PHYSIOLOGICAL MEASURES OF THEORETICAL CONCEPTS: SOME IDEAS FOR LINKING DEFLECTION AND EMOTION TO PHYSICAL RESPONSES DURING INTERACTION

Dawn T. Robinson, Christabel L. Rogalin and Lynn Smith-Lovin

ABSTRACT

After a vigorous debate in the late 1970s, the sociology of emotion put aside most discussion of whether or not the physiological arousal associated with emotion labels is differentiated. Since this early period, scholars have made great progress on two fronts. First, theories about the interrelationship of identity, action and emotion have specified a family of new concepts related to emotion. Second, a large corpus of research on the physiological correlates of emotional experience emerged. In this chapter, we review the well-developed control theories of identity and emotion, and focus on the key concepts that might relate to different physiological states. We then review the general classes of physiological measures, discussing their reliability, intrusiveness and other features that might determine their usefulness for tracking responses to social interaction. We then offer a highly provisional mapping of physiological measures onto the concepts

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that they might potentially measure, given past research about how these physiological processes relate to environmental stimuli. While any linkage between concepts and measures must be speculative at this point, we hope that this review will serve as a stimulus to theoretically guided research that begins to assess the validity of these new measures for sociological use.

INTRODUCTION

There are as many definitions of emotion as there are theoretical views of its origins and consequences. This apparent disarray is not as troubling as it might sound. Instead, it represents the fact that such concepts are only scientifically useful in the context of a theoretical statement that embeds them in a larger process. Nonetheless, reviews of the sociology of emotion both early (Thoits, 1989) and late (Turner, 2000) note that virtually all definitions of emotion contain two elements – some element of physiological arousal and an interpretation of that arousal using contextual cues and cultural knowledge.

Much of the early debate in the subfield centered on which of these two elements was dominant. Those called "positivists" (e.g. Kemper, 1978) argued that social interaction led to predictable, distinctive, differentiated physiological states; cultural labels were then attached to the multiplicity of social situations and mixes of physiological arousal that were meaningful (and frequently encountered) within a given culture (Kemper, 1987). Social constructionists (e.g. Gordon, 1990; Hochschild, 1983) gave more weight to the socio-cultural nexus that gives us the words, behavioral cues, and narrative scripts to define emotions. While these scholars ranged from those who implied a "real" emotion that is then managed by actors to comply with social norms (Hochschild, 1983, 1990) to those with the more radical position that even the autonomic responses entailed by an emotion are specified by our cultural understanding of it (Gordon, 1990), they shared a distaste for any serious reliance on the biological substrate for our understanding of the important social dynamics that produced and were motivated by emotion.

Turner (2000) reviewed 20 authors (ranging from Darwin in 1872 to Turner himself in 1996) who posited between 3 and 10 primary emotions that they believed to be primary, basic and universal across cultural settings. While the search for a set of primary emotions centered in psychology and evolutionary biology, most sociologists and anthropologists interested in understanding emotion were adamant about emotion's social and cultural rather than physiological roots. Kemper (1978, 1990) and Turner (1996, 1999a, b, 2000) were notable exceptions to this general position among social scientists. This often rancorous debate[1] gave way to a more productive period of synthesis and development in the late 1980s and 1990s. Marked roughly by Kemper's (1987) article in the *American Journal* *of Sociology*, sociologists reached a point of relative consensus that the social process that led to emotional experiences was a more important focus than the issue of whether there were one or four or ten primary, universal emotions that had a physiologically distinct profile. Theory development proceeded with little attention to the biological substrate with which social processes were intertwined.

Not surprisingly, research on the physiology of emotion did not remain dormant during this period. A wealth of new evidence has been generated by new measurement technologies. While much of the attention in recent years has been focused on the cognitive neuroscience of emotion (for example, Lane & Nadel, 2000), several substantial research programs developed a much fuller understanding of the autonomic nervous system and related endocrine physiology.

Since these developments have proceeded in parallel, with relatively little attention by sociologists (Turner, 2000, being a notable exception) to the progress of physiological research, we suggest that it is time to reassess whether or not physiological analogues to emotional experience might be useful for research on sociological theories of emotion. In this chapter we will review briefly the general types of physiological responses that might be related to socio-emotional experience. We will concentrate in particular on those classes of physiological response that appear to have some usefulness in monitoring responses to ongoing social interaction. Because of this constraint, we will largely ignore the voluminous new literature on direct measurement of central nervous system activity through positron emission tomography (PET) and functional magnetic resonance imaging (fMRI) technologies, although there is evidence that these patterns may be reliably linked to specific emotional experience (LeDoux, 1996). While technology is developing that would allow real time assessments of brain activity during social interaction, that technology is unlikely to become available to social scientists in the near future. Instead, we will concentrate on measures that could be implemented in current laboratory settings. We try to concentrate on measures that have some demonstrated reliability across gender, culture and other major social divides, noting limitations of this sort when they are known.

Arguably, the first step in discovering whether or not a measurement technology is useful for one's research is a pre-existing conceptual understanding of what one is trying to measure. Therefore, before we delve into the often contradictory research on physiological responses and emotional experience, we briefly review the sociological theories that might most productively employ such measurement technology. Since such measures are most feasible inside the laboratory, we will concentrate our summary of concepts in need of measurement within the structural symbolic interactionist theoretical tradition. These researchers have used experimental studies to test and elaborate their theories, and have potential for making use of physiological measurement. They also offer a wide array of affective concepts within the context of fairly well-defined theoretical structures, so that we might expect the interplay between theoretical prediction and measurement over the course of a series of studies that would be necessary to firmly establish the validity of any physiological measure for a theoretical concept.

CONCEPTS IN THE STRUCTURAL SYMBOLIC INTERACTIONIST THEORIES OF EMOTION

The two major theories of emotion in the more quantitative, structural branch of symbolic interaction are affect control theory (Heise, 1979; MacKinnon, 1994; Smith-Lovin & Heise, 1988) and identity control theory (Burke, 1991, 1996; Burke & Reitzes, 1991). As variants of symbolic interactionism, both emphasize the central role of identity meanings and the ability of social interactions to sustain them in producing emotional responses. Both theories share a common basis in William T. Powers' (1973) cybernetic control model of perception. We therefore begin with the concepts that they share in common, before proceeding to the somewhat differing predictions that they make about emotional response.

As control systems, both theories have as their central mechanism the comparison between a reference signal (which is constant for all purposes within the context of a given social interaction) and input from the situational context in which the actor is embedded. The reference signal in both theories is a set of meanings. In affect control theory, these meanings are fundamental sentiments that are acquired through past interactions, exposure to cultural materials and other sources. The meanings have both cognitive and affective components, which are inseparably evoked when self, other interactants and actions are labeled in the definition of a situation (MacKinnon, 1994). The affective meanings fall on three dimensions that, based on the work of Charles Osgood and his colleagues (Osgood, May & Miron, 1975; Osgood, Suci & Tannenbaum, 1957), are presumed to be universal and applicable to all concepts that actors use to define the situation. The three dimensions are evaluation (goodness vs. badness), potency (powerfulness vs. powerlessness), and activation (lively vs. quiet). Identity control theory presumes a somewhat less cultural, more personalized set of self-identity meanings that are arranged in a salience hierarchy within a stable self structure (Burke, 1991; Stryker, 1980). The meanings can vary in the number and type of dimensions that are relevant, making the assessment of the reference signal a more individualized, domain-specific enterprise.

In both theories, actors operate to maintain the meanings that act as their reference levels within a situation. Perceived events within the situation are compared to the reference meanings to assess the current state of the system with regard to meaning maintenance. In affect control theory, the actor processes an event of the general form “the *actor* does *behavior* to the *object person* within this *setting*” to produce a set of situated meanings for the actor, behavior, object-person and setting, which are then compared to the fundamental sentiments associated with those event elements. This comparison process results in an assessment of *deflection*, which is mathematically defined as the sum of the squared differences between the situated meanings and the fundamental sentiments for each event element on each dimension (Heise, 1979). An equivalent way of describing deflection is the distance in the multiple-dimensional evaluation – potency – activity space that the event elements have been disturbed by the perceived event. In identity control theory, the reference level is an identity standard (a stored set of self-meanings) that serves as a guide for behavioral outputs by the actor. The perceptual input is how people see themselves in the situation, a result of reflected appraisals by others and of self-perception within the setting. A comparator compares the perceptual input with the identity standard and assesses the amount of *discrepancy* between the two. While identity control theory is not formulated in mathematical terms, the discrepancy is clearly a difference between the two theoretical elements – the identity standard and the perceptions from the situation.

