonomic arousal elicited by the covert behavior represented by the micro-behavioral tensing and flexing of the striated musculature. Specifically, prospective changes in the VR schedule co-vary with an 'anticipatory' skin conductance response (SCR) or muscular tension that occurs prior to or in anticipation of incorrect choices (Bierman et al. 2005), and the magnitude of the SCR co-varies with the importance of the reinforcer (Tomb et al. 2002). For example, for the VR schedule inherent in a gambling task (e.g. choosing cards from a deck, such as in a poker game), the level of the SCR is driven by the amount and likelihood of money to be gained or lost per each turn of the card.

As indirectly indicated by the SCR, tension occurs and co-varies with the moment to moment perception of the size of schedule variances of the deck and the magnitude of the loss those variances signify. But as with affective events, and in contrast to Damasio's hypothesis, tension does *not* co-vary with the overall goodness of the response set under a contingency. Tension indeed is agnostic to the goodness of overall responding, as tension would occur while choosing cards from bad or good decks (Tomb et al., 2002), or it may

occur when the goodness of the decision is already known (Maia, 2004). Finally, in the many situations when the goodness of a decision cannot be known, as when a plenitude of choices surprisingly change the *relative* or contrasting goodness of a response, regret and tension also occurs (Schwartz, 2004).

Behavioral Contrast and Tension

Tension will occur not only with and in anticipation of a discrepant negative variance while performing under a response contingency, but also concurrently with a discrepant negative variance between alternative schedules of reward, as illustrated by the concept of *behavioral contrast* (Williams, 1997). This occurs when the goodness or badness of a reinforcer is determined through its contrast to other reinforcers or response options that are revealed *subsequent* to choice. In the many situations when a plenitude of options or reinforcers make their goodness difficult or impossible to logically calculate, choosing one option will more likely result in a subsequent interpretation of loss or regret when comparatively better choices are revealed in hindsight. For example, choosing to wait in one check out line among several at a grocery store will result in regret and tension when other lines move faster relative to yours. Similarly, choosing one pair of clothes among a myriad options at a clothing store will more likely result in regret upon the subsequent appraisal of options foregone. This 'tyranny of choice' (Schwartz, 2004) has been repeatedly demonstrated by social psychological observations of the correlation of tension, anxiety, and stress with multiple choices.

Finally, the goodness of alternative reinforcing events may be difficult to calculate not because of the lack of information, but also because their respective values are determined by incommensurable *types* of information whose 'goodness' is assessed in different time scales (Marr, 2006). Behavioral incentives are the product of separate but interactive processes that are different behaviorally and neurologically (Berridge, 2001). Specifically, incentive or value may be rooted to logical principles that map to molar means-end expectancies or response contingencies, or to molecular abstract and analogical principles derived from the affective events that are elicited through the perception of positive or negative discrepant events. Choosing between such rational and affective events will always result in loss because they cannot be logically ordered or compared. That is, from moment to moment, an affective choice may have greater value over a logical alternative, but over time and experience that choice will habituate and the logical choice may become more important, resulting in regret (which also occurs because of an estimation of cumulative or molar behavioral events) over opportunities lost. For example, 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 affective and rational choices where we must literally experience or 'live' to regret, creating prospective loss and hence tension regardless of what option is taken.

The conclusion follows that moment to moment 'surprising' or discrepant outcomes, occasioned or represented by variances in primary or alternative (i.e. contrasting) reinforcement schedules that mismatch prediction and outcome because of the quality or type of available information co-vary with neurochemical and neuro-muscular changes that can predict the value or goodness of an individual response, but not a response set. Thus these changes as somatic markers predict not the goodness of molar responses indicative of a particular response set, but rather the goodness of molecular responses that indicate the appropriateness of moment to moment responding. By attributing tension to the discriminative function of negative variances in schedules, the perceptual events or discriminative stimuli that account for tension are empirically described. This is in contrast to Damasio's somatic marker hypothesis, in which no adequate account is given of which perceptual or cognitive stimuli elicit peripheral changes (i.e. tension) that lead in turn to systemic autonomic arousal or emotion (Rolls, 1999), or how such changes may be induced. But if this is true, is the function of the somatic event of muscular tension the same as its neurochemical counterparts, or is it different?

