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Feeling and Facial Efference: Implications of the Vascular Theory of Emotion

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Is facial muscular movement capable of altering emotional state? Facial feedback theories answer this question in the affirmative but do not specify the intervening process. Cognitive appraisal theories do not address this question at all. The vascular theory of emotional efference (VTEE) holds that facial muscular movement, by its action on the cavernous sinus, may restrict venous flow and thereby influence cooling of the arterial blood supply to the brain. Subjective reactions resulting from facial action (phonetic utterance), resembling but unrelated to emotional efference, were found to differ in hedonic quality and to produce correlated changes in forehead temperature. Direct tests that introduced air into the nasal cavity revealed that cooled air was pleasurable, whereas warm air was aversive. It is conjectured that variations in cerebral temperature might influence the release and blocking of emotion-linked neurotransmitters—a consequence that would explain, in part, why some experiences are felt subjectively as pleasant and others as unpleasant.

Photographers ask us to say *cheese* because that word transforms facial muscles into a facsimile of a spontaneous smile. It is reasonable to inquire whether such a "smile" is merely an outward appearance or whether it also contains some genuine emotional elements. No definitive answer to this question presently exists. Among theories of emotion, only facial feedback theories (Izard, 1977; Tomkins, 1962) regard facial expression as an important determinant of the subjective feeling state. In cognitive appraisal theories (Arnold, 1960; Averill, 1983; Lazarus, Averill, & Opton, 1970; Mandler, 1984; Roseman, 1984; Smith & Ellsworth, 1985, 1987), facial expression does not figure as a significant process that modifies or induces feeling states. According to cognitive appraisal theories, subjective feeling derives from and follows a prior cognitive appraisal. Facial expression is regarded as the terminal link of the emotional episode and as such could not be expected to contribute systematically to the subjective experience. Yet another approach to the understanding of emotions, the one offered by the classic Schachter and Singer (1962) theory, assumes as a necessary condition the presence of a subjectively felt arousal that, when ambiguous, seeks cognitive elaboration. The ensuing cognitive construal specifies the arousal's particular meaning and is thereby capable of altering certain qualities of the subjective state that the person experiences.

These diverse views provide different answers to the significant questions about emotion: What occasions the subjective feeling state? Which elementary processes cause or constitute what is known as *feeling?* Where in the chain of causal events lies the emergent feeling of fear, euphoria, or rage? Is expression of emotion invariably the terminal link in the process, or can it, on its own, engender subjective feeling? What is it that we *feel* when we feel sad, angry, or happy? What are the more fundamental processes that underlie the experience of pleasure or disgust? This article addresses certain aspects of these problems. Specifically, it seeks to determine whether facial muscular movements alone are capable of altering subjective feeling states, and it proposes a physiological process making such effects possible.

Theories of Emotional Expression

James (Lange & James, 1922/1967) contradicted the view of his predecessors and contemporaries that "bodily disturbances [occasioned by an emotion] are said to be the 'manifestation' of these . . . emotions, their 'expression' or 'natural language' " (p. 12–13). Rather, he argued,

> *the bodily changes follow directly the* PERCEPTION *of the exciting fact, and . . . our feeling of the same changes as they occur* IS *the emotion.* Common sense says, we lose our fortune, are sorry and weep; we meet a bear, are frightened and run; we are insulted by a rival, are angry and strike. The hypothesis here to be defended says that this order of sequence is incorrect, that the one mental state is not immediately induced by the other, that the bodily manifestations must first be interposed between, and that the more rational statement is that we feel sorry because we cry, angry because we strike, afraid because we tremble, and not that we cry, strike, or tremble, because we are sorry, angry, or fearful as the case may be." (p. 13)

For James (1890), *feeling* was the very essence of emotion, without which the concept was vacuous. After having asserted that "*every one of the bodily changes whatsoever it be, is* FELT, *acutely or obscurely, the moment it occurs*" (p. 1066), James goes on to say that "If we fancy some strong emotion, and then

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try to abstract from our consciousness of it all the feelings of its bodily symptoms, we find we have nothing left behind" (p. 1067). Facial feedback theories revived one aspect of James' assertion, namely, that "*the bodily manifestations must first be interposed between*" the eliciting event and emotional expression. But, rather than including all bodily changes, facial feedback theories focused primarily on the face. According to facial feedback theories, the subjective experience of emotion derives from the sensory (cutaneous or proprioceptive) feedback of facial motor action (Buck, 1980; Cupchik & Leventhal, 1974; Izard, 1971, 1977, 1981; Kraut, 1982; Laird, 1974; Tomkins, 1962, 1979, 1981; Zuckerman, Klorman, Larrance, & Spiegel, 1981).

"Strong" and "weak" versions of the facial feedback hypothesis have been distinguished, but these distinctions have not always been consistent. For example, according to Rutledge and Hupka (1985), the strong version considers facial feedback "sufficient to induce and specify emotion," whereas the weak version calls only for an intensification of any emotion that was previously elicited by other causes. This latter form of the weak version dates to Darwin (1955), who proposed that expression intensifies emotion, whereas suppression "softens" it (p. 22). In fact, a recent study by McCanne and Anderson (1987) has demonstrated just that. Winton's (1986) definition of the strong version of facial feedback is the same as that of Rutledge and Hupka (1985). However, he attributed to the weak version more than simply the capacity of intensifying an otherwise elicited emotion. Even at its weakest, facial expression, according to Winton, has the capacity of producing global hedonic effects, that is, feelings of positivity or negativity, liking or disliking, and tendencies of avoidance or approach, independently of what emotion is present at the time. Both strong and weak versions of the facial feedback hypothesis hold, nevertheless, that subjective feeling is a consequence of facial movement.

Critics of the facial feedback hypothesis claim that the evidence offered in support of the hypothesis is at best ambiguous. Matsumoto (1987) performed a meta-analysis of facial feedback studies and concluded that there is only a modest effect. It is, indeed, reckless to suppose that facial efference is the main, let alone the only, factor in *all* subjective feelings. Clearly, in the more complex emotions, such as jealousy or pride, most of the variance in the subjective experience derives from a prior cognitive process. However, such an observation does not in itself preclude facial efference from having subjective consequences of its own.

The most serious criticism of studies seeking to document that subjective feeling states derive from muscular action, is that subjects can make inferences about the subjective feelings that they "should be" experiencing under the experimental manipulations. Thus, in the typical facial feedback experiment, subjects are asked to imagine an emotional situation, arrange their facial musculature to conform to classical emotional expressions, or emotions are induced directly by presenting emotional stimuli (Colby, Lanzetta, & Kleck, 1977; Cupchik & Leventhal, 1974; Duncan & Laird, 1977; Ekman, Levenson, & Friesen, 1983; Kotsch, Izard, & Walker, 1978; Laird, 1974; Laird & Crosby, 1974; Lanzetta, Cartwright-Smith, & Kleck, 1976; Leventhal & Mace, 1970; McArthur, Solomon, & Jaffe, 1980; McCaul, Holmes, & Solomon, 1982; Tourangeau & Ellsworth, 1979; Zuckerman et al., 1981). As a result, these manipulations contain emotional elements based on subjects' common knowledge about the relation between feeling and expression and, as such, constitute ambiguous evidence that facial muscular movement *alone* can have objective or subjective emotional aftereffects. Besides the aforementioned criticism, Rutledge and Hupka (1985) listed no less than 12 additional experimental artifacts that characterize facial feedback research.

In an ingenious experiment that addresses the most serious of these criticisms, Strack, Martin, and Stepper (1988) prevented subjects from drawing a connection between facial action and emotion by having them hold a pen either in their teeth (simulating a smile) or in their lips (requiring the opposite muscular action) while exposing them to affective material (humorous cartoons). These authors found support for the facial feedback hypothesis in their studies. However, effort could have played a significant role in their subjects' reactions because it is considerably more effortful to hold a pen by its tip in one's lips than in one's teeth.

At the theoretical level, some ambiguity exists as well for the concept of facial feedback. It is not yet clear, for example, why cutaneous and proprioceptive feedback should be either necessary or sufficient for the emotional experience, nor how it fits in the entire physiological and behavioral process that constitutes emotion. For Buck (1985), facial feedback is a matter of self-perception. The person feels his or her teeth clench and infers, "Oh, I must be angry." An earlier theorist (Tomkins, 1962), on the other hand, attributed to facial feedback a more active causal and compelling role. Moreover, some researchers have emphasized the role of musculature (e.g., Izard, 1977), whereas others have looked on facial skin (Tomkins, 1979) as the major source of feedback. Clearly, a fully developed statement of a facial feedback process requires the specification of mechanisms that link facial movement to feeling.

The fact that there may exist a theoretical conflict between facial feedback theories and appraisal theories over the temporal location of the subjective affective state in the causal chain of emotion has been largely ignored. Simply stated, in the former theories, cognitive appraisal is not considered a necessary precondition for the emergence of the subjective emotional state because such a feeling state can be achieved by muscular facial action alone. The latter theories, however, regard appraisal as a strictly necessary factor in all emotional experience (Lazarus, 1982). Dialogue between the two schools of thought regarding the role of facial expression has been scarce, and consequently, experimental confrontation between the cognitive and feedback theories of emotion has been equally scarce. Appraisal theories formulate their experimental paradigms entirely within the confines of cognitive processes. Consequently, cognitive appraisal research is unlikely to determine the contribution of expressive elements to the emotion experience because data on expressive output are almost never collected. Likewise, feedback theories are seldom concerned with appraisal and instead induce emotions by methods in which appraisal is either taken for granted or ignored. Evidence bearing on the resolution of the theoretical conflict is, therefore, lacking.