While they differ in the location of the reference signal (all event elements vs. self-identity), the dimensions on which they are compared (three stable dimensions vs. more individuated, domain specific structure), and the form of the comparison (mathematically specified vs. a general sense of difference), both theories share the same central control principle. They assume that people operate so as to confirm the meanings that they hold for the situation. Under normal circumstances, people act so as to confirm their identity meanings given the social resources (e.g. network alters and behavioral options) that the situation offers. When events fail to support meanings, new actions (or, if action is not possible, cognitive relabelings) will occur to restore those meanings.

Burke (1991, 1996) has been most explicit about the psychological, and presumably physiological, experience of discrepancy between self-meaning reference levels and situational perceptions. He relies heavily on Mandler (1982) in predicting that autonomic activity (including distress and anxiety) will result whenever some organized act or thought process is interrupted. Such interruptions may occur when demands are made on individuals that tax or exceed the resources that those individuals have for managing them, or they may be the result of social factors outside of the individual (e.g. other actors with competing ideas about the meaning of the individuals’ role-identities). Interruption happens whenever expectancies are disconfirmed or when lines of action are prevented from completion. Since, under identity control theory, people expect their identity meanings to be confirmed by those around them and engage in lines of action consistent with those meanings, clearly discrepancy constitutes an interruption and leads to stress. Among other things, this response leads the actor to re-orient attention to the identity that is being threatened.

In spite of its precise mathematical definition, affect control theory has been less explicit about the direct experience of deflection. Perhaps because it has a more elaborated model of emotion (see Averett & Heise, 1987; MacKinnon, 1994; Smith-Lovin, 1990; and discussion below), most affect control scholars have regarded deflection as a theoretical construct without a direct experiential component. However, it is clear from the discussions of deflection in the context of the theoretical model and from the few studies that have directly linked deflection to perceived likelihood (e.g. Heise & MacKinnon, 1987) that this disconfirmation of the affective meanings implied by one's definition of a situation would lead to a sense of disequilibrium, surprise (or even shock in its extreme instances), and stress. Autonomic arousal should result in the sense that the control system explicitly predicts some response to this state of disconfirmation. The response can be either: (a) action to create new events that, when processed, restore situated meanings to their fundamental profile; or (b) a rethinking of events such that the new labels do not generate so much meaning disturbance. But in either case, action by the individual confronted by deflection is required.

While the two control theories agree that some type of disequilibrium and arousal (which we might label stress) will be produced when deflection/discrepancy is high, they have rather different positions on the specific emotions that will be experienced. As noted above, Burke (1991, 1996) is clear that the valence of emotion produced by discrepancy is negative. He follows Stryker (1987) in suggesting that failure to meet normative expectations for performance in salient role-identities will result in negative emotion. Burke labels the discrepancy-produced emotions as anxiety and distress. While psychologists might see these two emotions as relatively distinct (because distress is backward looking and anxiety refers to worry about future events), they share the character of being negative and activating. Indeed, their motivational role leading to attention and action within the theory argues explicitly for some type of autonomic arousal as well as displeasure. Similarly, Stets (2003) combines identity control theory and justice/equity theory to hypothesize that over-reward (reflected appraisals that are higher than those expected for confirmation of identity meanings) will lead to guilt and fear. When she finds that over-reward produces more positive feelings, she modifies the theoretical ideas somewhat (Stets, 2003, pp. 118–119). She suggests that in cases of moderate upward discrepancy, the self-enhancing impact of the over-reward might weaken the effect of the non-verification. In negative discrepancies, we effectively have two negatives: the non-verification and the punishment or under reward that constitutes negative treatment from the interaction partner. In cases of positive discrepancy, the non-verification of identity is counterbalanced somewhat from the positive feedback of the treatment of others – the fact that one is being treated well, and the "just world" belief that "good things come to good people." Therefore, she argues it is easier to adjust the self-identity meanings upward in a self-enhancing way; the fact that she finds that repeated over reward leads to lower levels of emotion, while repeated under reward leads to higher levels of emotion is a primary impetus for this theoretical revision.

While the effects of positive discrepancy may be in theoretical flux, Stryker (1987), Burke (1991, 1996) and Stets (2003) all agree that confirming identity meanings by producing role performances that are expected and approved by others will result in positive emotion. When reflected appraisals from the environment produce no discrepancy, people are confirming their identity meanings and no restorative action is required. These positive effects will strongest when the identities are salient in the self hierarchy and when interactions are with alters who are important and intimate in the individual's social network.

Affect control theory's predictions are quite a bit more complex, because of its mathematical model (Averett & Heise, 1987; Heise & Calhan, 1995; MacKinnon, 1994; Robinson & Smith-Lovin, 1992, 1999; Smith-Lovin, 1990). Emotions accompany deflections and signal to an actor how his or her experience did or did not confirm expectations based on the current definition of the situation (Smith-Lovin, 1990; Smith-Lovin & Heise, 1988). The type of emotional response is determined by both the size and direction of the deflection as well as by the transient impression produced by the situation, all of which are calculated on the three underlying dimensions of affective meaning – evaluation, potency and activity. In other words, the two components of emotions in the model are: (a) the situated meanings brought about by the interaction; and (b) the distance and direction of movement between those meanings and the fundamental meanings culturally associated with the role-identity of the focal actor. Thus, when deflections are small (i.e. when events are confirming), an actor's emotional response is largely determined by his or her identity (i.e. the fundamental evaluation, potency and activity meanings of that cultural symbol). However, when events are disconfirming, the nature of this deflection heavily determines the character of the emotional response. Considering only the evaluation component of emotion, the equation predicting the emotional response in affect control theory can be reduced to:

$$E = 2T - I \quad \text{or} \quad T + (T - I)$$

where E is the evaluation of the emotion, T is the transient evaluation produced by the social interaction, and I is the evaluation of the fundamental self-identity (Averett & Heise, 1987). Thus, we see that emotional response will be influenced both by the impressions created by the current situation (T) and by the deflection of one's situated identity meanings away from fundamental self-identity ($T - I$) (Averett & Heise, 1987; Smith-Lovin, 1990). When social events fail to confirm fundamental identity, the nature of one's transient feelings in the current setting (T) is very important in predicting the evaluative content of one's emotional response. If we take a negative transient impression and subtract from it a positive self-identity (I), a quite negative emotion will be the result. If a person with a negative self-identity is deflected to a temporarily positive self-image, the emotion will be positive (T will be high, and the subtraction of a negative I will add to this positivity). The emotion is positive both because of the pleasant transient impression, and because it is so far above the normally negative fundamental self-image.

On the other hand, when social events confirm the sentiments of one's fundamental identity, or

$$T = I$$

Then,

$$E = 2T - I = 2I - I = I$$

In other words, when one is not deflected, the valence of one's emotional experiences mirror the valence of one's fundamental identity. The empirically estimated equations in the mathematical model differ somewhat for the other two dimensions (see Averett & Heise, 1987, for a full discussion) but the basic form of the emotions predictions is similar. Rather than assuming that discrepancies have the same emotional impact on everyone, affect control theory stresses the importance of identity in determining emotion. And, rather than assuming that discrepancy only produces positively and negatively valenced emotions (either satisfaction with current role performance or distress/anxiety about failure to maintain identity standards), the mathematical model underlying affect control theory predicts specific three-dimensional profiles (on the evaluation, potency and activity dimensions) for the emotions that will be produced by a given identity embedded in an event defined by another actor's role-identity, an action that one of them takes, and perhaps a socially defined setting in which the action occurs.

RELATED THEORIES IN PSYCHOLOGY

Despite our focus on sociological theories relating identity, action and emotion, we will mention two closely related psychological theories that suggest similar emotion productions. These psychological traditions might also benefit from the physiological measures of the emotion that we attempt to map conceptually in the next sections, since they share some close conceptual links with the sociological approaches. The two theories with the most obvious connections are Carver's and Scheier's (1981, 1990, 2000) self-regulation theory and Higgins' (1987, 1989) self-discrepancy theory.

Carver and Scheier, like Heise and Burke, drew explicitly on William T. Powers' (1973) perceptual control model in developing their ideas about how intentions, actions and emotions were related. Their theory is focused on how people accomplish goals, and has much in common with an earlier treatment of cybernetic systems in Miller, Galanter and Pribam (1960). The core idea is that actors have hierarchically organized sets of goals. Goals at one level imply behavioral programs at lower levels to accomplish those goals (if one has the goal of winning a Nobel Prize, one would implement a lower-level goal of earning a Ph.D., which would also imply lots of lower routines about going to class, meeting with professors, conducting research, etc.). The system is a control model because the goals act as a reference level for monitoring the environment and assessing whether or not progress is being made toward the goal. Actors act to minimize discrepancies, which mean to accomplish goals.