Experiential Avoidance

In an earlier example, it was postulated that an individual will modulate or change his behavior due to somatic events that are generated by that behavior. Thus a runner will slow down when his muscles ache, or keep up or even quicken the pace when he experiences a 'runner's high' due to the body's natural release of endorphins to relieve pain (Sparling et al., 2004). Assumptions such as these are trivially true, since many behaviors from drinking to eating are modulated due to bodily feedback from satiation to a stomach ache that are perceived as affective events. But overt avoidance and approach behaviors are also mediated by the affective valence of neurochemical events that mark discrepant outcomes for moment to moment responding. We are more inclined to engage in behaviors that are rich in positively discrepant outcomes, and contingencies that are fine tuned to create them through the matching of skill and task such as mountain climbing, creating art, playing games, etc. (Csikszentmihalyi, 1990) are actively pursued because of their affective value, or 'intrinsic' reinforcing properties. This 'flow experience' is characterized by a

sense of euphoria and total relaxation (Perry, 1997; Bargdill, 2000) marked by the affective appraisal of continuous positive prediction error, a fact that is neurologically verified by the observed release of the neuromodulator dopamine in events that are characterized as flow producing, such as gaming and creative behavior (Fried et al., 2001, Koepp et al., 1998). On the other hand, we are inclined to avoid behaviors that are equally plentiful in negatively discrepant outcomes, and are quick to avoid painful or 'frustrating' activities where responding is marked by repeated and unexpected failure. Negative variances do elicit neurological changes that are painful (Camille et al., 2004), and presumably by themselves should increase avoidance behaviors, yet the additionally painful event of muscular tension often occurs when these variances are affectively perceived as the emotion of regret. This is in contrast to 'flow' producing contingencies that only produce positive variances and are highly correlated with relaxation. But what decision rule is followed that may predict the occurrence of tension when negative variances are perceived?

As common experience suggests, tension occurs when an individual is able but not certain to avoid the loss that occurs when moment to moment behavioral outcomes are surprisingly negative or are anticipated to be negative. But because these outcomes are also represented by and elicit an affective neurological response (i.e. recognizing loss is painful), loss therefore represents not just a cognitive or computational event, but an affective or analogical one as well. That is, it is perhaps not the knowledge of loss that initiates avoidance, but the actual discomfort (e.g. worry, regret, tension)that that information elicits or causes (Borkovec et al. 2004). Similarly, tension also occurs when the discriminative function of a stimulus does not cause affect, and is merely *correlated* with negative affect. For example, to revisit Damasio's gambling experiment, given ongoing experience with the good and bad results of selecting among decks of cards, an individual will experience tension in anticipation of selections from bad decks that will elicit the discomfort of regret. Yet, if all the cards were dealt face up for an entirely neutral deck (i.e. cards that have no inherently bad or good discriminative function) , and with the subject possessing full knowledge of what card will come next, the pairing of a specific card with a noxious stimulus (e.g. a very mild shock) would also cause an individual to feel tense in anticipation of that event. In this case, tension could not somatically mark decision because information about the response contingency was fully known, and more likely mediates the avoidance of choice rather than enhancing the ability to choose.

Finally, the correlating event of tension in turn mediates avoidance because it is also painful. Pain interrupts and redirects attention, and imposes a new action priority to escape (Eccleston & Crombez, 1999), and it follows that the pain of tension serves the same

function. Like an individual becoming apprehensive or tense in anticipation of the discomfort of a day at the dentist or at the gym, the discomfort of tension attends the anticipated discomfort of regret. Similarly, the occurrence of tension in anticipation of painful events, whether neurological or physiological in origin, will be mitigated or disappear when avoidance is not possible. Thus, a individual will be less anxious if he cannot avoid the inevitability of a dental exam or a day of lifting weights, or a student who is experiencing test anxiety becomes less anxious if avoidance is eliminated through a 'time out' (Gresham & Kern, 2004) that extinguishes tension by reducing the prospect of avoiding prospective loss. Although the student may still experience loss and the regret it entails, muscular tension will not occur because it cannot be reinforced. Similarly, individuals who perceive the moment to moment uncertainty that they will suffer a significant loss of life or property (e.g. a hurricane or disease) will feel tense when there is still a prospect that the loss will be avoided, and merely regretful or depressed when they know it cannot.