Vascular Theory of Emotional Efference

A novel idea, albeit one that has been in abeyance for more than 80 years, is to be found in the vascular theory of emotional efference (VTEE) proposed by Israel Waynbaum (Zajonc, 1985). Waynbaum (1907) argued that facial gestures in general, and emotional gestures in particular, have regulatory and restorative functions for the vascular system of the head. He first observed that all emotional experiences entail a considerable and rapid disequilibrium of the vascular process. For example, blood is redistributed to supply skeletal muscles to meet the demands of an incipient activity. Noting the intimate relation between facial and cerebral blood flow (CBF), Waynbaum suggested that facial muscular movements contribute to the regulation of CBF by pressing against facial veins and arteries and thus shunting blood to the brain when needed, or diverting it away when the brain is threatened with excess. The main carotid artery is divided at the neck into two arteries—the internal, which supplies the brain, and the external, which supplies the face and skull—a curious configuration that prompted Waynbaum to search for a particular function that would justify it. This vascular arrangement exists, Waynbaum conjectured, to allow the facial branch of the main carotid artery to act as a safety valve for the brain, where blood supply can vary only within narrow limits. Waynbaum also suggested that these regulatory muscular actions of the face have subjective consequences, such that changes in CBF caused by facial motor movement are reflected as changes in feeling states. He did not disagree with Darwin (1955) that the function of emotional facial gestures is to communicate the individual's internal states to those around him, but rather that they do not in themselves have hedonic consequences. Waynbaum's focus on these consequences was more in line with the thinking of James (1890), who wrote

> Smooth the brow, brighten the eye, contract the dorsal rather than the ventral aspect of the frame, and speak in a major key, pass the genial complement, and your heart must be frigid indeed if it does not gradually thaw! (pp. 1067–1068)

The VTEE was based on physiology of the turn of the century. It is not surprising, therefore, that several of Waynbaum's (1907) assumptions are questionable and others are outright wrong (Burdett, 1985; Fridlund & Gilbert, 1985; Izard, 1985; Zajonc, 1986). For instance, arterial flow is unlikely to be much affected by muscular action of the face because it is under the control of so many other central factors that the periphery can have only negligible direct effects. However, much of Waynbaum's thinking can be useful (Zajonc, 1986) and can actually be correct, albeit for the wrong reasons. For instance, facial muscles, might not have a significant effect on arteries, but they can affect venous flow. More important, facial action might alter temperature of blood entering the brain by interfering or facilitating cooling. Such a process may in turn have subjective effects through its impact on the neurochemical activity in the brain. We develop this point more extensively later.

Independent of the validity of the *particular* physiological processes that could be involved in producing subjective effects, the basic principle that facial efferents may have regulatory functions, and thereby subjective consequences, has a great deal of plausibility and, if true, profound theoretical importance. If true, VTEE organizes diverse findings such as biofeedback, placebo effects, unconscious preferences and aversions, the growth of preference with repeated exposure, empathy, and such actions as fingernail biting or scratching one's forehead (Zajonc, 1986). It moreover offers a better understanding of the universality of emotional expression and of its recognition across cultures and species. The *particular* neurophysiological and neurochemical processes are yet to be specified by empirical investigations. Useful speculations about such processes that would guide future research, however, can be made now.

A testable hypothesis that follows from VTEE is that facial efferents can produce changes in brain blood temperature, which in turn have significant hedonic consequences (Stellar, 1982). Hedonic consequences are obtained for a variety of reasons. For instance, subjective changes can be obtained because changes in brain temperature can facilitate and inhibit the release and synthesis of a variety of neurotransmitters. Thus, if a certain action of facial muscles results in changing the temperature in a particular brain region that is active in releasing norepinephrine, for example, then norepinephrine might be either partially blocked or released, and the individual might experience calming or excitation. Not all neurochemicals that have subjective effects are region-specific. Peptides, for example, are found in profusion throughout the brain, and a change in temperature might change the threshold of the enzymatic action that releases them.

To be sure, the conjecture that changes in brain temperature can influence the release and synthesis of neurohormones and neuroenzymes that are associated with subjective emotional states still needs empirical documentation, but it is consistent with the fact that all biochemical processes are affected by temperature. The Q_{10} law describes the proportional change in the rate of a reaction over a 10 °C interval. Within the range of human body temperature, the value of Q_{10} for many processes is about 3, which means that a rise of 10 °C increases a given reaction by as much as 300% (Precht, Christophersen, Hensel, & Larcher, 1973). Values of Q_{10} that are much smaller and much larger than the typical, however, are quite common. In the immune system these values vary over a very wide range, with some reactions requiring minute temperature changes. For example, thymus-dependent antigens have Q_{10} values as high as 1,000 to 5,000, whereas thymus-independent antigens have Q_{10} values of only 2 (Jampel, Duff, Gershon, Atkins, & Durum, 1983; Miller & Clem, 1984). Less is known about the temperature dependence of the neurotransmitters implicated in emotional reactions. But there are indications that these, too, as do most neurochemical processes, vary with regional cerebral temperature. For instance, a decrease in the neuronal accumulation of adrenaline by a factor of 3.6 was found when the spleen temperature of the Atlantic cod (*Gadus morhua*) was lowered by 10 °C to 14 °C (Ungell, 1984).

It suffices for present purposes to note that (a) brain temperature is partially regulated by the cavernous sinus, a venous structure that surrounds the internal carotid as it enters the brain (see Figure 1), (b) that the cavernous sinus receives cooled blood from some facial veins, and (c) that facial action can cool the blood in these veins by direct mechanical action on the veins (such as Waynbaum, 1907, proposed) or by allowing greater air flow of ambient temperature into the nasal cavity. Finally, we will make the plausible assumption that some temperature changes of the brain are correlated with hedonic states.

Thermoregulation of the brain is controlled mainly by the

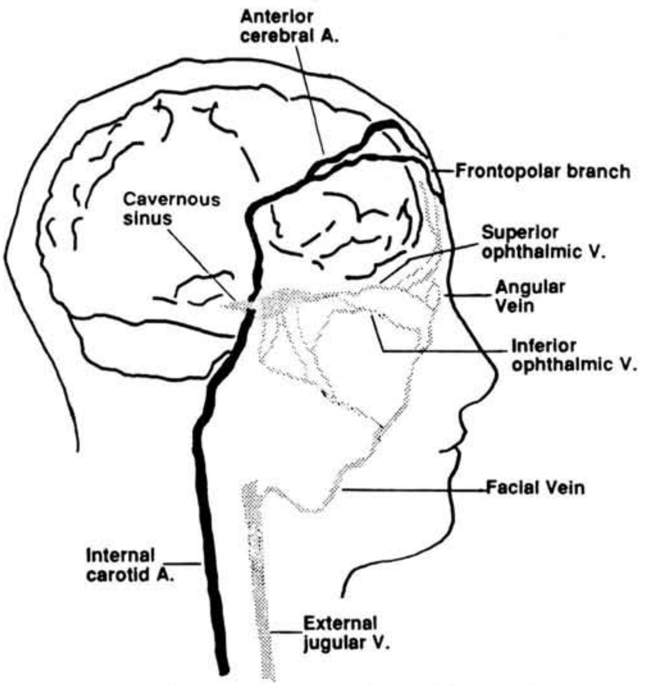

Figure 1. Parts of the vascular system involved in phonetic output and homologous emotional expressions.

anterior hypothalamus and preoptic area (Satinoff, 1964). Numerous findings (e.g., Corbit, 1969, 1973; Dib & Cabanac, 1984) show that hypothalamic cooling is a rewarding event of considerable incentive value.

Behavioral aspects of thermoregulation, such as shivering, panting, or vasodilating, are controlled by the anterior and the lateral hypothalamus (Satinoff & Shan, 1971). It is significant that these behaviors can be elicited not only by changes in temperature but by emotional stimuli as well. In general, there is a close link, both at the behavioral and the physiological level, between thermoregulation and emotion. For example, the bilateral lesion of the anterior hypothalamus-preoptic area in the snake disturbs equally courtship behavior and thermoregulation (Krohmer & Crews, 1987). Also, it has been shown recently (Hori, Kiyohara, Shibata, & Oomura, 1986) that thermosensitive neurons in the preoptic area show a significant change in activity in response to emotional stimuli.

Cooling of the brain is a crucial physiological function. The brain, which is a heat producer many times more active than any other tissue, is also an organ that cannot tolerate temperature variations as readily as do other organs. In the upper limits, the human brain can tolerate temperatures up to about 40.5 °C, whereas the trunk often reaches much higher temperatures. For example, trunk temperature during marathon running goes as high as 42 °C (Cabanac, 1986; Caputa, 1981). The temperature of the human brain depends on the rate of heat production in its cells, cerebral blood flow, and the temperature of the blood that supplies the brain. The cooling of the brain relies heavily on heat exchange, whereby venous blood cooled by evaporation exchanges heat with arterial blood that enters the brain. In addition, brain temperature is controlled conductively by the temperature of venous blood that reaches the cavernous sinus, a venous configuration enveloping the internal carotid just before the latter enters the brain. This structure, which is the only one in the body in which an artery passes in the interior of a vein, participates actively in the regulation of brain temperature (Figure 1). The cavernous sinus is able to perform this function because its veins (that drain blood from nasal and oral mucosa) are air cooled in the course of normal breathing. In an elegant experiment, Kluger and D'Alecy (1975) demonstrated the role of breathing in the cooling of the hypothalamic temperature via the cavernous sinus. Using a reversible tracheal canula, they were able to observe rabbits that were either breathing normally or directly through the trachea, thus bypassing the upper nasal passage and, therefore, also the cavernous sinus. Measures of hypothalamic temperature revealed an increase when the cavernous sinus was bypassed. When the rabbits were breathing normally, the hypothalamic temperature was 0.3 °C lower than rectal temperature. When the rabbits were breathing directly through the trachea, their brain temperature rose to the level of rectal temperature. Parallel results are reported for dogs by Baker, Chapman, and Nathanson (1974).