In addition to the negative (discrepancy reducing) feedback system, Carver and Scheier also write about positive (discrepancy enlarging) feedback systems with reference levels that the actor is motivated to move *away* from.[2] They relate these two types of systems to physiological research differentiating the approach/engagement behavioral activation system and the avoidance/withdrawal behavioral inhibition system (Carver & Scheier, 2000, pp. 46–47). There is evidence that these systems are independent and located in different neurological domains. Their predictions about emotional responses are in some ways highly parallel to the affect control theory model. In particular, there is a distinction between the general sense of expectancy (discrepancy or deflection), and the emotions produced: they

> . . . suggest that the result of the comparison process at the heart of this loop (the error signal generated by the comparator) is manifest phenomenologically in two forms: one is a hazy and nonverbal sense of expectancy – confidence or doubt; the other is affect, feeling – a sense of positiveness or negativeness (Carver & Scheier, 2000, p. 51).

There are some important differences, however. In self-regulation theory, actors experience emotion not as a direct result of discrepancy between goal and environment, but as a result of the *rate* at which they are progressing toward the goal (or, in the case of positive feedback loops, avoiding the undesired outcome). In effect, they posit a second-order loop that measures whether or not progress in reducing or enlarging the discrepancy is adequate. The rate of discrepancy change becomes the reference level against which the current state is judged. If the rate of discrepancy change is lower than anticipated, people experience negative emotions; if the rate of discrepancy change is as rapid (or more rapid) than expected, positive emotions are experienced. Emotions are somewhat different in character in discrepancy reducing (negative feedback) and discrepancy enlarging (positive feedback) loops. Fast progress in discrepancy reduction (moving toward a goal) produces elation, while inadequate progress produces depression. Rapid progress in a discrepancy enlarging an avoidance loop results in relief, while poor progress produces anxiety. In each case, moving in the undesirable direction leads to a negative evaluation emotion, but the potency and activity of the emotion vary – for slow progress toward goals, potency and activity are low (depression is low evaluation, low potency and low activity), while for slow progress away from disliked states the emotion is low potency and high activity. When moving in desirable directions, emotions are also differentiated on the non-evaluative dimensions. Doing well toward goals leads to high potency and activity, while doing well at avoidance produces lower activity (Carver & Scheier, 1990).

While Carver and Scheier deal more with goals than with self-identities, one direct descendent of this approach, Higgins' (1987, 1989) self-discrepancy theory, deals directly with different representations of the self. Higgins distinguished between multiple selves – the actual self, the ideal self (a personal standard) and the ought self (a standard derived from responsibilities to others). Here, the two major comparisons – between the actual and ideal and between the actual and ought – create potential discrepancies that lead to negative emotions. Again, these emotional responses are different on the potency and activity dimension. Failing to achieve congruence between the actual and the ideal self leads to depression, a low potency, low activity emotion. Failing to achieve congruence between the actual and the ought self leads to anxiety, a high activity, low potency emotion. Clearly, these predictions are closely related to the approach and avoidance systems that are the core of the self-regulation model – people want to approach the ideal self and to avoid failing in their responsibilities to others, the ought self. Higgins' arguments differ from Carver's and Scheier's in dealing only with the negative emotions, and in concentrating on the more social aspects of fear of punishment by others in not fulfilling the ought self.

ASSESSING THESE THEORIES

We have presented the dominant control theories in the sociology of identity and emotion and discussed some related theories in psychology. Now we turn our attention to a search for physiological analogues of the main concepts invoked by these theories. There are at least four aspects of affective/emotional response that we would need to measure to assess these theories and their predictions. We would need a measure of the generalized stress/surprise/disequilibrium that corresponds to deflection and/or discrepancy. We would need a measure of positively evaluated emotion – the response to confirming identities in identity control theory and the positive pole of emotion evaluation in affect control theory. We need a measure of negatively evaluated emotion – the response to disconfirming identity meanings in identity control theory and the negative pole of emotion evaluation in affect control theory. And, for a more complete assessment of emotion for affect control predictions, we would need measurements of potency and activation in emotional response as well.

This theoretical outline may sound like a rather unrealistic goal, given the current state of our knowledge about the physiology of emotion and the difficult of measuring it in socially-meaningful experimental situations. We offer two grounds for hope in our endeavor. First, the voluminous literature on variants of primary emotions, while it varies a great deal in its details, almost always includes a few key elements (see Turner 1999a, b, 2000 for a more complete discussion). Scholars acknowledge that satisfaction/happiness, aversion/fear, assertion/anger and disappointment/sadness combine with some sense of intensity or activation to produce basic, primary emotions. This common ground can be mapped onto a three-dimensional representation (see MacKinnon & Keating, 1989; Morgan & Heise, 1988) that supports the three-dimensional conception of emotion in affect control theory (with the activation operating more to discriminate positive emotions, and activity and potency combining to discriminate negative emotions). Happiness contrasts with fear, anger and sadness to form the evaluative dimension, fear contrasts with anger to form the potency dimension, and the level of intensity forms the activity dimension (contrasting states like irritation with fury, gratification with elation, and dispirited concern with terror and anguish). If this roughly three-dimensional representation is so central to the experience and observation of emotion across cultures and situations, it is more likely that we will be able to find reliable physiological analogues to these components of emotional experience. Our second point of optimism is more theoretical than empirical in nature. Having two theories that present well formulated models for when we expect to find various emotional responses greatly increases our chances of matching measures to concepts. We will return again in our conclusion to the route that we believe will be most effective in homing in on an understanding of the potential physiological measures and how they relate to theoretical concepts; suffice it to say at this point that we would not even begin this journey without a clear theoretical understanding of how we expect identity, action and emotion to interrelate.

THE PHYSIOLOGY OF EMOTION AND (MAYBE) DEFLECTION

There has been an explosion of recent research on the neurophysiology of emotion. Much of this more recent work focuses on activity in the central nervous system through the use of positron emission tomography (PET) functional magnetic resonance imaging (fMRI) techniques. These studies are giving us insight into processes such as the lateralization of brain activity that will undoubtedly lead to more refined theories about the relationship between the brain and social experience. Unfortunately, that theoretical development has yet to happen and the cost and constraints of these techniques do not suit them well for use in contemporary group processes laboratory research. Research on peripheral nervous system activity has experienced a similar explosion. More fortunately for our purposes, many of the processes generated in this system do lead to outcomes that are measurable in contemporary group processes research. In fact, recent technological advances have made many of these measures more reliable, more affordable, and less intrusive to the point that they can now be usefully employed even in the context of open interaction research. Accordingly, in the sections below we will first describe the physiological processes that appear relevant to the basic processes we want to study and then present information about some specific measures that might help group processes researchers to capture those processes.

We delineate three major types of physiological emotional response – behavioral, autonomic, and hormonal (see Carlson, 1998; Frijda, 1986). The behavioral component refers to activity of the skeletal muscles involved in respiration, muscle tension, and overt movement. The autonomic nervous system primarily involves changes in the functioning of smooth muscles and other internal organs, which have evolved to facilitate the behaviors and provide a quick mobilization of energy for those actions that might require vigorous motion (e.g. attacking a threatening intruder or running from it). Hormonal responses are also produced by the autonomic nervous system and reinforce the other autonomic responses by altering the chemical processes determining blood flow and the use of stored energy by the muscles.

These systems are obviously interrelated, in the sense that they are all three evolved through natural selection to help us respond to the environment in ways that will increase survival and reproduction. Escaping from threats and embracing good fortune were types of physical activity that helped organisms prevail in the face of changing surroundings. More problematically for measuring them as indicators of theoretical concepts, they are related in very complex ways with experienced emotion. Since more than one action can be implied by a single emotion (e.g. freezing or running in response to fear) and more than one emotion can be implied by a given action (i.e. we can jump out of fear of injury or for joy), none of these responses are likely to show a direct one-to-one correspondence with a single, socially interpreted, labeled emotion (Gray, 1994). Neurological responses, measured directly by brain activity, may have more potential for isolating specific emotional response. Still, as social scientists, we may benefit from the decades of research before the current emphasis on fMRI and other direct measurement of neurological activity shifted the emphasis in the physiological measurement of emotion to this domain.[3] What we hope is that configurations of behavioral, autonomic and endocrinological responses will correspond to our interests in stress, positive or negatively valenced emotion, and the additional dimensions of potency and activity.