For any decision, there is always the loss of the opportunity to do something else. For predictable and unavoidable losses that reflect decisions that we could not have avoided or would never have chosen (e.g. death and taxes), tension and regret do not occur. Thus, we do not become anxious or regretful because these losses are unavoidable or inevitable. On the other hand, unpredictable or regretful losses or the anticipation of possible loss and regret will always correlate with tension *if* the decisions that lead to them can be altered or avoided. It is thus hypothesized that *the somatic event of tension occurs not to modulate the effectiveness of decisions, but to increase the speed and likelihood of our avoidance of the perceived moment to moment loss due to present or anticipated (but not certain) negative information perceived in the process of making a choice and the pain that information will entail*. This may be done through the alteration or outright avoidance of that behavior (whether exercised through an overt change in behavior or covertly through rumination regarding other response options or 'worry'), or through parsing behavior by completing that behavior more rapidly. As peripheral feedback, generalized muscular tension has no functional role in increasing the efficacy of decision making, or is merely 'noise' (Rolls, 1999), yet Rolls' position that tension merely prepares an organism for 'action' must be altered, as tension does not merely prepare an organism for action, it *is* action. Because tension is painful or uncomfortable, tension *acts* by calling attention to and indirectly expediting avoidance behavior. That is, because tension does not increase the efficacy of decision making through preparing an individual to make a correct decision or allowing him to correctly parse between decisions, its only logical role is to expedite the avoidance *of* decision. As such the somatic marker does more than merely signal behavior, it indirectly *operates* on behavior, or is in other words an operant. Similarly, when avoidance behavior is not

reinforced, the non-behavioral state of relaxation or muscular inactivity will occur. This position that tension mediates avoidance conforms with Zajonc's (1998) argument that emotions are designed to help individuals make approach-avoidance distinctions, and contrasts with the true-false determinations that are mediated by Damasio's somatic marker (Damasio, 1994). Finally, the fact that tension and regret embody an *affective* quality distinguishes the hypothesis from the computational role assigned by Damasio. That is, tension and regret do not mark value because they are perceived, but rather they mark value because they are perceived to hurt. This affective value of tension and tension induced arousal serves as a mechanism to interrupt and redirect cognitive processing by bypassing cognitive filtering and thus expediting action (Lowenstein et al., 2001, Armony et al., 1997). It is through this facilitation of action that tension is reinforced.

If tension occurs to mediate avoidance of loss, it will not occur when avoidance is impossible, and will occur when avoidance *is* possible. Furthermore, tension will have no correlation with situations that require problem solving or declarative reasoning, and thus cannot somatically determine or mark the correctness of decisions. Thus, as a general rule, relaxation will occur in circumstances where there is no avoidable loss, such as situations where only moment to moment gain is perceived (e.g., flow experiences), or when no moment to moment gains or losses are perceived, as in parsing or eliminating thought, or attending to thoughts that have no negative or positive import (e.g., meditation, mindfulness meditation, resting). However, in our workaday lives, moment to moment gains and losses are randomly interspersed, and the positive affect of gain is intermingled with the regret and accompanying tension due to loss. This concept of 'eustress', a neologism that merges the terms of euphoria and stress (Selye, 1972), conflates the causes of negative affect and tension with positive affect, rather than representing them as two different types of perceived events that elicit two very different neurological and behavioral outcomes. For example, during a closely contested football game, at times a fan will perceive negative prediction error, as when a play goes for a loss, or positive prediction error, as when the play results in a score. In this case, resulting disappointment, tension and euphoria seem to merge into a combined emotion of 'eustress', even though they are respectively due to different informative causes. Since positive surprises almost always come with the potential 'cost' of negative turns of fortune, the cost of feeling good is at times to feel bad! Furthermore, since positive discrepancy is necessary for effective learning and the motivation to learn, its invariable accompaniment with negative discrepancy leads to the conclusion that the latter's entailments of tension and regret seem to become necessary for effective decision making, even though they are in fact incidental and detrimental to effective decision making. Because tension facilitates avoidance, it will always decrease the efficiency of information processing and prevent critical information

from entering the 'cognitive system' (Tataryn et al., 1989). This observation conforms with the classic Yerkes-Dodson thesis (Yerkes & Dodson, 1908) that predicts that performance will increase with increasing stress to an optimum point until the stress 'load' becomes too great, resulting in progressively decreasing performance. For example, a predictable situation with little or no positive or negative variance will not stimulate performance (an easy, routine task), but will increase performance and peak as positive variance increases (e.g. flow experiences), and then result in the progressively decline of performance as moment to moment behavior signifies progressively more negative results (e.g. a complex task with an unrealistic deadline).