It is here that contact can be made between the kind of speculation that Waynbaum (1907) offered and what we now know about brain blood processes, thermoregulation, and facial efference. In several emotional expressions, the muscles of the face press against facial veins that empty into the cavernous sinus. And more important, breathing pattern is altered, enhancing or impeding nasal air intake. Both the rate of ambient air intake and the venous flow to the cavernous sinus may have significant roles in altering brain temperature. In a thorough review of research on brain cooling, Baker (1982) described the anatomy and the vascular thermoregulation process in ways that make the VTEE hypothesis quite plausible:

> The cavernous sinus receives venous blood from the nasal mucosa and the skin of the face. Anteriorly, the nasal mucosal veins empty into veins of the palate and into the subcutaneous dorsal and lateral nasal veins, which also drain the skin of the face. Blood in these veins can enter the cavernous sinus via the angularis oculi and ophthalmic veins . . . or can flow into the facial vein and then into the external or internal jugular, bypassing the cavernous sinus. This pattern of venous drainage appears to be similar in most mammals studied . . ., including humans. Since there are no valves in the angularis oculi vein, flow in this vessel can be in either direction. . . . Magilton and Swift (1969) found that the dorsal nasal, angularis oculi, and facial veins in the dog had thick muscular walls and suggested that flow could be diverted either to the cavernous sinus or to the external jugular vein by constriction of one or the other pathways. The direction and rate of blood flow in the angularis oculi vein in humans is dependent upon the thermal state of the subject (Caputa, Perrin, & Cabanac, 1978). Blood flow was low and directed toward the face in cool subjects. In subjects with elevated deep body temperatures, blood flow was higher and directed away from the face toward the cavernous sinus. (pp. 86–87)

Thus, when brain temperature is elevated, blood can be cooled by evaporation on the face and directed toward the cavernous sinus. In some forms of facial emotional efference, the zygomatic muscle, for example, presses against the deep facial vein that receives blood from the angular vein whose tributaries are the supraorbital and the supratrocheal veins (see Figure 1). Constricted at the same time are the superior and the inferior ophthalmic veins. All of these veins empty into the cavernous sinus that cools the internal carotid artery as it enters the brain.

The role of the cavernous sinus is indeed important, and perhaps unique, in thermoregulation. Baker and Hayward (1968) concluded "that the changes in brain temperature which we observe in conscious mammals are not due to changes in local cerebral blood flow or in local neuronal metabolism" and wrote that they "have never observed temperature changes in the brains of conscious animals which were not due to changes in temperature of the arterial blood perfusing the brain" (p. 576). Cooling cannot occur by a reaction that lowers the level of local metabolic activity because it would disturb the ongoing brain processes and the life functions they control. The same can be said about local cerebral blood flow. Although local temperature could be changed by a flow of cooler blood to warmer regions, a change of blood flow for cooling purposes alone would also disrupt vital functions. Thus, brain must be cooled by an external source and process, and if the arterial blood passing through the cavernous sinus does not change its temperature, hypothalamic temperature will not change either.

Winquist and Bevan (1980) have demonstrated bidirectionality of blood flow in the facial vein of the rabbit, finding that it is extremely sensitive to minute changes in temperature. An increase of only 1 °C produced a 100% increase in the vascular myogenic tone of the facial vein. More important, with respect to the relationship between thermoregulation and the emotions, Winquist and Bevan pointed out that the buccal segment of the facial vein shows an unusual preponderance of β-adrenergic receptors. Therefore, if it is true that altered brain temperature can influence the neurochemistry of the brain, then if we can influence the cooling capacity of the cavernous sinus, we will succeed in altering subjective feeling state. One clue to this process can be found in the discomfort we experience during the common cold and profuse nasal congestion. Under these conditions, the cooling action of the cavernous sinus is severely restricted, and as a result, we feel distinct discomfort. Likewise, individuals with a deviated septum, a condition that impairs efficient air cooling of the angularis occuli and the ophthalmic veins, often suffer recurrent headaches. At the extreme end of the continuum, many patients who for various reasons must breathe through tubes inserted directly into the trachea, and thus bypassing the cavernous sinus, experience severe emotional shock (Bendixen, Egbert, Hedley-Whyte, Laver, & Pontoppidan, 1965).

In some cases of severe chronic nose bleeding, a procedure is performed that consists of packing the nose with gauze tampon. The pack is so tight that no ambient air reaches the nasal mucosa, and the patient feels essentially incapable of taking any air through the nose. The procedure can result in a violent emotional reaction, quite often that of severe panic. On removal of the pack, the patient experiences exceptional relief. Monkeys whose nasal airways were packed developed severe distress symptoms, and to some rats this procedure is fatal after only a few hours (P. S. Vig, personal communication, November 1988).

The role of the cavernous sinus in these surgical procedures has never been explored. The nasal-pulmonary syndrome, which has as one of its features the panic felt by the patient, is attributed to hypoxia. However, research indicates no differences in oxygen desaturation for patients with and without nose packing (Taasan, Wynne, Cassisi, & Block, 1981). There is, after all, sufficient air intake through the mouth. More likely is the possibility that the failure of cooling the cavernous sinus is responsible for the panic attacks that the patients suffer.

It has also been supposed that individuals who are mouth-breathers prefer air intake through the mouth because of some nasal obstruction or difficulty. The supposition is based on the least effort hypothesis, which holds that because there are two sources of air intake, the individual will use the one that requires least effort. However, research by Vig (1985) and his colleagues (e.g., Drake, Keall, Vig, & Krause, 1988; Spalding & Vig, 1988) that examined the least effort hypothesis consistently failed to find changes in the proportion of total air breathed nasally as a function of changes in nasal resistance. That is, even when breathing through the nose is made very difficult and effortful, the proportion of nasal breathing is largely unaffected. This must mean that nose breathing serves another function besides taking in air, very likely that of cooling the cavernous sinus.

If facial efference occurring in the course of an emotional experience has an influence on the cavernous sinus, then it too will cause altered subjective feeling states. Stellar (1982) noted quite explicitly that "an operantly produced change in temperature on the skin or in the brain is a highly rewarding hedonic process" (p. 390). From experiments on thermoregulation cited earlier (e.g., Corbit, 1969, 1973), we would expect a slight cooling of the brain to be rewarding and a rise above normal to be noxious.

Theoretical Views of the Sources of Subjective States

The two large divisions among theories of emotion, the feedback view and the cognitive appraisal view, assign roles to facial efference that differ in significance. The feedback position regards facial action as virtually necessary to the subjective emotional experience, whereas cognitive appraisal theory has no specific predictions to make about the subjective effects of facial action.

This article is mainly concerned with two aspects of the emotional process—facial efference and subjective state. It seeks to determine if there is a causal path from the first to the second, and what are the specific links in this process. In Figures 2 and 3, we diagram the basic concepts of the theories of emotion just discussed. We show only those factors with which we are concerned here, facial efference and subjective state. We then diagram the process hypothesized by VTEE that links facial efference to feeling.

Note that, in general, facial feedback theories do not require extensive computation of the stimulus as a necessary prerequisite for either facial efference or feeling—nor does VTEE, as shown in Figure 4.

Specificity of Emotions

Cannon (1927) and James (1890) represent the opposing views on the question of specificity of emotions. For Cannon there was virtually no physiological specificity, whereas for James physiological specificity was a necessary basic premise.

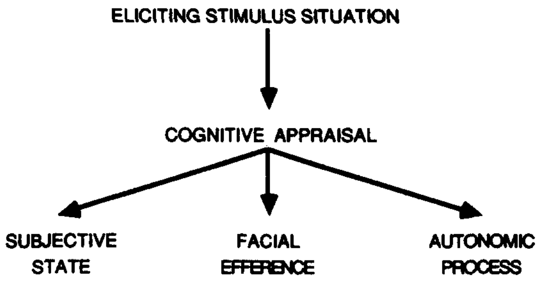

Figure 2. Role of facial efference and subjective feeling in cognitive appraisal theories.

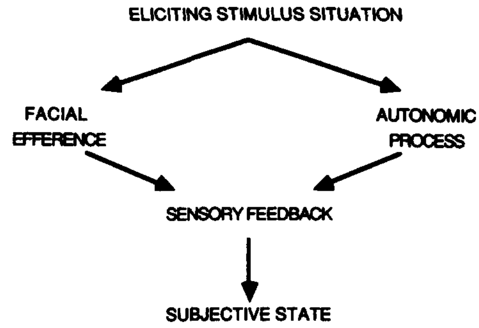

Figure 3. Role of facial efference and subjective feeling in facial feedback theories.