The peripheral nervous system consists of all of the neurons throughout the body that are not in the brain, brainstem, and spinal cord (which compose the central nervous system). The peripheral nervous system is composed of two systems, the somatic nervous system and the autonomic nervous system. The somatic nervous system consists of all of our sensory and motor pathways. These include the neurons that control our skeletal muscles. This system regulates the way that we directly experience – and act upon – our environments. The autonomic nervous system, in contrast, consists of the neurons a number of systems that operate outside of our conscious direction – including the cardiovascular system, the respiratory system, the digestive system, and the endocrine system.

The autonomic nervous system is further divided into the sympathetic nervous system and the parasympathetic nervous system. Neurons from the middle (i.e. thoracic and lumbar) regions of the spinal cord lead to a variety of organs (e.g. heart, lungs, liver, salivary glands) and comprise the sympathetic nervous system. Neurons from the brainstem and from the lowest (i.e. sacral) regions of the spinal cord lead to many of the same organs (e.g. heart, lungs, stomach, bladder) and comprise the parasympathetic nervous system. Classic theories of the nervous system understood the sympathetic and parasympathetic nervous systems to operate in opposition to one another – with the sympathetic response working essentially to "speed things up" and the parasympathetic response working essentially to "slow things down." For example, activation of the sympathetic nervous system leads to pupil dilation, decreased salivation, accelerated heartbeat, increased blood flow to/from lungs, secretion of epinephrine and norepinephrine, production of bile, and inhibition of bladder contractions. Parasympathetic nervous response, on the other hand, includes pupil constriction, increased salivation, decelerated heartbeat, decreased blood flow to/from lungs, release of bile, and bladder contraction. These two sets of responses have traditionally been seen as two sides of the same coin. However, the contemporary view (e.g. LeDoux, 1986) is more complex. For example, both parasympathetic and sympathetic activity produce related outcomes in the liver – the former stimulating production of glucose and the latter stimulating its release. And, while the sweat glands and peripheral arterioles (small blood vessels in skin) are stimulated by the sympathetic system (producing a "cold sweat"), they are not inhibited by the parasympathetic nervous system (Carlson & Hatfield, 1992). In addition, some experiences seem to produce partial activation of both systems. For example, when looking at gruesome autopsy photographs, subjects' heart rates slowed and electrodermal activity increased (Lacey & Lacey, 1970, as cited in Carlson & Hatfield, 1992). So, the systems do not appear correspond in any simplified way to a general sense of high and low arousal. Rather, it appears that patterns of autonomic nervous response may correspond in a more specific way to discrete emotional experiences.

The literature on the expression and experience of emotion is vast. It is beyond the scope of this paper to provide a comprehensive review of the behavioral, autonomic, and endocrinological responses to emotion. Instead, we will review the evidence for particular patterns physiological expression that correspond to the basic theoretical concepts invoked by the sociological theories described above. Accordingly, we will organize our discussion below around evidence that appears to link behavioral, autonomic, and endocrinological responses to deflection, positive affect, negative affect, potency, and activity.

The Physiological Experience of Deflection

For decades, emotion researchers relied on a notion of generalized physiological arousal that underpinned our visceral experience of emotion. Empirical evidence accumulated during the past fifty years provides no support for understanding the physiology of emotion as the result of a singular, general, and diffuse experience of arousal. However, the mounting empirical evidence that there maybe physiologically distinct expressions of discrete emotional experiences does not preclude the existence of a non-specific form of general arousal – in addition to the more emotion specific physiological responses. Affect control theory and identity control theory both predict that individuals will respond to deflection (or discrepancy) by acting to reduce it. It might be that deflection has no translation into direct experience at all. If it is experienced as anxiety and distress, then it should show up in measures of negative affect. On the other hand, if it is experienced as a general sense of doubt, uncertainty, or imbalance, then it might more closely correspond to more general indicators of stress.

Engineers use the term, stress, to refer to departures from integrity or balance. Biologists borrow the term and use it to refer to a non-specific departure from some preferred internal reference state, or homeostasis. Physiologists and social scientists alike often use the term in vague ways – sometimes referring to stress as the force that brings about the state of imbalance, sometimes referring to stress as the outcome of that imbalance. Moreover, while social scientists often recognize that positive events can and do produce stress, stress is discussed in our research literatures as if it is primarily negative and most research focuses on responses to negative stressors. Recent work in the physiology of stress has led some to doubt on the idea that stress even exists as a generalized response to departures in homeostasis (see review in Kemeny, 2003). However, the research on stress as a non-specific response to imbalance has been hampered by research designs that confound stress with negativity. So, in our opinion, the idea that humans actually do experience stress in the classic sense – as a non-specific response to departures from homeostasis – remains an open question. Accordingly, we review below evidence for some of the more promising potential measures of generalized stress.

Behavioral Response

Little of the research on the physiological response to stress seems to provide evidence for clear behavioral indicators of stress that would cleanly distinguish it from the experience of emotion and valenced emotion. Consequently, at this point we offer no suggestions about somatic measures of deflection.

Autonomic Nervous Response

The research literature examining stress responses of the autonomic nervous system is large and growing. In particular, the cardiovascular system seems to be highly responsive to environmental stressors. Even this literature however, is somewhat equivocal. For example, while a few notable studies report no statistical association between blood pressure and perceived stress (Maier et al., 2003; McCann et al., 1999), a recent meta-analysis of 15 studies looking at responses to stressful experimental stimuli did find that blood pressure increased with stress, when compared to the baseline effects (Feldman et al., 1999). The same meta-analysis reported that heart rate increased in response to stress (compared to baseline findings). The results of these meta-analyses encourage us to look toward measures of heart rate and blood pressure as potential measures of deflection.

Another physiological process implicated in the stress response is vagal tone. Researchers use vagal tone to index an individual's control of the autonomic nervous system via the vagus cranial nerve and consider vagal tone to be related to emotion regulation. In general, heart rate increases when individuals breathe in, and heart rate decreases when individuals breathe out. One indicator of vagal tone is a measure of heart rate variability to respiration, or respiratory sinus arrhythmia

(RSA). In particular, researchers tend to look at how quickly RSA returns to baseline after an emotion-provoking event (for a more in-depth description of vagal tone see Porges et al., 1994). Ostensibly, high vagal tone reflects high regulatory control, while low vagal tone reflects low regulatory control. Katz and Gottman (1995) argue that having high vagal tone helps to "buffer" children from the negative effects of marital hostility (which is a stressor), compared to those children with low vagal tone. Larsen et al. (1986) argue that those individuals who are able to regulate their physiological responses to stress are likely to experience less negative emotional arousal, compared to those individuals who are less able to regulate their physiological response to stress. Regulation of physiological response can be captured with vagal tone. The intensity of the stressful event moderates the relationship of regulatory capacity and negative emotional arousal. The need to regulate physiological responses to stress increases as the intensity of the stress increases. Fabes and Eisenberg (1997) argue, and find, that in situations of moderate to high stress, high regulatory control leads to lower negative emotional arousal. They found that individuals who were high in regulatory control (high vagal tone) were less likely to experience high levels of negative emotional arousal in response to stress, but that this finding held only in situations of moderate- to high-intensity stressors.

We think this measure may help us understand more about deflection and responses to deflection. In general, the psychological literature has focused on individual differences in vagal tone and its role in mediating the effects of stressors on negative affect. However, if vagal tone indeed reflects individuals' efforts to regulate their emotional responses to evocative events, then it might be that this is in some way reflecting the deflection an individual is experiencing in a particular situation.

Endocrine System

There is considerably more work on the relationship between stress and the physiology of the endocrine system. Early last century, Cannon (1927) coined the term homeostasis and argued that maintaining internal balance in the body's systems was a high physiological priority, arguing that we respond to assaults to homeostasis with a non-specific fight or flight response, signaled by the secretion of adrenaline (or epinephrine). Selye (1976) later described another non-specific response to stressors – the secretion of glucocorticoids – as a general adaptation syndrome. These non-specific stress responses bear some resemblance in individuals who are too hot, too cold, hungry, in pain, or terrified. Sapolsky (2002) argues that even though the necessary response to being too hot or too cold may be quite different, there is enough in common about the body's response to being too hot, too cold, or hungry or in pain to warrant the non-specific response of the body to stress. Specifically, he argues that even when different types of stressors throw the body out of homeostasis in different directions, some of the resources necessary for re-establishing balance are alike. In particular, a stressed individual needs to mobilize energy. The stress response increases levels of glucose and oxygen in bloodstream by inhibiting energy storage, breaking down existing stores into simpler forms, increasing breathing rate, increasing cardiovascular tone, elevating heart rate and blood pressure, retaining water (to increase blood volume), and shutting down important parts of the cardiovascular system. Other non-essential processes and systems are also shutdown – including digestion, reproductive physiology and behavior, growth, tissue repair, inflammation, and pain perception.