Finally, minor variances in schedules will elicit tension for even incidental day to day choices that entail discrepant loss. For example, the small variances that occur while meeting a deadline at work, or choosing between rational and affective outcomes (e.g. browsing the internet vs. keeping focused on one's job) results in muscular tension that can 'build', thus causing end of day muscular pain and exhaustion. Surnamed the 'Cinderella Effect' (Wursted et al. 1991, 1996; Hagg, 1991), the continuous tensing of one group of muscles causes them to eventually fail, and thus recruit other groups of muscles more peripheral to the original group, resulting in a literal pain in the neck.

The Paradox of Choice

If the pain of tension and regret is the result of surprising knowledge of the negative moment to moment results of choice, and muscular tension occurs to expedite the avoidance of regret once it is perceived, then tension and regret may be avoided *before* they are experienced by simply avoiding knowledge of the negative results of choice. This avoidance may be accomplished incidentally or intentionally. For example we can choose a spouse, a career, or waste time at work without regret because the prospective losses for alternative choices are only obscurely perceived, and we thus have no perceptible cause *for* tension or regret. On the other hand, we may intentionally avoid perceiving the potential negative implication of choice by avoiding sources of information that may provide counterfactual information that conflicts with the perceived goodness of our decisions. Thus, if we refinance our house, buy a new car, or make reservations for a plane flight, subsequently refusing to access information that demonstrates that we could have made more cost effective choices effectively avoids the regret they will elicit.

A third approach to avoiding regret is to simply postpone decision. We can if we choose

window-shop 'forever', and pleasurably appraise the novel implications of future choices. The appraisal of future positive choices elicits the same neurological events that underscore feelings of pleasurable anticipation (Nestler et al. 2001), but because actual choice is not entailed, loss is not perceived and tension or regret is not experienced. In the past, this was more often incidentally rather than purposively performed, but an aspect of modern life is that appraised values may be chosen at any time. For example, in times past making phone calls, watching TV, shopping, etc. could only be performed at certain times and places. Nowadays, these diversions can be chosen at any time, thus making choice much more portable than before. Besides the increasing portability of choices, the fact that the pleasurable appraisal of response options is sustained through the ever increasing multiplicity of new or novel choices leads to the conclusion that a surfeit of options is a good thing. But this results in a behavioral paradox, as multiplying future choices is good for anticipation, but bad for choosing. That is, increasing choices increase the pleasure of anticipating them as future events, but also increases the likelihood that actually choosing between them will be attendant with negative variances that parallel tension and regret. This results in a paradox of choice. Like Aladdin beholding the untold treasures in the Magician's cave, we marvel and take pleasure appraising all options of choice, but incur distress when we have to make a choice. So, to have one's cake but enjoy *apprehending* eating it too, choice is deferred or perhaps not even made. The irony is that approach or consumnatory behavior will be reduced, even though the summary appraised value increases with the number of available options. In other words, just 'wanting' to eat the cake is reward enough.

Finally, the *actual* rather than prospective experience of regret and tension can be mitigated by avoiding rumination that entails considering what options or judgements to take, or through re-conceptualizing the event so the source of regret is interpreted as inevitable or unavoidable. Avoiding judgments that can result in the pain of regret is represented in mindfulness or acceptance based psychotherapeutic procedures (Hayes et al. 2006) that contrast with cognitive therapies (e.g. Alford & Beck, 1997) that involve the reformulation rather than avoidance of judgment.