Nearly 100 years of research has shown that the sort of specificity of emotions that exists at the level of semantic labels is not paralleled in the fundamental correlates of emotion—the subjective, the physiological, and the efferent. Thus, although the distinction between guilt and shame is quite clear at the semantic level, it is otherwise obscure.

More than 30 years ago, M. A. Wenger and Cullen (1958) took measures of nine autonomic nervous system (ANS) variables in reaction to 14 stimulus situations, such as an injection, cold pressor, and electric shock. Of course, different stimuli elicited different ANS patterns. However, nothing systematic was learned from the experiment because one could not connect the reactions to the stimuli in a meaningful way.

There are good reasons why this is so. First, there is no one-to-one correspondence at the afferent point of the emotional process, that is, between the eliciting stimulus and emotion. Even for the same individual, the same stimulus will often evoke different emotions on different occasions, habituation being only one among a host of factors that introduce changes in emotional reaction to the same stimulus.

The sensory quality of the eliciting stimulus plays an important role as well. The fear of receiving a failing grade on an exam and the fear of snakes, of loud noises, or of punishment are all types of fear. But the sensory processes in these emotional reactions are quite different, and because these sensory processes are integrated into the physiological reaction, emotions evoked by different sensory and cognitive events will have different physiological responses.

Second, there is *no* one-to-one correspondence at the efferent point of the emotional process either. Many, but not all, emotions originate a chain of motivated action. Often, this action is initiated even before the sensory signal is consciously registered, as for example, in the case of pain reactions. Hence, emotional expressions often overlap with instrumental acts.

Physiological changes take place not only in the course of instrumental action, but even in the anticipation of such action. Obviously, different physiological demands are placed on the angry organism that lurches in blind fury than on the organism that remains immobile and freezes.

More important, some emotions require no instrumental acts at all. The positive emotions, such as joy, pleasure, or happiness, for example, do not instigate instrumental behavior following the emotion because there is nothing to correct or adjust. Generally, although the positive emotions may instigate instrumental action to gain an emotional experience later, the negative emotions elicit instrumental acts afterward to remove the distress. Fear, anger, rage, and disgust, as soon as they had been experienced, motivate complex and often vigorous behavior. Happiness and pleasure do not. Because the negative emotions place substantial energy demands on the organism (e.g., preparation for flight or fight), different autonomic reactions should be expected than from positive emotions. But the differences in these reactions derive not from differences in expressive aspects of the emotions but in their instrumental consequences.

Anger that is repressed and contained will evoke a different physiological response than anger that is expressed in a furious

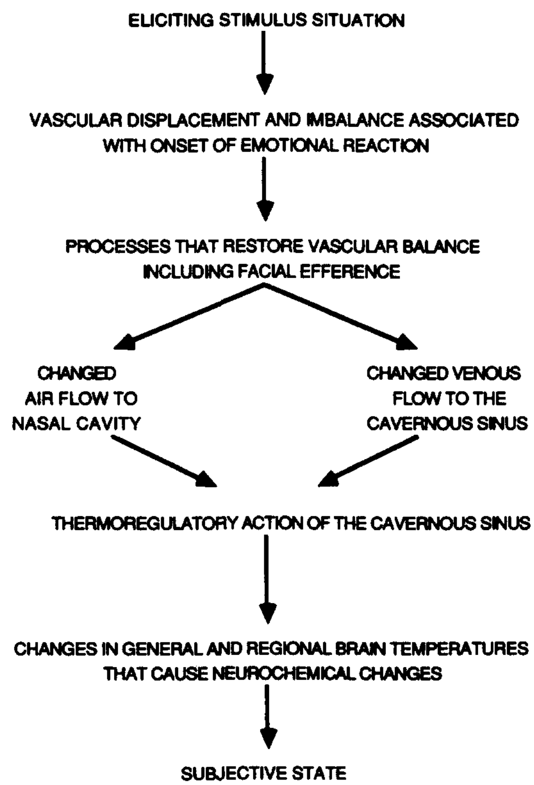

Figure 4. Role of facial efference and subjective feeling in the vascular theory of emotional efference.

attack. Ax (1953) reported an increase in diastolic blood pressure under conditions of manifested anger, but suppressed anger was found to be associated with a decrease in diastolic pressure by Funkenstein, King, and Drolette (1957). Escape from a threatening stimulus must be associated with a very different ANS pattern than freezing.

Not only are the three components weakly intercorrelated, these correlations must surely vary from individual to individual. Take facial efference as an example. There are significant differences in skeletal and muscular structure of the face. The *risorius Santorini* shows enormous range of variation (Gray, 1985, p. 445), as do other muscles and skeletal structures of the face. There are also differences in the reinforcement history of an individual's display behavior. Some children are lavished with rewards for their first smile; others may be ignored. Societies differ in the degree to which emotional efference is permitted to surface as an outward signal, and the display rules that relate facial efference to particular eliciting events differ as well. Moreover, they differ depending on the audience that might be present (Ekman, 1984). It clearly follows that there will be significant individual differences in expressive facial acts.

Despite the disagreement on the taxonomic boundaries of emotion labels, there is virtually full agreement about one important fact—emotions can be discriminated from each other quite reliably according to their positive–negative hedonic polarity. Many theorists consider this polarity to be a fundamental feature of all emotions (Plutchik, 1984; Russell & Bullock, 1986; Tomkins, 1962, to name only a few). The significance of the positive–negative polarity has been underscored by theoretical and empirical work claiming asymmetrical structures for the two polarities (e.g., Davidson, 1984). Consequently, the empirical work presented here focuses exclusively on this fundamental hedonic polarity and does not aspire to shed light on emotion specificity.

Empirical Evidence on the Link Between Facial Efference and Subjective State

Most aspects of the basic questions we raised earlier in the article cannot be resolved without further empirical work. We are not yet in a position of designing critical experiments that would definitively establish the causes of subjective feeling states in emotion, mainly because subjective states and facial action cannot be manipulated independently of one another. So far, no method exists whereby a subjective emotional state can be induced while facial action is arrested. Even if we were to use patients suffering facial paralysis, we could not be entirely sure that all muscular facial impulses, especially those of low amplitude, were absent. And in these patients the cavernous sinus action is not critically deficient. But we are in a much better position in attempting to elicit facial efference in the absence of *prior* emotional arousal. If facial efference can *by itself* induce positive or negative affect, then according to VTEE, natural facial gestures having no apparent tie with emotions, but which have a similar muscular and cutaneous topography, must also produce such effects. The following studies offer data showing that facial movement alone, elicited not by emotional stimuli but by conditions unrelated to emotion, is capable of producing a subjectively felt hedonic experience. The studies must not be understood to claim that facial efference is *a necessary condition* for the elicitation and modification of subjective feeling states nor that its effects are very powerful. What will be claimed, however, is that facial efference in itself can produce altered subjective feeling states.

To examine the hypothesis that facial action, unrelated to emotion, can in itself produce subjective feelings, a naturally occurring facial action was examined for its affective consequences. Consider the following example. The French vowel *u* (as in *sur*) or the German vowel *ü* (as in *für*), require a vigorous action of muscles around the mouth. Benguerel and Cowan (1974) have demonstrated that the upper lip protrusion that accompanies pronunciation of the French *u* begins four to six phonemes in advance of its actual production. The zygomatic muscle, which is contracted in smiling, is extended in uttering *ü*, whereas the corrugator performs the same action in various negative emotions and in uttering *ü*. In addition, the nostrils are constricted, reducing air flow to cool veins draining into the cavernous sinus. If facial action alone can induce subjective feeling changes, either by virtue of some form of facial feedback or by the causal chain that is suggested here, then uttering certain phonemes, whose pronunciation requires muscle movements analogous to those in emotional expressions, should reveal objective and subjective emotional effects.

Study 1

Method

Subjects. A total of 26 native German speakers, who were either exchange students, visiting scholars, or University of Michigan professors, and who spoke German daily, were solicited to participate in the following study. They ranged in age from 20 to 65 years. The ostensive purpose of this and of the following four studies was that they dealt with language acquisition.

Materials. Four short (approximately 200 words) stories were written in German for the purposes of Study 1. Of the four stories, two contained a high frequency of the vowel *ü*, whereas the remaining two contained no words at all with the vowel *ü*. Two sets of stories were compiled, each consisting of one *ü* story and one no-*ü* story. One set of stories involved young boys, Peter and Jürgen (in the no-*ü* story and in the *ü* story, respectively), who wished for their birthdays either dogs and cats (Hunde und Katzen) or foxes and hens (Füchse *und* Hühner). The second set of stories were written in the style of newspaper articles, depicting Peter Meier, who excelled in shot put (Kugelstosser), and Günter Müller, a promising young hurdler (Hürdenläufer). Within each set, every attempt was made to match the *ü* and no-*ü* stories for emotional tone and semantic content.

Procedure. Each subject was asked to read aloud one set of two stories; one half of the subjects read an *ü* story first followed by a no-*ü* story, and one half read the stories in the opposite order. To obtain an indication of cerebral temperature changes, thermographic images of subjects' faces were collected using an AGA infrared Thermographic 782M system. The argon-cooled thermographic camera takes an infrared television image that generates isotherms of surface temperature variations. Depending on the range of temperature variations investigated, different absolute degrees of resolution can be obtained. For our purposes, a range of variation was selected that generated a resolution of 0.5 °C, which was found adequate at the aggregate level. After a 10-min habituation period that stabilized facial temperature, baseline images were collected from each subject prior to reading each story. Subsequent images were taken immediately after subjects read each of the four paragraphs of a story.