The stress response triggers a cascade of events beginning in the brain and ending in the adrenal cortex. The set of systems involved with this cascade are the hypothalamus, the pituitary, and the adrenal. Physiologists refer to this system of interrelated organs as the hypothalamus-pituitary-adrenal (HPA) axis. The response of the HPA axis to stress begins at the base of the brain, in the hypothalamus. Upon perceiving a stress, the hypothalamus releases corticotropin-releasing hormone (CRH). CRH stimulates the pituitary gland to release adrenalcorticotropic hormone (ACTH) which in turn stimulates the adrenal gland to release a class of steroid hormones called glucocorticoids. Other hormones released by the pituitary gland during this cascade include endorphin, a natural opiate, vasopressin (an antidiuretic) and prolactin (a reproductive hormone). In addition, the pancreas releases glucagon, which helps to regulate carbohydrates.

The adrenal gland is the last stop in the cascade of responses triggered in the HPA axis. The medulla, or the core of the adrenal gland, secretes epinephrine (adrenaline). The adrenal cortex, or the outer layer of the adrenal gland, secretes glucocorticoids – in particular, cortisol. Cortisol is sometimes called the "stress hormone."

Our physiological response to stressful events has implications for more than how we feel. In recent years, physiologists have made great strides in understanding the relationship between endocrine responses to stress and the immune system. We have known for some time that one of the body's responses to stress is to suppress the immune system. On the face of it, however, it seems of questionable utility – especially in the face of long term stressors – to respond by making the body more vulnerable to disease and illness. However, recent research suggests that the immune response to stress is complex, leading to the strengthening of some systems, the weakening of some systems and short term bolstering and long term weakening of other systems.

The thymus is the primary site of T cell (immune cell) development and is one of the central organs at the crossroads of the neuroendocrine and the immune systems. The thymus is extremely sensitive to both acute and chronic stress. Experiments with rats reveal that social defeat produces a long-lasting reduction in peripheral blood T cells and as well as a persistent suppression in the process by which T cells migrate from the bone marrow to the thymus and proliferate (Stefanski & Engler, 1999). In these experiments, researchers expose rats to repeated fighting in a subordinate role. Similar experiments show that social stress directly disturbs homeostasis in the thymus (Engler & Stefanski, 2003). The HPA axis mobilizes and the adrenal glands respond by secreting more gluticorticoids, which interfere with the production and migration of T cells, resulting in fewer immune cells available for attacking infections agents.

As this ongoing research provides an ever clearer specification of the mechanisms that link social disruption with well-being and health, it also provides us some guidance about where to look in the short term to see human stress responses in social situations. In particular, cortisol seems clearly linked to the experience of stress in social and non-social situations (Brantley & Jones, 1993; Brantley et al., 1988; Czeisler et al., 1976; Hellhammer et al., 1985; Mason et al., 1973; Ockenfels et al., 1995; Smyth et al., 1998; van Eck et al., 1996). In a study more reminiscent of the television show, *Survivor*, than a typical group processes experiment, Jeffcoate and colleagues (Jeffcoate et al., 1986) confined five men in a boat for 14 days, measuring plasma levels of hormones at intervals throughout the study. The researchers found that cortisol levels corresponded tightly with day-to-day changes in the self-reported anxiety levels of the men. As with other research on the physiology of stress, there is a frequent confound between negativity and stress because most of the stressors studied are negative in valence. Some evidence suggests that cortisol may respond more to valence of affect than to stress (Buchanan et al., 1999; Smyth et al., 1998). However, other work suggests that the cortisol response may be more general.

One recent study illustrates the promise cortisol response for serving as a potential signal of deflection: Gaab et al. (2003) measured salivary cortisol in 48 male university students who were exposed to a standard experimental stress procedure – the Trier Social Stress Test. Members of the treatment group received "innoculation" style stress management training before being exposed to the social stressor. Members of the control group received the same training after the social stress test. Students who had prior "innoculating" experience with the stressor in the form of the training displayed an attenuated cortisol response compared to students in the control group. It appears that the exact same social experience can trigger different cortisol responses in individuals with different degrees of expectations about the event.

The endocrine system is complex and creates some unique measurement issues to contend with in the context of group processes research. We describe some of these in more detail in the section below. For example, the diurnal patterns are very important in the measurement of cortisol. Steptoe et al. (2000) illustrate this with their study of job stress among local school teachers. These researchers found that the teachers' levels of cortisol measured in saliva between 8:00–8:30 am positively varied with job stress, while there was no relationship between job stress and cortisol over the rest of the day. In addition to time of day, there are several other known sources of systematic variation in cortisol levels that might serve as potential confounds to group processes research. We revisit these in more detail in the section on measurement below.

The Physiological Experience of Positive Affect

Behavioral Response

Among the most studied behaviors in the physiology of emotion are those of the facial muscles. When we emote we move our facial muscles in ways that correspond to recognizable facial expressions. Sociologists have long attended to the importance of emotion displays in interaction. However, since the mid-1980s, emotions researchers have been excited about new opportunities to measure undisplayed emotions in the face. Cacioppo and colleagues (Cacioppo et al., 1986) proposed that visually undetectable microexpressions, corresponding to the discrete emotions could be detected by looking at the activation of various facial muscles using electrodes attached to the skin. For example, when we smile we make use of a muscle in our cheeks, the zygomatic muscle. The zygomatic major draws the corners of the lips upward (Hietanen et al., 1998). Researchers frequently use activation of the zygomatic major to measure happiness responses (e.g. Dimberg & Petterson, 2000). However, the empirical literature on this relationship is somewhat mixed. While Larsen et al. (1992) found that positive affect increased zygomatic major activity, several other studies report no association between zygomatic major activity and positive or negative affect (Cacioppo et al., 1992; Wexler et al., 1992). Bradley and Lang (2000) found no association with the zygomatic major when participants listened to pleasant vs. unpleasant sounds (Bradley & Lang, 2000). As suggested by Hietanen et al. (1998), perhaps this lack of association is due to the fact that the muscles in the lower face are under more voluntary control of the individual, the zygomatic major being one of those muscles.

The *orbicularis oclui* muscle is also involved in the expression of positive emotion. The *orbicularis oculi* is the facial muscle that causes the corners of the eye to wrinkle and bag under the eye (Hietanen et al., 1998). This muscle is thought be under less voluntary control of the individual than the *zygomatic* *major*. Hearing content voices increases responses in the *orbicularis oculi* muscle compared to angry voices (Hietanen et al., 1998).

Another facial movement that has received considerably recent attention as a discriminator of positive and negative affect is the eye blink response to startle. The eye blink startle response is reflexive and not thought to be under voluntary control. However, it does seem to vary with affect. The empirical literature on the relationship between positive affect and the startle blink response is not conclusive, but positive emotion seems to dampen the relationship between startle/arousal and blinking. Schupp and colleagues found a suppressed startle blink response while participants were viewing pleasant pictures, compared to unpleasant pictures (Schupp et al., 1997). The suppression of the startle blink response also holds when participants are exposed to other types of positively valenced or appealing stimuli (Codispoti et al., 2001; Ehrlichman et al., 1997; Lang et al., 1990; Sutton et al., 1997).

However, not all researchers have been able to detect an association between the suppression of the blink response and positive affect either. Other researchers looking report no significant associations between eye blink suppression and exposure to positive stimuli (pictures, films, sounds, odors or images), compared to neutral stimuli (Bradley & Lang, 2000; Bradley et al., 1990, 1996; Cook et al., 1991; Ehrlichman et al., 1995; Jansen & Frijda, 1994; Larson et al., 2000; Miltner et al., 1994; Vrana, 1995; Vrana et al., 1988). Skolnick and Davidson (2002) suggest that this lack of association could be due to the nature of the tasks. In many of these designs, there may be a confound between positive affect and arousal. Skolnick and Davidson (2002) argue that the level of arousal of the stimuli has a greater impact on positive affect's suppression of the startle eye blink response than the impact of negative affect's enhancement of the startle eye blink response, which is discussed in the next section. Significant suppression of the startle eye blink response is usually observed when the stimuli are arousing in nature (see Vrana et al., 1988 for an example).

Autonomic Nervous Response

As an indicator of general sympathetic arousal, some researchers have looked to cardiovascular activity as an indicator of positive emotion. Compared to neutral affect, positive affect does seem to be associated with an increase in blood pressure (Maier et al., 2003). The relationship between positive affect and heart rate is a bit mixed. While Maier et al. (2003) found a marginal association with positive affect, Bradley and Lang (2000) found no association with heart rate and pleasant sounds, compared to neutral sounds. Codispoti et al. (2001) found no association with heart rate and the valence of the pictures presented.