The Pragmatics of Tension Control

Ultimately, to avoid tension is to simply eliminate the circumstances in which it can be reinforced. That means to be relaxed, one must simply avoid or postpone making choices large and small that entail avoidable loss. Schwartz (2004) calls controlling significant choices 'satisficing', when options are limited by choosing agents who will choose for you,

by restricting response options before choice, or by restricting the times when one can choose. But the many incidental or micro-behavioral choices of a workaday life that elicit tension also can be avoided or postponed. This strategy indeed conforms with the everyday heuristics we use to manage our emotional lives. We commonly exclude in working environments any choices that can seriously impede our productivity by simply removing ourselves to office environments where we cannot be distracted by affective choices (e.g. TV, refrigerator) that abound at home or otherwise consistently avoid indulging in them during working hours. This in effect separates decisions that are hindered by conflicting values that are determined by logical (molar) and affective (molecular) choices. Theoretically, by eliminating all affective distractions (e.g. chatting, checking email, personal phone calls) for the span of a working day, there can be no regret during the day for time misspent, and thus no tension or stress. But we don't as a rule go to this extreme. The reason for this is the presumed inefficacy of a higher *degree* of avoidance as a means to reduce tension. It is simply not generally conceived that the indulgence in minor distraction is just as responsible for tension as major distractions. Indeed, the benefits of the *avoidance* of distraction is generally equated with the *indulgence* in distraction, and although tension is meliorated by taking a time out to chat, surf the internet, or take a coffee break, its reinforcement by such activity will sustain such distractions as a continuous prime for future choices and attendant tension. In other words, the ongoing loss of the opportunity to pursue distracting events will elicit tension if this loss is perceived as avoidable, but will not if such loss cannot be avoided, as when such options are made *consistently* unavailable. This radical and consistent reduction of distraction shares much in common with meditative disciplines that achieve relaxation through reducing or attenuating thought, yet it is not thought that causes tension and anxiety (Hayes et al. 2006), but the non-verbal appraisals that are precursors to choice. Indeed, the radical reduction of appraisal or judgement is core to mindfulness techniques (Kabat-Zinn, 1993) that are commonly used separately or in conjunction with meditative procedures as a means of reducing or preventing tension or stress. Ultimately, if the control of tension is dependent upon the moderation of an abstract property of thought (i.e. judgement or appraisal) rather than parsing or attenuating thought, then the popular and academic conceptions of the etiology and treatment of stress must substantially change.

Learning Theory and Tension

A generally accepted principle in psychology is that relaxation occurs because of focused attention, and tension occurs because of demand. In turn, tension becomes a subset of a

reflexive fear based mechanism, or a 'flight or fight' response. But 'attention' (Donahoe & Palmer, 1993) and 'demand' are taxonomies for general and not specific events, and demand rarely implicates a threat to well being, as is essential to fear. In fact, the use of attention and demand as literal and specific causes can result in plainly erroneous predictions. For example, if stress is due to demand, then any demanding activity is stressful, and if focused attention causes relaxation, then any activity that leads to focused attention is relaxing. These predictions of course are absurd for an individual who is relaxed while reading a book due to the demand of a homework assignment, or for a nervous individual who is attentively focused on finishing a final exam.

In the academic and popular literature of stress, because the independent measure of muscular tension and anxiety is defined through non specific categories or taxonomies of events such as demand or attention, the 'cures' for stress are equally as broad. Thus relaxation occurs through focusing attention or eliminating demand. There is no fine grain relationship of behavior and the environment that can be controlled, and we can only be relaxed by secluding ourselves from the world rather than making adjustments to our world. Thus elements of choice are not even considered as causal factors for muscular tension and anxiety. Specifically, fine grain co-variations between stimuli and behavior are not considered as independent measures of tension, and are subsumed under molar concepts such as 'attention' or 'demand' that are only indirectly and imperfectly contacted through the use of literal language. For therapies that employ literal language, an individual becomes therefore less regretful or tense if his appraisal of response options is altered through sources that reinterpret information, and thus change abstract relationships between events. Although this may describe how psychotherapeutic interventions (or the helpful advice of a friend) mitigate stress, the underlying molecular causes of tension remain unaddressed. Because tension results from events that are far broader in kind and much higher in frequency than intermittent interpersonal causes, therapies for tension and stress such as meditation and rest must center on the mundane rather than the personal choices of our lives.