After reading both stories aloud, subjects completed a questionnaire probing both their affective reactions to the stories and their recall of the information conveyed. The affect questions asked the subject to make pairwise comparisons of the two stories regarding the suitability of each story for children, their relative resemblance to a fable, the quality of the German prose, the formality of the language, which story was more interesting, and most important, which of the two was more pleasant and which the subject liked better. Free recall questions for the animal stories asked for the names of the protagonists, the color of a truck that brought the animals, which birthday was being celebrated, and what animals the children wished for and received. Similar items were asked in the sports stories.

Results

Two points on the subject's forehead, midway between the eyebrows and the hairline and directly above the pupil of the eye, were measured for surface temperature. These points are on or near the frontopolar branch of the anterior cerebral artery, which issues from the internal carotid as it enters the brain. Hence, the distance of these arteries from the cavernous sinus is small, and the locations give reliable estimates of changes in brain temperature.[1] Individual change scores were calculated by subtracting each subject's baseline temperature from their subsequent temperature at the same two points on the forehead following the first, second, third, and fourth paragraphs. These change scores were then subjected to a 2 × 2 × 2 × 4 (Phoneme × Story Set × Lateral Position × Paragraph) mixed-design repeated measures analysis of variance (ANOVA).

The two forms (one from each set) of the *ü* stories did not differ from one another either in thermographic measures or in subjective ratings. The same was true of the two forms of the no-*ü* stories. Also, no differences were detected in temperature changes between the left and the right frontal locations. However, forehead temperatures changed markedly when subjects read the *ü* stories. The mean rise for the reading of the *ü* stories was +0.30 °C, whereas there was virtually no temperature change (+0.02 °C) for the no-*ü* stories. This difference was significant at the .001 level, $F(1, 24) = 18.16$. Also, the rise for the *ü* stories was significantly different from each subject's baseline, $t = 5.55$, $p < .001$, and not significant for the no-*ü* stories, $t = 0.45$. Figure 5 indicates that the change in temperature observed for the *ü* stories was not gradual, but rather it rose sharply during the first paragraph and remained elevated for the remainder of the *ü* stories.

At the subjective level, the no-*ü* stories were liked significantly better than the *ü* stories by 78% of the subjects ($p < .005$), and 81% ($p < .001$) found the no-*ü* stories more pleasant. No differences were found between the *ü* and no-*ü* stories in how interesting they were, which was written in better or more formal German, which was more like a fairy tale, and which was more suitable for children. The accuracy of recall was quite high, and no differences between stories were obtained. Hence, differences in the ease of processing apparently did not contribute to the obtained differences.

Study 2

Elevated negative affect, which in the first study was manifested by elevated forehead temperatures and the lower pleas-

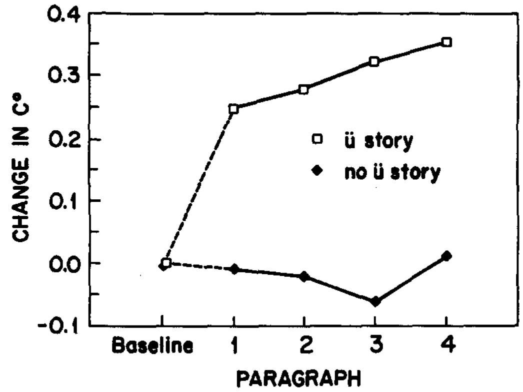

Figure 5. Changes in facial temperature for reading *ü* and *o* stories.

antness and liking ratings, was attributed to the muscular movements made in reading material containing the frequent occurrence of the phoneme *ü*. But a possibility remains that the muscular movements were not actually necessary for the physiological and subjective changes that we found in association with uttering the phoneme *ü*. If there was a quality in the semantic patterns, for example, that made the *ü* stories less pleasant, independent of the subjects' facial muscular involvement, and if the subjective experience deriving from this quality (and established perhaps by some form of interoceptive conditioning) acted to increase facial temperature, then it cannot be claimed that facial muscular movement is a sufficient condition for change in subjective affective state.

It is the case that beyond differences in liking and pleasantness ratings, the stories were not judged to be different in their quality of German, interestingness, or suitability for children. Nor were there any recall differences. But there could have been other unmeasured properties of the stories that were responsible for the obtained differences. For example, it might be possible that *ü* is semantically associated with generally negative affect. This is unlikely, however, because a vast number of positive words contain the phoneme *ü* in German. Many German nouns that in the first syllable contain *u* change it into *ü* in their plural form. This would mean that if *ü* is associated with nega-

[1] Typically, brain temperature in humans is estimated from tympanic membrane (Baker, Stocking, & Meehan, 1972; Benzinger, 1969). However, these measures are intrusive; for instance, one of the criterion for a proper placement of the probe against the membrane is the subject's affirmation of an acute pain (Brinnel & Cabanac, in press). As we noted above, in several veins of the head that are implicated in the thermoregulation of the brain, blood flows in both directions. This is true of the ophthalmic veins (Caputa, Perrin, & Cabanac, 1978), of the angularis oculi (Baker, 1982), and of the mastoid and parietal emissary veins (Cabanac & Brinnel, 1985). When the brain temperature is elevated, flow in these veins is from the surface toward the brain. But in the case of hypothermia, the flow is away from the brain and toward the surface of the skin. Hence, some surfaces of the face and head are a good indication of the thermal status of the brain. The forehead represents such an area. Although forehead temperature cannot be used to estimate absolute levels of brain temperature, it is a good estimate of *changes* in brain temperature (see, e.g., Germain, Jobin, & Cabanac, 1987; McCaffrey, McCook, & Wurster, 1975).

tive affect, the same must hold for *u*. More important, however, such nouns also change *u* into *ü* in their diminutive form (e.g., *Mutter–Mütterchen, Bruder–Brüderlein*), and the diminutive form is clearly a mark of particularly positive affect. Nevertheless, an experiment was carried out for the purposes of further control, using subjects who could not process the semantic content, that is, Americans who could not speak or understand German, and whose native language does not contain the phoneme *ü*.

If some form of conditioning takes place in the German subjects' early linguistic experience whereby negative affect is conditioned to the sound *ü*, such conditioning is not possible for American subjects because these subjects have virtually never been exposed to the sound *ü* as a conditioned stimulus, nor have they ever learned to produce the response *ü*. Even for Germans, it is quite unlikely that *ü* could have become *uniquely* conditioned to negative affect, inasmuch as words containing *ü* are likely to have positive as well as negative valence.

Nevertheless, new insights can be gained by comparing a population that has access to the semantic content of the stories with one that does not. Because of the obvious constraints in Study 2, therefore, subjects did not read the stories, but they listened to them instead. This aspect of the experiment makes the comparison between native Germans and Americans especially informative, because if both the German and the American subjects show negative affect that is equal in strength to that obtained as a result of uttering the phoneme *ü*, then we would conclude that facial muscular action is not necessary for the elicitation of negative subjective feelings.

Method

Subjects. A total of 20 native German and 20 American subjects who spoke no German participated in this study. The American subjects were recruited from the University of Michigan subject pool, and they received credit in an introductory psychology course for their participation. Of the German subjects, 12 had participated in the previous study; the remaining 8 were recruited from the same population as in Study 1. The stories presented to the German subjects who participated in the previous research were never those that they had been exposed to in Study 1.

Procedure. Subjects listened to one of the two sets of stories used in Study 1, including one *ü* story and one no-*ü* story. The stories were played aloud. Baseline thermographic images were collected following habituation but before subjects listened to the stories. Because in Study 1 the major changes in temperature were evident after the first paragraph and no other temporal trends in forehead temperature were detected, changes in temperatures were now observed by taking measures only before and after listening to the stories. Finally, subjects were asked to report subjective information similar to that gathered in Study 1. The German subjects were also asked to recall factual information as in Study 1. No recall data were collected from the American subjects.

Results

Data from 2 American subjects were excluded because of head movement artifacts. Data collected from the remaining American subjects revealed no significant shifts in temperature between listening to the *ü* and no-*ü* stories. Both story types resulted in small but insignificant elevations from subjects' baseline temperature, +0.07 °C, $t(17) = 0.30$, $p < .24$, for the *ü* stories, and +0.03 °C for the no-*ü* stories, $t(17) = 0.2$, $p < .77$.

German subjects from whom free recall data were collected showed no differences in recall of the two stories. Although German subjects experienced somewhat greater deviations from their baseline temperatures, +0.10 °C for the *ü* stories and −0.22 °C for the no-*ü* stories, these shifts were likewise insignificant, $t(19) = 0.54$, $p < .59$, and $t(19) = 1.80$, $p < .09$. Together with data from Study 1, this result indicates that motor involvement, such as was present in reading the stories, contributes in a significant degree to temperature change. The fact that German subjects show a somewhat greater, albeit nonsignificant, temperature change than do American subjects is probably due to the fact that they understand the stories. Therefore, they respond more uniformly to particular phrases and particular features than do the American subjects. These reactions may also involve some facial actions, such as smiles, frowns, surprise expressions, and raised eyebrows. Americans, too, may have made some minimal facial responses in listening to the stories, but because they do not understand the content, their reactions are likely to vary randomly from subject to subject, preventing systematic effects.