Another autonomic response researchers have tried to link to positive affect is skin conductance. Skin conductance refers to the electrical conductivity (or lack of electrical resistance) of the skin. Changes in conductance are a function of sweat gland activity and the skin's pore size. An increase in conductivity arises through increased skin moisture, pre-secretory activity of the sweat gland cell membranes or both. The relationship between positive affect and skin conductance activity is not quite clear. While Bradley and Lang (2000) found an increase in skin conductance activity with pleasant sounds, compared to neutral sounds, they found no association with pleasant sounds, compared to unpleasant sounds. Codispoti et al. (2001) observed a similar pattern. While they found an increase in skin conductance activity with pleasant pictures, compared to neutral pictures, they did not find an association with pleasant pictures compared to unpleasant pictures. It appears as if the increase in skin conductance activity could just be due to the existence of an emotion, but it does not differentiated between positive and negative affect. Given the overall pattern of empirical findings it seems most likely to us that electrodermal activity is more related to activation than to affect valence. We will discuss this further in the section on the physiology of activity below.

Endocrine Response

We could find no research that attempts to link endocrinological response directly to positive emotion. As we suggested in our discussion of cortisol responses to stress, we think that direct examination of the relationship between positive events and cortisol response will go a long way toward helping us untangle the relationship between stress, affect, and cortisol.

The Physiological Response to Negative Affect

Behavioral Response

The major facial muscle involved with the expression of negative affect is the *corrugator supercili* activity (Larsen et al., 2003). This is the muscle we use to pull together our brow. When we do so in an upward direction we appear sad. When we do so in a downward direction we appear angry. Most of the research on the corrugator muscle seems to focus on anger. When Dimberg and Petterson (2000) presented angry stimuli to participants, they observed an increase in *corrugator supercili* activity. Hietanen et al. (1998) observed increased *corrugator supercili* activity increased after participants heard angry voices compared to content voices. When Jackson et al. (2000) asked participants to enhance their negative affect, they observed increased *corrugator supercili*. In contrast, when Jackson et al. (2000) asked participants to suppress negative affect, they observed decreased *corrugator supercili* activity. Other researchers report increased *corrugator supercili* activity when participants are presented with unpleasant stimuli (scenes, sounds, pictures), compared to pleasant stimuli (Bradley & Lang, 2000; Cacioppo et al., 1986; Codispoti et al., 2001; Lang et al., 1990). It does appear that activation of the *corrugator supercili* may be a useful behavioral indicator of negative emotion.

The same startle eye blink response that is inhibited by positive affect is intensified by negative affect. Numerous studies report significant associations between the startle eye blink and negative stimuli (pictures, films, sounds, orders, or images), compared to neutral stimuli or positive stimuli (Bradley & Lang, 2000; Bradley et al., 1990, 1996; Cook et al., 1991; Ehrlichman et al., 1995; Jansen & Frijda, 1994; Lang et al., 1990; Larson et al., 2000; Miltner et al., 1994; Schupp et al., 1997; Vrana, 1995; Vrana et al., 1988). In a different demonstration of the relationship between negative affect and the startle blink, Jackson et al. (2000) asked participants to either suppress or enhance negative affect. They found that smaller startle eye blinks occurred when participants were asked to suppress negative affect, while larger startle eye blinks occurred when participants were asked to enhance negative affect.

Autonomic Nervous Response

The relationship between cardiovascular response and negative affect is unclear. Both Brondolo et al. (1999) and Maier et al. (2003) found no association between negative affect and blood pressure. Kamarack et al. (1998), on the other hand, did find that negative affect increased blood pressure. And, in a meta-analysis of 15 studies, Feldman et al. (1999) found that increases in undifferentiated negative emotion were associated with increases in blood pressure. The picture looks more hopeful – and even more complicated – when we consider discrete emotions. For example, some studies show that diastolic blood pressure rises with anger, compared to fear (Schwartz et al., 1981; Roberts & Weerts, 1982) or sadness (Schwartz et al., 1981). Several studies report higher finger temperatures for anger than for fear (see review in Cacioppo et al., 1993).

The relationship between heart rate and negative affect is also unclear in the literature. Bradley and Lang (2000) found that unpleasant sounds, compared to pleasant, were associated with heart deceleration. Gross et al. (1994) found crying to be associated with heart deceleration. However, Codispoti et al. (2001) found no association between heart rate and valence of picture presented. In the meta-analysis conducted by Feldman et al., they found that increases in undifferentiated negative emotion were associated with increases in heart rate. However, the associations Feldman et al. find are small. They argue that this could be due to the tasks involved in the experiments. They also discuss the methodological problems of measuring emotions via subjective response as a reason for the small associations. Taken together, the empirical evidence suggests to us that cardiovascular responses may vary more closely with potency and activity than with simple valence. So, we will revisit this literature in the next two sections.

Researchers have also investigated the relationship between vagal tone and negative affect. Fabes and Eisenberg (1997) found vagal tone be correlated with frustration (Fabes & Eisenberg, 1997). Gross et al. (1994) argue that crying is associated with slower respiration rates and that this independent association may lead to an increase in RSA. Rottenberg et al. (2003) found that RSA was elevated both at the onset of crying and at the resolution of crying. Rottenberg et al. (2003) compared clinically depressed individuals to non-depressed individuals. They found that depressed individuals did not have an elevated RSA at the onset of crying. This does not encourage us to look toward vagal tone as a general indicator of negative affect.

The relationship between negative affect and skin conductance is a bit muddied as well. While Bradley and Lang (2000) found skin conductance activity to increase with unpleasant sounds, compared to neutral sounds, they found no association with unpleasant sounds, compared to pleasant sounds. Codispoti et al. (2001) found the exact same pattern. While they found skin conductance activity to increase with unpleasant pictures, compared to neutral pictures, they found no association with unpleasant pictures, compared to pleasant pictures. As mentioned in the section on positive affect, it appears as if the association between negative affect and the increase in skin conductance is due to the presence of an emotion, the actual valence of the emotion does not seem to matter.

Endocrine Response

As reviewed in the section on deflection/stress, there is considerable indication that cortisol may be a good indicator of general negative affect. Because of the theoretical advantages of finding a measure of deflection that is independence of emotion valence, we are holding out hope that this is not true. However, it remains an open question and one that we hope group processes researchers might consider a useful one to pursue.

The Physiological Experience of Potency

Affect control theory distinguishes between the potency of an emotional experience and the potency of an actor's transient identity impressions. In affect control theory's emotion model, the powerfulness of one's transient identity impressions correlates with the powerfulness of one's experienced emotion in a situation. However, this correspondence is not as strong as it is on the evaluation dimension (as demonstrated in the reduced formula presented above). Hence, it is possible to feel a weak emotion while operating in a powerful identity, and *vice versa*. We can imagine, then, reasons for wanting to be able to capture both of these aspects of potency. So, in this section we review evidence for physiological measures that might be related either to the potency of discrete emotions, or the potency of transient identity impressions.

Behavioral Responses

Recall, that *corrugator supercili* is the muscle above the eye thought to be related to anger (Dimberg & Petterson, 2000; Dimberg & Thunberg, 1998). More specifically, the movements of the *zygomatic major* distinguish between the negative, powerful emotion of anger and the negative, weak emotion of sadness. This is the muscle that we use to scrunch the brow together when we are angry or sad. When we are angry, we bring the center part of our brow together and down (Ekman & Friesen, 1975). When we are sad, the center part of our brow comes together in an upward direction (Ekman & Friesen, 1975). Thus, when controlling for negative affect, activation of the *corrugator supercili* might be useful in distinguishing between more and less potent emotions.

Creative work done by Stanford Gregory (Gregory & Gallagher, 2002; Gregory & Webster, 1996; Gregory et al., 1997) reveals another interesting physiological response that we might use to signal potency, vocal frequencies. Gregory and colleagues point out that as air moves through the speech organs (e.g. pharynx, sinuses, nasal cavities, mouth) those organs act as filters or resonators for the frequencies passing through. Using spectral analysis to look at non-verbal vocal frequencies, Gallagher and Webster (2002) measured the fundamental frequency of presidential candidates' voices during presidential debates. They found that the fundamental frequency of the candidates' voices predicted relative social dominance as well as popular vote. While this vocal stress shows promise, then, as a measure of relative potency, earlier work by Gregory and Webster (1997) leads us to pose a caveat. In this study, the researchers found that, as with other paralinguistic behaviors, lower status speakers tend to accommodate their vocal frequencies to those of higher status partners. Research attempting to use vocal frequency as a signal of transient potency would also have to bear in mind the effects of local relative status on accommodation patterns.