Yet even the mundane origin of tension is attributed to S-R metaphors that cannot describe how tension co-varies with ongoing experience. Near universally accepted explanations for stress that posit relaxation (Benson, 1974) and tension (Selye, 1980) as reflexive events to simple stimuli encapsulated as attention or demand are incapable of describing tension, stress, and its remedies except in the broadest terms. If the metaphor of choice replaces 'demand' or 'threat' as the primary descriptor of the etiology of tension and anxiety, then the management of simple contingencies of reinforcement are implicated in the origin, prediction, and control of everyday tension and stress. But this avenue has scarcely been

researched due in no small measure to the a-priori rejection of learning as a valid explanatory perspective. Ultimately, this argument is won not by the parsimony of a behavior analytic explanation, but through the power of procedure to effect behavioral change. That of course is the mandate and justification of a true science of behavior.

References

Alford, B. A. & Beck, A. T. (1997) *The Integrative Power of Cognitive Therapy*. Guilford: New York

Antony, M. M., Orsillo, S. M., Roemer, L. (2001) *Practitioner's guide to empirically based measures of anxiety*. Springer: New York

Armony, J. L., Servan-Schreiber, D. Cohen, J. D. & LeDoux, J. E. (1997) Computational modeling of emotion: Explorations through the anatomy and physiology of fear conditioning. *Trends in Cognitive Sciences*. I. 28-34

Bargdill, R. W. (2000) The study of life boredom. *Journal of Phenomenological Psychology*, 31: 188-219

Bargh, J. A. & Chartrand, T. L. (1999) The unbearable automaticity of being. *American Psychologist*, 54(7), 462-478

Bechara, A, H., Damasio, D. Tranel, A. Damasio, (1997) Deciding Advantageously Before Knowing the Advantageous Strategy, *Science*, 275, 1293-1294

Benson, H. (1975) *The Relaxation Response*. Harper Collins: New York

Berridge, K. (2001). Reward Learning: Reinforcement, Incentives, and Expectations, *The Psychology of Learning and Motivation*, 3, Academic Press, New York.

Bierman, D. J., Destrebecqz, A., Cleeremans, A. (2005) Intuitive decision making in complex situations: somatic markers in an artificial grammar learning task, *Cognitive, Affective, & Behavioral Neuroscience*, 5(3) 297-305

Borkovec, T. D., Alcaine, O., & Behar, E. (2004). Avoidance theory of worry and generalized anxiety disorder. In R. G. Heimberg, C. L. Turk, & D. S. Mennin (Eds.), *Generalized anxiety*

disorder: Advances in research and practice, pp. 77-108. New York: Guilford Press.

Camille, N. Coricelli, G. Sallet, J. Pradat-Diehl, P., Duhamel, J. & Sirigu, A. (2004) The involvement of the orbitofrontal cortex in the experience of regret. *Science*, 304(5674), 1167-1170

Clore, G. L., Storbeck, J., Robinson, M. D. & Centerbar, D. (2005) Seven Sins in the Study of Unconscious Affect. In B. L. Feldman, P. Niedenthal, and P. Winkielman (Eds.) *Emotion, Conscious and Unconscious*, New York: Guilford Press

Clore, G. L. & Ortony, A. (2000) Cognition in emotion: Always, sometimes, or never? In R. D. Land & L. Nadel (Eds.) *Cognitive neuroscience of emotion*. *Series in affective science* (pp. 24-61). New York, NY: Oxford University Press

Csikszentmihalyi, M. (1990). *Flow, the psychology of optimal experience*. New York: Harper Collins.

Damasio, A. (1994). *Descartes Error: Emotion, Reason, and the Human Brain*. Avon: New York.