In fact, a breakdown by story reveals that what appears to be a marginally significant drop in temperature of −0.22 °C for Germans listening to the no-*ü* stories is primarily due to a significant reduction in temperature of approximately −0.30 °C associated with a particular no-*ü* story entitled "Hunde und Katzen" or "Dogs and Cats", $t(9) = 2.25$, $p < .05$. Listening to the alternate no-*ü* story "Kugelstosser," about Peter Meier, a man who excelled in shot put), resulted in a much smaller (less than −0.10 °C) and insignificant shift in temperature among the German subjects, $t(9) = 0.56$, $p < .59$. No parallel differences for stories were found among the American subjects.

The suspicion that one version of the no-*ü* stories ("Hunde und Katzen") aroused positive feelings among the German subjects who appreciated its content and therefore responded accordingly with an appropriate facial action, is supported by subjective evidence. Of German subjects listening to the "Hunde und Katzen" story, 80% liked it better and rated it as more pleasant and less formal than they did the corresponding *ü* story. These differences were significant at the .05 level for each of the three ratings. Germans listening to the alternate set of stories showed no systematic preference between the *ü* and no-*ü* stories.

Parallel findings were obtained in Study 1. The "Katzen und Hunden" story was perceived as more pleasant than the "Kugelstosser" story in that study as well. However, no corresponding significant differences were found in temperature changes.

As noted, no significant differences between story sets was found for American subjects in Study 2. These subjects, however, did show a marginally significant preference for the no-*ü* stories, as 70% of these subjects reported liking the no-*ü* stories better and finding them more pleasant ($p < .06$) than the *ü* stories. American subjects also found the *ü* stories more interesting, whereas German subjects found the no-*ü* stories somewhat more interesting. This interaction is significant at the .02 level. The other subjective measures showed no significant main effects or differences between Germans and Americans.

The results of Study 2 support the proposition that facial

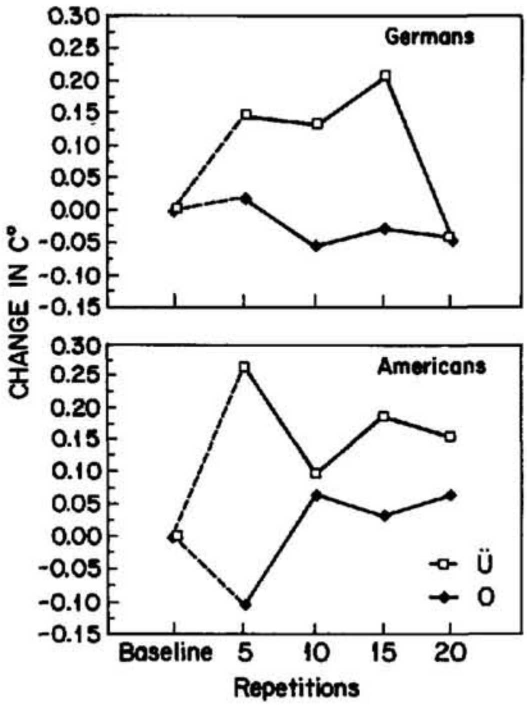

Figure 6. Changes in facial temperature for *ü* and *o* vowels.

movement contributes significantly to altered subjective feeling. It does not rule out the possibility, however, that changes in subjective feeling may occur for other reasons. In Study 2, facial movement was not eliminated; it was merely reduced. If there was any facial action at all, it was now elicited when subjects reacted to the semantic content of the stories. Temperature associated with positive subjective reaction to a particular story suggests that content of the stimulus materials may have induced some facial movement and may have therefore constituted a source of confounding in the first two studies. The studies that follow seek to exclude any such confounding effects deriving from semantic content.

Study 3

Study 3 seeks to examine the affective reactions to a naturally occurring muscular movement that is free from virtually any semantic or affective content. Semantic content, except for phonetic symbolism, was eliminated as completely as possible by having subjects utter phoneme sounds. The task, thus, consisted simply of repeatedly pronouncing the phoneme *ü* and a control phoneme *o*. If differences are now obtained in forehead temperature and in subjective ratings, there is less suspicion that the stories in Study 1 varied along dimensions that we did not measure but that nevertheless contributed to the obtained effects. There is also stronger support for the hypothesis that muscular movement of the face has objective and subjective affective consequences and that its effects are revealed in altered facial temperature. A comparison between German and American subjects would again be informative.

Method

Subjects. A total of 20 native German speakers and 20 Americans served as subjects. The subjects were the same as in Study 2.

Procedure. Both German and American subjects repeated aloud after a tape-recorded voice the vowel sounds *ü* and *o* 20 times each, at 3-s intervals. In the course of uttering the vowel phonemes, thermographic readings were taken before the vowel session (baseline) and after the 5th, 10th, 15th and 20th repetition of each vowel sound. Finally, subjects rated the two sounds on 7-point scales according to how pleasant, familiar, and difficult they were to produce, and how much they liked each sound.

Results

Data from 1 German and 2 American subjects were excluded from the analysis because of head movement artifacts. A 2 × 2 × 2 × 4 (Phoneme × Native Language × Lateral Position × Trial Blocks) mixed-design repeated measures ANOVA revealed significant temperature effects when subjects uttered the vowel sounds *ü* and *o* (Figure 6).

The phoneme *o* had no apparent effect on forehead temperature, producing a change of only +0.02 °C. In response to the phoneme *ü*, however, there was a rise of +0.14 °C, $F(1, 35) = 4.40$, $p < .04$. The differences in temperature appeared to be slightly greater for the American speakers (+0.17 °C and −0.02 °C for the *ü* and *o*, respectively) than for the German speakers (+0.11 °C and −0.03 °C). However, this interaction did not reach an acceptable significance level.

As seen in Figure 7, both German and American subjects liked the *o* sound better than the *ü* sound and rated it as more pleasant, $t(36) = 7.70$, and $t(36) = 6.37$, $p < .001$, respectively, for liking and pleasantness for both groups together. It is interesting that the less the German subjects liked the vowel *ü*, the greater was their average rise in temperature across the 20 repetitions ($r = -.45$, $p < .05$). For the American subjects, however, this correlation was not significant.

American subjects, *but not the German subjects,* rated the *ü* sound as less familiar, $t(17) = 4.51$, $p < .001$, and more difficult

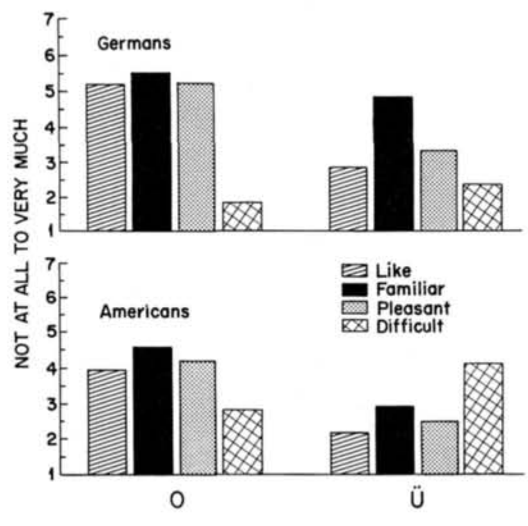

Figure 7. Subjective ratings of *o* and *ü* vowels.

Table 1
Standardized Regression Coefficients for Liking Regressed on Temperature Change, Familiarity, and Difficulty in Response To Uttering ü *and* o *Phonemes*

Subjects/ condition	R^2	Temperature change	Familiarity	Difficulty
Germans				
o	.17	−.13	.37	−.09
ü	.61***	−.50***	.64***	.03
Americans				
o	.38	.10	.58**	−.09
ü	.50**	−.40*	.66***	−.02

* $p < .06$. ** $p < .02$. *** $p < .01$.

to produce, $t(17) = 2.61$, $p < .02$, than the *o* sound. For the German speakers, *o* and *ü* were equal in difficulty. Because we have here two samples showing similar affect ratings and similar temperature changes, and because one found the phoneme *ü* difficult and the other found it easy, we can eliminate the possibility that *o* was perceived as more pleasant than *ü just* because it was more familiar or easier to produce. The German subjects who found the two sounds equally familiar and equally difficult, nevertheless had a decidedly more positive affective reaction to the *o* phoneme than to the *ü* phoneme, $t(18) = 5.08$, $p < .001$. This preference for the phoneme *o*, although somewhat weaker, was also true for Americans, $t(18) = 3.83$, $p < .001$), for whom the phoneme *ü* is strange and difficult.

To determine whether temperature change has an independent effect on liking, a set of multiple regression analyses were carried out in which liking was regressed on temperature change, familiarity, and difficulty ratings (see Table 1). Pleasantness ratings were not included in these analyses because they were very highly correlated with liking. As shown in Table 1, the multiple regressions are significant and substantial for the *ü* conditions and not significant for the *o* condition. This is so because there was virtually no temperature effect for the phoneme *o*, and hence hardly any variance. The standardized regression coefficients are significant for the phoneme *ü*, both among the German as well as the American subjects. The data, therefore, can be taken as indicating that the subjective feeling associated with uttering phonemes is directly related to temperature change, even when other factors are held statistically constant.

Discussion

The results of these studies indicate that muscular movement of the face, analogous to that involved in emotional expression, is a sufficient condition for the induction of affective reactions. At the level of the physiological measure used, as well as on the basis of subjective affect ratings, consistent results indicate that facial efference plays a significant role in generating affect.