Autonomic Nervous Response

There is some evidence to think that cardiovascular response may be a good place to look for signals of emotion potency. As reviewed in the section on negative affect, diastolic blood pressure rises with anger, compared to fear (Roberts & Weerts, 1982; Schwartz et al., 1981) or sadness (Schwartz et al., 1981). Also, finger temperatures tend to rise more for anger than for fear (see review in Cacioppo et al., 1993).

It is also possible that skin conductance maybe be a useful indicator of potency. For example, Markovsky (1988) found an increase in skin conductance reactivity in response to a perceived injustice. However, it is far from clear whether this response was a result of transient potency, or deflection. Most studies that compare skin conductance levels across between emotion conditions and control conditions find significant effects (see review by Cacioppo et al., 1993). To date, however, skin conductance has not proved to be a replicable way to distinguish more critically between disparate emotions.

Endocrine Response

Endocrine response may well provide some insight into potency dynamics among humans. Testosterone, produced by the gonads, is another one of the steroid hormones. Losing a competition decreases testosterone (Elias, 1981; Mazur, Booth & Dabbs, 1992). Winning a game of chance increases testosterone (McCaul et al., 1992). Jeffcoate et al. confined five men to a boat for fourteen days, measured cortisol prolactin and testosterone, found testosterone varied with position in emergent dominance hierarchy. There is also some indication that cortisol levels vary by gender and socioeconomic status (Kunz-Ebrecht et al., in press; Steptoe & Marmot, 2002; Steptoe et al., 2002).

Finally, work on non-human primates finds evidence for a relationship between rank and stress. In species with stable hierarchies (e.g. rhesus monkeys, baboons, rats), low ranking individuals experience greater stress. In species with less clear hierarchies (e.g. marmosets and tamarins), there is little relationship between rank and stress. In contrast to both of those, among mongooses, whose hierarchies are more turbulent, high ranking members display the greatest stress responses (Sapolsky, 2002). Rather than speaking to stress hormone (i.e. cortisol) as an indicator of potency, this suggests an interaction between potency, deflection, and social structure that we might be able to assess with measures of stress (such as cortisol).

The Physiological Experience of Activity

Behavioral Responses

We might expect individuals who experience more active emotions or more expressive transient impressions to move more and with larger motions. However, beyond classical approaches to coding body motions from videotape, there maybe more systematic physiological responses that could help us distinguish activity from other dimensions of affect. Although, the relationship is not straightforward, the startle eye blink is one possibility. As we mentioned in our review on the startle eye blink above, the startle blink response seems to be mediated by the level of overall arousal. The higher the arousal (either positive or negative), the greater the startle response (Cuthbert et al., 1996).

Autonomic Nervous Response

The findings on activity and the cardiovascular system are much less muddy. General activity and arousal are clearly associated with increases in blood pressure (Gellman et al., 1990; Jacob et al., 1999; Pollard & Schwartz, 2003; Schwartz et al., 1994). In addition, in general, heart rate seems to be higher for more active emotions (e.g. anger) than for quieter emotions (e.g. happiness, sadness) (see review in Cacioppo et al., 1993).

Finally, there seems to be a relationship between arousal and electrodermal response. The assumption of this relationship underlies the use of polygraph techniques which use electrodermal responses along with respiration, pulse, and relative blood pressure to measure arousal in response to (supposed) lying. Markovsky's (1988) findings on injustice and galvanic skin response referred to above are consistent with the idea that arousal increases electrodermal activity. In addition, Bradley and Lang (2002) found that arousing (pleasant) sounds, compared to neutral sounds, generated increased electrodermal responses. Taken together, we think that electrodermal activity may be a promising physiological marker of activation.

Endocrine Response

In our review of the literature, we found no compelling evidence for looking to the endocrine system to help us distinguish activity from other dimensions of affect.

PULLING IT TOGETHER: PROVISIONAL PHYSIOLOGICAL PROFILES OF SOCIOLOGICAL CONCEPTS

As should be clear from our review of the information above, the physiological literature on the measurement of stress and emotion is undergoing rapid development and revision. However, from the existing literature, we have suggested some patterns that may advance our ability to test theoretical ideas in the sociology of identity and emotion. Table 1 summarizes our conclusions drawn from the previous sections. More specifically, Table 1 shows our tentative suggestions for linking profiles of measurable physiological response to the five theoretical concepts

Table 1. Provisional Physiological Profiles of Concepts in Control Theories of the Sociology of Emotion and Identity.

	Theoretical Concept				
	Deflection	Positive Affect	Negative Affect	Potency	Activity
Predicted physiological index	• Higher levels of cortisol • Increased heart rate • Increased blood pressure • Changes in vagal tone	• Activation of zygomatic muscle • Activation of periocular region • Decreased eye blink response to startle	• Activation of corrugator muscle • Higher levels of cortisol? • Increased eye blink response to startle	• Up/down movement of corrugator muscle • Higher levels of testosterone • Lower fundamental frequencies in vocal spectra • Increase in finger temperature • Increase in face temperature	• Pupil dilation • Increased electrodermal activity • Increase in diastolic blood pressure • Increase in finger pulse

critical for testing ideas derived from affect control theory and identity control theory. In the following section we revisit these physiological responses with suggestions about how to measure them in the context of typical group processes research settings.

MEASURING PHYSIOLOGICAL RESPONSE

Behavioral Responses

Facial Muscular Activity
There are two main approaches to studying facial muscular activity. The more traditional approach uses videotapes of actors and hand coding of emotion displays. The most developed approach in this tradition is the Facial Action Coding System (FACS) developed by Ekman and Friesen (1978). This approach uses frame-by-frame visual coding of muscle movements in order to look for both intended and unintended (leaked) emotion displays. The second approach, Facial electromyography (EMG) measures the electrical activation of specific muscles in the face. These methods require attaching electrodes to the skin in order to assess electrical activation of the specific muscles at a specific location. The advantage of EMG over FACS is that it is able to measure activation in muscles whose movements are not visible to the eye (e.g. a suppressed smile). One disadvantage of this method requires that a researcher must choose specific muscles to investigate, prior to collecting data. Consequently, the method is not well-suited for collecting information about multiple emotions over the course of an interaction. In fact, this method is not well suited for collecting data during interaction. This method is fairly socially intrusive and somewhat sensitive to motion. Electrodes hang from the face and connect an individual to a data collection unit. These data must be collected in laboratory setting, rather than in the field. Another drawback of EMG is that it is unable to assess how the specific facial movement moved, it can only determine if there was muscle activity. More traditional methods (such as FACS) also enable a researcher to determine the *character* of a particular facial muscle movement. For example, while EMG could only reveal that there was brow activity; with FACS a researcher could determine whether the brow went up or down. A new potential alternative to EMG or the traditional hand coding of videotapes is the use of high-definition thermal imaging. New thermal imaging cameras can detect increased blood flow to parts of the face in the form of spectral images reflecting warming patterns. This option may be an answer to the lack of specificity and intrusiveness of the EMG and the cost and measurement errors associated with the time-consuming FACS procedures.

Autonomic Nervous Response

Cardiovascular Activity

The cardiovascular system is part of the autonomic nervous system. There are many different measures are used by researchers to capture cardiovascular activity, including heart rate, heart rate variability, respiratory sinus arrhythmia (which captures vagal tone), blood pressure, and peripheral vasoconstriction.

Heart rate and heart rate variability can both be measured either by finger plethysmograph (FP) or electrocardiogram (ECG). The use of FP is fairly non-intrusive and fairly accurate. It allows researchers to record continuous real time data and link it to other aspects of interaction. However, ECG measures tend to be less prone to measurement error – especially those produced by motion. Giardino et al. (2002) conducted two experiments comparing FP and ECG and found that the FP is more sensitive to non-resting states, thus less reliable. Giardino et al. (2002) argue that while FP may yield reliable results under resting conditions, they express caution in its use under non-resting states.

One noninvasive method for indexing vagal tone is respiratory sinus arrhythmia (RSA). RSA is used as a measure of parasympathetic nervous system activity. RSA is a measure of heart rate variability to respiration patterns. In order to measure RSA one must be able to detect both the heart beat and the timing between heart beats, which are referred to as heart periods (for a detailed description of the calculation of RSA see Fabes & Eisenberg, 1997 or Porges et al., 1994).