Donahoe, J.W., & Palmer, D. C. (1993) *Learning and Complex Behavior*, Needham Heights, Ma: Allyn and Bacon

Dunn, B. D., Dalgleish, T., & Lawrence, A.D. (2006) The somatic marker hypothesis: A critical evaluation. *Neuroscience and Biobehavioral Reviews,* 30(2): 239-271

Eccleston, C. & Crombez, G. (1999) Pain demands attention: a cognitive-affective model of the interruptive function of pain. *Psychological Bulletin*, 125(3): 356-366

Ernst, M. & Paulus, M. P. (2005) Neurobiology of decision making, A selective review from a neurocognitive and clinical perspective, *Biological Psychiatry*, 58(8), 597-604

Fried, I., Wilson, C. L, Morrow, J. W., Cameron, K. A., Behnke, E. D., Ackerson, L. C., & Maidment, N. T. (2001). Increased dopamine release in the human amygdala during performance of cognitive tasks, *Nature Neuroscience*, 4(2), 201-206.

Friman, P. C., Hayes, S. C., and Wilson, K. G. (1998) Why behavior analysts should study emotion, the example of anxiety. *Journal of Applied Behavior Analysis*, 31, 137-156

Gellhorn, E. (1967) *Principles of autonomic-somatic integration*. Minneapolis: University of Minnesota Press

Gellhorn, E. & Kiely, W. F. (1972) Mystical states of consciousness: Neurophysiological and clinical aspects, *Journal of Nervous and Mental Disease*, 154, 399-405

Greicius, M. D. Krasnow, B., Reiss, A. L., Menon, V. (2003)Functional connectivity in the resting brain: A network analysis of the default mode hypothesis. *Proceedings of the National Academy of Science,* 100, 253-258

Gresham, F. G., Kern, L. (2004) Internalizing Behavior Problems in Children and Adults. In Rutherford, R. B., Quinn, M. M., Mathur, S. R. (Eds.), *Handbook of Research in Emotional and Behavioral Disorders*. New York: Guilford

Hagg, G. (1991). Static Work loads and occupational myalgia- a new explanation model. In P. A. Anderson, D. J. Hobart, and J. V. Danhoff (Eds.). *Electromyographical Kinesiology* (pp. 141-144). Elsevier Science Publishers, P. V.

Hayes, S. C., Luoma, J., Bond, F., Masuda, A., and Lillis, J. (2006). Acceptance and Commitment Therapy: Model, processes, and outcomes. *Behaviour Research and Therapy*, 44, 1-25.

Jacobson, E. (1970) *Modern treatment of tense patients*. Springfield, Il: Charles C. Thomas.

Kabat-Zinn, J. (1993) Mindfulness Meditation: Health Benefits of an Ancient Buddhist Practice. In Goleman, D. and Gurin, J. (eds.) Mind/Body Medicine, Consumer Reports Books, Yonkers, Ny.

Kilstrom, J. (1987) The cognitive unconscious, *Science*, 237, 1445-1452

Koepp, M.J., Gunn, R.N., Lawrence, A.D., Cunningham, V.J. Dagher, A. Jones, T., Brooks, D.J. Bench C. J., & Grasby, P.M. (1998). Evidence for striatal dopamine release during a video game. *Nature*, 393. 266-268.

Lamal, P. A. (1998) Advancing backwards. *Journal of Applied Behavior Analysis*, 31, 705-706

LeDoux, J. (1997). *The Emotional Brain: The Mysterious Underpinnings of Emotional Life*. New York: Touchstone.

Lewicki, P., Hill, T., & Czyzewska, M. (1992) Nonconscious acquisition of information. *American Psychologist*, 47, 796-801

Lowenstein, G. F., Weber, E. U., Hsee, Christopher, K. , & Welch, N.(2001) Risk as feelings, *Psychological Bulletin*, 127(2), 267-286

Maia, T. V. & McClelland, J. L. (2004) A reexamination of the evidence for the somatic marker hypothesis: What participants really know in the Iowa gambling task. *Proceedings of the National Academy of Sciences*, 45, 16075-16080

Malmo, R. B. (1975) *On emotions, needs, and our archaic brain*. New York: Holt, Reinhart, and Winston.