In the aforementioned studies, we were able to eliminate artifacts due to task difficulty, affective reactions based on semantic content, and most important, artifacts that derive from the subjects making inferences about the relation between their own facial action and emotions such as are present in many studies of facial feedback. When the subjects were questioned after the experiment, none guessed that affect was of any interest in the study. Furthermore, none of the German subjects in the reading study spontaneously mentioned that the two stories differed in the frequency of the *ü* phoneme, although a few acknowledged it when this difference was pointed out to them. Finding similar results in Study 3 in subjective affect and objective measures for both German and American subjects eliminated the possibility that semantic symbolism played a role in the subjective and objective reactions. One cannot rule out, however, unconscious cognitive appraisal such as is postulated by Leventhal and Scherer (1987). But the influence of unconscious cognitive factors can be neither proven nor falsified (Zajonc, 1984) under the conditions of the present experiments, nor can it be specified what aspect of the stimulus or the situation was being appraised.

Study 4

Studies 1–3 succeeded only in generating negative affect by means of phonetic utterance. If we are to approximate emotional expressions by muscular action associated with phonetic utterance, it is useful to discover if positive affect can also be so generated. Study 4 examined subjective and objective reactions over seven vowel sounds—*i, e, o, a, ü, ah,* and *u*—in an attempt to discover if some of them produce positive affect. A priori, we would expect that the phoneme *e*, having facial action similar to a smile, and the phoneme *ah*, which is similar in muscular pattern to that in pleasant surprise, might have such effects. We would further expect that positive affect is associated with a drop in temperature. If so, then temperature will have become a new physiological measure, besides heart rate (Winton, Putnam, & Krauss, 1984) and brain asymmetry (Davidson, 1984) to discriminate affective polarity.

Method

Subjects. A total of 26 male introductory psychology students at the University of Michigan participated in this study in partial fulfillment of a course requirement.

Procedure. Subjects arrived separately and were informed that the experimenter would be with them momentarily. A 10-min habituation period that stabilized facial temperature was necessary to ensure that subjects, who had been exposed to varying weather conditions, returned to a normal range of temperature. After this time elapsed, subjects were told that they would be involved in a study of language acquisition and were given a copy of the following instructions:

> The first segment of this experiment requires that you repeat seven vowel sounds aloud twenty times each following a tape-recorded voice. Please try to repeat each sound as accurately as possible even though several vowels may sound unfamiliar. Because you will be photographed periodically throughout these repetitions, it is extremely important that you do not move your head. Following each series of twenty repetitions you will be asked several questions about that particular vowel sound. Do you have any questions?

Subjects then repeated aloud after a tape-recorded voice the first vowel sound 20 times, at 3-s intervals. Thermographic readings were collected, as previously, prior to the vowel session (baseline) and following the 5th, 10th, 15th and 20th repetitions. After the 20 repetitions, subjects were asked to rate the sounds on 7-point scales according to how pleasant, familiar, and difficult it was to produce, as well as how much they liked the sound and whether it put them in a good or bad mood. This procedure was repeated for the remaining six vowel sounds.

To control for possible order effects, one half of the subjects were presented with the seven vowel sounds in one order (i, e, o, a, ü, ah, u) and one half in another order (i, ü, o, a, e, ah, u). Note that only the phonemes that are of focal interest, namely *e* and *ü*, change places to control for position effects. The positions of the other phonemes remained constant.

Results

Two points on the subject's forehead, midway between the eyebrows and the hairline and directly above the pupil of the eye, were again measured for surface temperature, and as previously, individual change scores were calculated by subtracting each subject's baseline temperature, taken immediately prior to a set of 20 repetitions from their subsequent temperature after the 5th, 10th, 15th and 20th repetition of each vowel.

The mean of these change scores for each vowel was subjected to a 2 × 2 × 7 (Order × Lateral Position × Vowel Sound) mixed-design repeated measures ANOVA. This analysis revealed no significant differences in surface temperature between the left and right frontal locations. Likewise, the order in which subjects repeated the vowels appeared to have no effect on temperature. However, there was a significant temperature effect for the various vowel sounds, $F(6, 144) = 2.40, p < .05$.

Collapsing across order and right and left frontal location, the mean change scores for each of the vowel sounds are shown in Figure 8.

Tests revealed that the vowel sound *ü* resulted in a significant increase in forehead temperature from baseline, $t(25) = 2.24$, $p < .05$, whereas the sounds *ah* and *e* both resulted in a marginally significant decrease in temperature, $t(25) = 1.86, p < .07$, and $t(25) = 1.83, p < .08$, respectively.

In general, the subjective ratings are consistent with the changes in temperature. The phoneme that was associated with the highest rise in forehead temperature (*ü*) was liked least and put the subjects in the worst mood, whereas the phonemes that were associated with the greatest decrease in forehead temperature (*ah* and *e*) were liked best, $t(25) = 3.45$, and $t(25) = 3.46$, respectively, $p < .01$, for both, and put subjects in the best mood, $t(25) = 2.41, p < .05$, and $t(25) = 1.58, p < .12$, respectively; see Figure 9A and 9B. Because order was counterbalanced for *ü* and *e*, we can be fairly certain that the differences are due primarily to the muscular movements associated with pronouncing these phonemes.

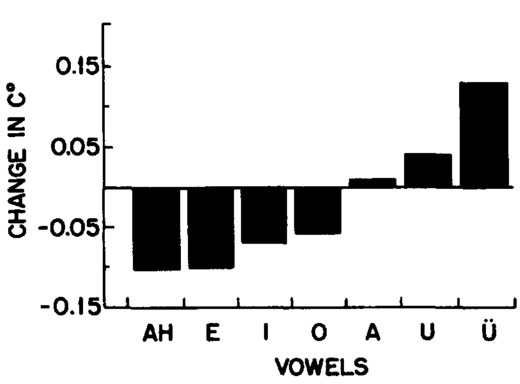

Figure 8. Changes in facial temperature for vowel phonemes.

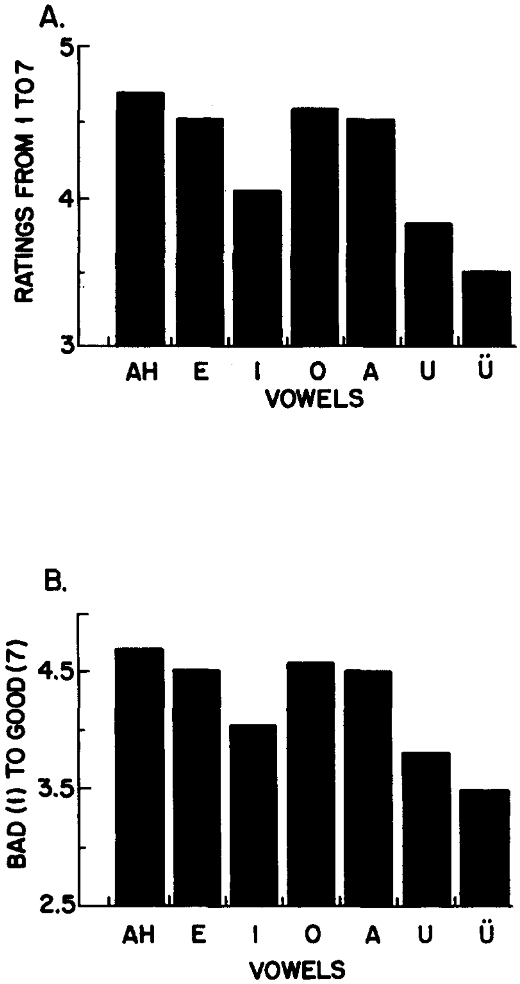

Figure 9. Subjective ratings of (A) liking and (B) mood for vowel phonemes.

Thus, the present study, along with previous results, confirms that the phoneme *ü* raises forehead temperature and receives the most negative affective ratings. But also, and more important, we found that some vowel phonemes are capable of decreasing temperature and eliciting positive subjective affect. This data represents a clear instance in which a physiological measure discriminated systematically between hedonic polarities. These findings then are in clear contrast to those that are generally obtained with such physiological measures as blood pressure and galvanic skin response (GSR) that discriminate only among hedonic intensities, and fail to discriminate between positive and negative affect. Thus far, there are only two such measures, recently discovered, heart rate (Winton et al., 1984) and brain asymmetry (Davidson, 1984).

It is important to note that both positive and negative reactions were obtained in association with different vowel sounds and that these positive and negative reactions were highly consistent with changes in temperature, both at the aggregate and at the individual level. For instance, even though forehead temperature increased for *ü* and decreased for *e* for both of these phonemes, the standardized regression coefficients for temperature change, when liking was regressed on temperature change, familiarity, and difficulty, were negative (−.36 and −.23 for *ü* and *e*, respectively). It is of interest that the results in the present study closely parallel the results in Study 3, in which we obtained a correlation of −.45 between liking and temperature change for the phoneme *ü*. Here, this correlation was −.43 for the phoneme *ü*. Thus, an hypothesis that seeks to explain affective ratings of vowel sounds on the basis of other factors, such as phonetic symbolism, familiarity, or effort would stop short of accounting for the correlated changes in temperature, obtained with these other factors held constant.

Discussion

Taken together, Studies 1–4 strongly suggest that facial muscular action is capable of inducing positive and negative subjective feeling states. The data agree with the theoretical expectations based on VTEE in showing correlated changes in forehead temperature. The precise details of the process, of course, still need to be documented and described. However, in fundamental aspects, especially those that involve the role of the cavernous sinus in cooling the brain and its vulnerability to facial action, VTEE seems to be supported. In other words, because the pronunciation of *ü* restricts nasal respiration, restraining cooled blood before it reaches the cavernous sinus, brain temperature is likely to be elevated. The phonemes *e* or *ah*, on the other hand, expand nasal air access. Facial muscles constrict the veins carrying blood to the cavernous sinus in *u* and *ü*, but in uttering *e* or *ah* these vessels are apparently free to carry blood unimpeded.