Blood pressure is obtained as a multiplicative function of the cardiac output and total peripheral resistance (Maier et al., 2003). Cardiac output is the amount of blood pumped by the heart per minute. Total peripheral resistance is the amount of resistance that is exerted on the blood flow throughout the body. Blood pressure is often measured using a sleeve, making it a somewhat more intrusive measure. It can easily be collected in a laboratory setting or in the field. However, sleeve-based measurement is not well suited for collection during interaction.

All of the finger transducer collected heart measures are fairly non-intrusive and can comfortably be used during ongoing interactions. These measurements can be collected either in a laboratory setting or in the field. However, all of the cardiovascular measures are somewhat sensitive to movement and are somewhat impaired if collected during unrestricted interaction. To maximize the reliability of these measures, one would want to either minimize movement of research participants, or find ways to statistically control for movement.

Electrodermal Activity

Galvanic skin response is a measure of the skin's conductance between two electrodes. Skin conductance is typically measured by applying a small current through two electrodes, placed on the fingers or toes, and the response is seen as a change in conductance (decrease in resistance) of the skin with time. Electrodermal activity can be measured using small, relatively non-intrusive finger transducers. Using portable data collection units enables research in the field as well as in the laboratory setting.

Endocrine System Response

The endocrine system is activated by the hypothalamus-pituitary-adrenal (HPA) axis, which is elaborated on in the section on stress. Cortisol and testosterone are two steroid hormones that are both measurable in saliva in ways that reliably relate to blood borne amounts. In the bloodstream, there are both "free" and bound hormones. Free (or unbound) hormones are those hormones that have yet to be bound to any other compound. Once hormones are bound, they cannot traverse into the brain. In other words, once hormones are bound, they are unable to impact the brain. The proportion of free hormones in the bloodstream is what is found in saliva. Only the unbound hormones are able to get into the saliva.

Prior to collecting saliva samples, individuals are asked to chew sugar-free gum, in order to stimulate the flow of saliva. There are two dominant methods to collect saliva. The first method is to have individuals put swabs of cotton, called a salivette, into their mouths, having them swish it around their mouth, saturating the swabs with their saliva (for example see Dabbs, 1990). However, cotton swabs may interfere with the measurement of certain hormone levels (see Dabbs, 1991; Shirtcliff et al., 2001). Specifically, it artificially increases testosterone concentrations but not cortisol concentrations. The second method is to have individuals spit into tubes (for an example see Schultheiss et al., 1999). This has the added advantage of allowing for the collection of larger amounts of saliva in order to test for multiple hormones, conduct repeated tests for reliability analyses, and to save samples for later re-analysis.

The two means of processing saliva are with radiation (radioimmunoassay, RIA) or chemicals (enzymeimmunoassay, EIA). The advantages to using EIA are: (a) that it does not require the use of radioactive materials and so there is no need for special licenses to conduct analyses; (b) EIA requires a lower sample volume; and (c) the measurement equipment necessary to conduct analyses is less expensive than the equipment required for RIA. There are also critical disadvantages to this method. First, the actual kits required to perform an EIA analysis are much more expensive than the kits required to perform an RIA, increasing the per sample cost immensely. For the size of studies that group processes researchers conduct (compared to many medical studies) this cost difference could get prohibitive. Second, the EIA method requires more steps in the processing of the saliva, which introduces greater potential for measurement error. Finally, recent research suggests that EIA may inflate measures of salivary cortisol, compared to RIA. Perhaps the best news to a sociologist who is interested in looking at steroid hormones in saliva, but is not interested in processing the saliva, is that for either the EIA or RIA method, researchers can collect and freeze the saliva samples and send them out for processing.

Saliva samples can be collected in a laboratory setting or in the field. Some studies have used self-collection, although some of this research shows a fairly high report of "cheating" (e.g. not collecting samples on the intended schedule, misreporting details of sample collections; Broderick et al., in press).

There are several things one must keep in mind when designing a study that involves collecting saliva samples. Steroid hormones are impacted by cyclical processes (to be discussed below), making it important to use a repeated-measures design, to control for within-person variability. In experiments, one should collect several (at least two) samples prior to the experimental manipulation in order to establish an individual's baseline. Furthermore, it is important to take a baseline as close to the treatment as possible in order to help rule out the possibility that the difference between the baseline and the treatment is due to the individual's regular cycle. Salivary glands take between 5 and 10 minutes to refill, so it is important to keep the time between samples at a minimum of 10 minutes.

Another thing to keep in mind in designing a study is that after HPA activation, it takes about 15–20 minutes for the hormones to show up in the saliva. Depending on the length of the experimental manipulation, changes in the steroid hormones may already be observable at the end of the treatment. So, if the manipulation is long (more than 10 minutes), it is worth trying to include an additional sample during the treatment. If a researcher can only afford to do one sample after the treatment, a sample should be taken about 15 minutes after the treatment. It is better, however, to have multiple measurements every 15 minutes after the experimental treatment.

Steroid hormone levels are sensitive to diet, medications, and time of day (circadian changes). For example, both testosterone and cortisol levels drop over the course of the day, with the largest decline in the morning (Dabbs, 1990). When collecting saliva samples it is necessary to collect samples at the same time of the day (or control for the time of day) and collect information about medical conditions, medications, and certain habits (e.g. smoking, alcohol, and caffeine). It is best to advise potential participants to not consume any alcohol the night prior to saliva collection. It is best to only use individuals who are not on any kind of medication. Since age matters too, it is best to use participants of approximately the same age (or control for age) (Riad-Fahmy et al., 1987). Participants should also be advised not to brush teeth their teeth for an hour before saliva collection. Brushing one's teeth cause micro lacerations, which can cause blood to be in the saliva, which inflates the hormone concentrations in the saliva.

There are also sex differences in the levels of salivary hormones. If one is using female participants it may be important to collect information on their menstrual cycle. Some hormones are impacted by the menstrual cycle, specifically estradiol and progesterone.[4] Dabbs (1990) found support for the notion that the menstrual cycle does not impact the level of testosterone in saliva. Also, it is also important to find out who is taking oral contraceptives. These impact steroid levels as well – including both testosterone and cortisol (Schultheiss et al., 2003). Finally, there is some evidence that salivary testosterone measures may underestimate testosterone levels for females, but not males (Shirtcliff et al., 2002).

CONCLUSIONS AND CAVEATS

In this paper we have outlined a set of concepts that have similar uses in a set of cybernetic theories that link action and emotion, along with a set of physiological measures that might be useful for assessing those concepts within the context of social interaction. The basis of the physiological measures made us confident this would not be an easy task. Since the autonomic, endocrinological and behavioral systems that are activated in emotional response have evolved to enable a variety of overlapping lines of action, we could be sure that the research linking them to social stimuli would be mixed. Indeed, we would not expect to find single physiological measures that corresponded to single emotional states; instead, we have attempted to develop profiles of physiological responses that can be linked to theoretical concepts.

We wish to emphasize that even these profiles are highly speculative at this point. Since the research using these physiological responses has not been conducted within the theoretical paradigms discussed here, we are in the very preliminary stages of linking the two. We do, however, have clear ideas about how the investigation should proceed. The theoretical research programs reviewed above can generate clear propositions about how their constitutive processes and concepts are related. If these propositions are then translated into hypotheses about patterns of both conventional and physiological measures that will be observed under different conditions, we should be able to establish the validity of the measures in the context of the larger research enterprise. Basically, the theoretical ideas and the physiological measurement of concepts will co-evolve as we learn more about both. Then, the physiological measures may be able to help us distinguish among some of the more subtle differences in the theoretical predictions.

At the very least, such a program would help us understand how the physiological aspects of emotion are related to its social construction within the context of interaction. By having a clearer picture of both, we are bound to gain insights about their interrelationship.

NOTES

1. Those lucky enough to have been active scholars during this feisty period may remember roundtable sessions at the American Sociological Association meetings attended by 30–40 people per table, culminating with shouted discussions between Dave Kemper, Norman Denzin, and Tom Scheff.

2. Carver and Scheier (2000) note that such loops must be embedded with negative feedback loops to be stable.

3. Gray (1994) uses the old joke about the man looking for his watch under a lamppost ("... the light is better here ...") to illustrate how physiologically oriented psychologists used the techniques that they had available to look, perhaps in the wrong places, for physiological analogues to specific emotions before precise neurological measurements were available. While the neurological measures may be more complex than a first enthusiasm would indicate, we hope to make use of the wealth of data that were generated while physiological psychologists were looking under the lamppost at the ANS and ES rather than neuroimaging.

4. If one is interested in looking at estradiol or progesterone, it is essential to collect information on the menstrual cycle. Specifically, you need to determine the date of last two menstrual periods. The menstrual cycle is a monthly hormone change so it is best to test all female participants at the same stage of the menstrual cycle.

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