Marr, A. J. (2006) Relaxation and muscular tension: A bio-behavioral explanation. *International Journal of Stress Management*,13(2), 131-153

McGuigan, F. J. (1991) *Calm down: A guide for stress and tension control* (rev. ed.) Dubuque, IA: Kendall/Hunt

Mellers, B. A., McGraw, A. P. (2001) Anticipated emotions as guides to choice. *Current Directions in Psychological Science.* 10, 201-214

Nestler, E. J., Hyman, S. E., Malenka, R. (2001) *Molecular Neuropharmacology.* New York: McGraw Hill

Perry, J. T. (1997) *In the Zone*. Chicago, Ill.: Contemporary Books

Raichle, M. E., MacLeod, A. M., Snyder, A. Z., Powers W. J., Gusnard, D. A., Shulman, G. L. (2001) A default mode of brain function, *Proceedings of the National Academy of. Sciences*. 98, 676-682

Rolls, E. (1999) *The brain and emotion*. Oxford: Oxford University Press

Schwartz, B. (2004). *The Paradox of Choice: Why More is Less*. Hopewell, N. J.: Ecco.

Selye, H. (1980) *Selye's Guide to Stress Research*, New York: Van Nostrand Reinhold

Schulkin, Jay, ed. (2005) *Allostasis, Homeostasis, and the Costs of Physiological Adaptation.* Georgetown University, Washington DC

Schultz, Wofram (1998) Predictive reward signal of dopamine neurons. *Journal of Neurophysiology*, 80, 1, 1-27

Sheppard, J. A. & McNulty, J. K. (2002) The affective consequences of expected and unexpected outcomes. *Psychological Science*, 13, 85-88

Sloman, S. A. (1996) The empirical case for two systems of reasoning. *Psychological Bulletin*, 119, 3-22

Sparling, P. , Giuffrida, A. , Piomelli C., Rosskopf, L., Dietrich, A. (2003) Exercise activates the endocannabinoid system. *Neuroreport*. 14(17):2209-2211

Storbeck, J. & Robinson, M. D. (2004). When preferences need inferences: A direct comparison of the automaticity of cognitive versus affective priming. *Personality and Social Psychology Bulletin*, 30, 81-93.

Storbeck, J. Robinson, M. D., McCourt, M. E. (2006) Semantic processing precedes affect retrieval: the neurological case for cognitive primacy in visual processing. *Review of General Psychology*, 10(1), 41-55

Tataryn, D. J., Nadel, L. Jacobs, W. J., (1989) Cognitive Therapy and Cognitive Science, in Freeman, A., Simon, K. Butler, L, & Arkowitz, H. (Eds.) *Comprehensive Handbook of Cognitive Therapy.* New York: Springer

Taub, E., Ellman, S. J., & Berman, A. J. (1966). Deafferentation in monkeys: effect on conditioned grasp response. *Science*, 151, 593-594.

Teuber, H. L. (1972). Unity and diversity of frontal lobe functions. *Acta Neurobiologiae Experimentalis*, 32, 615-656.

Tomb, I, Hauser, M., Deldin, P. & Caramazza, A. (2002), Do somatic markers mediate decisions on the gambling task*?* *Nature Neuroscience*, 5, 1103-1104

Williams, B. A. (1997) Varieties of contrast: A review of incentive relativity by Charles Flaherty. *Journal of the Experimental Analysis of Behavior*, 68, 133-141

Wursted, M., Bjorklund, R., & Westgaard, R. (1991). Shoulder muscle tension induced by two VDU-based tasks of different complexity. *Ergonomics*, 23, 1033-1046

Wursted, M., Eken, T., & Westgaard, R. (1996). Activity of single motor units in attention demanding tasks: firing pattern in the human trapezius muscle. *European Journal of Applied Physiology*, 72, 323-329

Yerkes, R. M. , & Dodson, J. D. (1908) The relation of strength of stimulus to rapidity of habit formation. *Journal of Comparative Neurology and Psychology*, 18, 459-482

Zajonc, R. (1984) On the primacy of affect. *American Psychologist*, 39, 117-123

Zajonc, R. (1998) Emotions. In D. Gilbers, S. Fiske, & G. Lindzey (Eds), *Handbook of social psychology*, New York: Oxford University Press

Zeelenberg, M. , van Dijk, W., van der Plight, J. Manstead, A., van Empelen, P. Reinderman, D. (1998) Emotional reactions to the outcomes of decisions: The role of counterfactual thought in the experience of regret and disappointment. *Organizational Behavior and Human Decision Processes*, 75, 117-141

Zuriff, G. E. (1985) *Behaviorism: A conceptual reconstruction*. New York: Columbia University Press.