Still, more direct evidence is needed in exploring the role of temperature in subjective states. In a preliminary experiment on the role of nasal cooling of the cavernous sinus in humans, we observed forehead temperature in 6 subjects who placed a swimmers' clip on their noses, thus restricting nasal breathing. Measures were taken during a 1-min baseline period (at onset and then after each of four 15-s intervals) and a 2-min experimental period (at onset and after each of eight 15-s intervals). There was an average of 0.25 °C difference between this experimental condition and the no-nose-clip control condition in temperature rise.

Study 5

If it is indeed the case that the cooling and warming of the cavernous sinus[2] plays a significant role in affective experiences, then we should be able to see these effects in reaction to a more direct manipulation. We might simply allow air that is slightly cooled or slightly warmed to enter the nasal cavity and observe the subsequent facial temperature and subjective state. Baker and Hayward (1968) reported that when air at 25 °C is blown over the nasal mucosa of the sheep, there is a precipitous temperature drop in the cavernous sinus, at the cerebral arteries, and in the brain. However, Baker and Hayward did not vary air temperature. An experiment with human subjects, similar to theirs but using ambient, cooled, and warmed air, would further strengthen the supposition that the temperature of the blood entering the brain has a great deal to do with subjective state.

The nose-clip study only dealt with temperature rise, but that effect could have been occasioned by a different process than the one we assumed to operate, because restricting air flow to the nasal arch may have a variety of confounding effects. Hence, it is desirable also to observe affective reactions when the cooling process is promoted. Note that other theories of emotional expression, such as facial feedback, are not able to predict whether cooling should be associated with pleasant or unpleasant subjective state. Neither can the cognitive appraisal theory. A theory involving subcortical factors in the emotional subjective state has no means of making such a prediction either. However, VTEE makes the prediction that warm air intake should be unpleasant, whereas cool air intake should be experienced as pleasant.

Method

Subjects. A total of 20 male introductory psychology students at the University of Michigan participated in this study in partial fulfillment of a course requirement.

Procedure. In order to conceal the purpose of the experiment and to eliminate any possible connection to emotion, the experiment was presented as dealing with reactions to olfactory stimulation. Subjects arrived separately and were informed that the experimenter would be with them momentarily. A 10-min habituation period that stabilized facial temperature was necessary to ensure that subjects, who had been exposed to varying weather conditions, returned to a normal range of temperature. After this time elapsed, subjects were told that they would be involved in a study of reactions to olfactory stimulation and given a copy of the following instructions:

> The experiment you will be participating in today involves individual differences in the perception of smell. You will be asked to smell several different scents, all of which are organic and totally harmless, and rate each on a variety of dimensions. During the two minute period in which you are evaluating a particular scent you will be photographed periodically. It is extremely important, therefore, that you find a comfortable position and do not move during the trials. Do you have any questions?

Air used in the three trials was generated by a heating and cooling unit, similar to that of a hair dryer, that was not visible to the subject. During the warm-air trial, the air was heated to 32.2 °C (note that this is less than normal body temperature by about 5 °C). Air temperature in the cool air trial was 18.9 °C. During the oregano trial, air of 22.2 °C, was slightly scented using a porous sachet of oregano. The ambient room temperature varied between 20.0 °C and 21.1 °C, the same as in all previous experiments.

The air was funneled at a rate of 111 ml/s through a 156-cm length of Norton Tryon plastic tubing, 0.64 cm in diameter, with a 2.56-cm-long removable tip that was replaced for each subject for sanitary purposes. Subjects held the tip of the tubing immediately below their right nostrils throughout the 2 min of a trial. The position of the tubing was justified to subjects on the grounds that otherwise they might miss some subtle scents. Even though there were substantial differences in air flow temperatures, no subject after debriefing indicated any awareness that the trials involved differing temperatures, perhaps because the trials were separated by approximately 3-min intervals.

[2] Some authors have recently questioned the cooling efficiency of the cavernous sinus in humans (C. B. Wenger, 1987).

To monitor cerebral blood temperature, thermographic readings were collected prior to each of the three trials (baseline), and every 15 s for the 2-min duration of the trial. After each of the three trials, subjects were asked to rate the "scent" on 7-point scales, according to how pleasant, familiar, and sweet it was, as well as how much they liked it and whether they thought that smelling this scent for a prolonged period would be more likely to put them in a good mood or in a bad mood.

To control for possible order effects, one half of the subjects were presented with warm air on the first trial, then with oregano, and then with cool air on the last trial, whereas the remaining subjects received the cool air first and the warm air last.

Results

As before, two points on the subject's forehead, midway between the eyebrows and the hairline and directly above the pupil of the eye, were measured for surface temperature. Individual change scores for each of the three trials (warm air, oregano, cool air) were calculated by subtracting subjects' baseline temperature taken immediately prior to a given trial from their subsequent temperature at the same two points on the forehead from the eight subsequent readings taken at 15-s intervals during a trial.

The means of these change scores for the three trials (warm air, oregano, cool air) were subjected to a 2 × 2 × 3 (Order × Lateral Position × Trial) mixed-design repeated measures ANOVA. This analysis revealed no significant differences in surface temperature due to the order in which the warm and cool air were presented. Also, no significant differences in temperature between the left and right frontal locations emerged. However, there was a significant temperature effect for the air presented, $F(3, 54) = 4.75$, $p < .01$. The mean change scores for each of the trials are shown in Figure 10, collapsed across order and right and left frontal location.

Pairwise *t* tests reveal that during the warm-air trial, subjects' facial surface temperature rose significantly, $t(19) = 4.14$, $p < .01$. Conversely, during the cool-air trial, subjects showed a marginally significant decrease in temperature, $t(19) = 1.84$, $p < .08$. Although surface temperature rose slightly during the oregano trial, this increase was not significant.

Subjective ratings across the three trials are shown in Figure 11. Subjects liked the "scent" that was ostensibly introduced

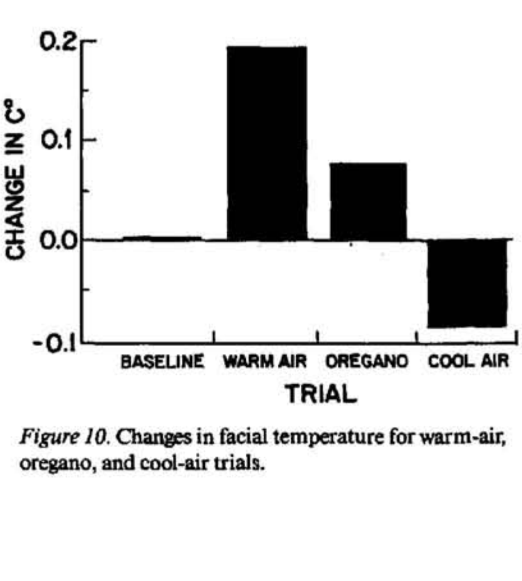

Figure 10. Changes in facial temperature for warm-air, oregano, and cool-air trials.

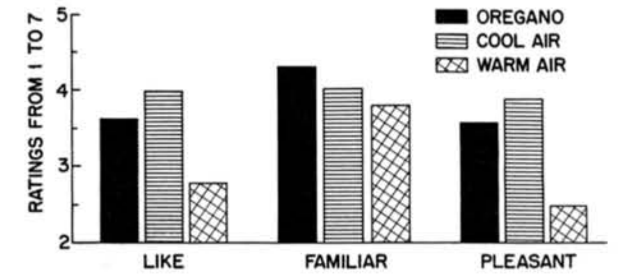

Figure 11. Ratings of liking, familiarity, and pleasantness of "scents" in warm-air, oregano, and cool-air trials.

with the warm air significantly less than that with both oregano and cool air, $t(19) = 6.29$, and $t(19) = 3.80$, $p < .01$, for both. (Of course, as noted in the Method section, no scent accompanied the warm- and cool-air trials.) This same trend was evident in subjects' ratings of how pleasant they found each of the trials, with the warm-air "scent" once again being given a significantly lower rating than both the oregano and the cool-air "scent," $t(19) = 6.29$, and $t(19) = 2.92$, $p < .01$, for both. No significant differences were found for familiarity or for the sweet–sour dimension.

The preceding findings show stronger effects for warm air than cool air, both in temperature change and in affective ratings. The increase in forehead temperature that was associated with warm air was greater than the drop associated with cool air; and liking ratings paralleled the temperature data. This result is entirely consistent with the differences between ambient air temperature and air that was introduced into the subjects' nasal cavities. Recall that ambient temperature of the laboratory room was kept at 20 °C to 21 °C. Thus, for warm air, the difference was +11.2 °C to +12.2 °C, whereas for cool air it was only −1.1 °C to −2.1 °C. It should not be surprising that our effect mirrors these differences with warm air, causing a more dramatic shift in both temperature and liking. For the same reason, oregano trials generated effects similar to cool-air trials. These differences between air introduced into the nasal cavities and ambient air were kept minimal in order to conceal from the subjects that temperature was a critical factor in the experiment. In fact, no subject became aware of temperature differences.

Table 2 shows the results of three multiple regression analyses in which liking ratings were regressed on temperature change

Table 2
Standardized Regression Coefficients for Liking Ratings Regressed on Temperature Change and Familiarity in Three Conditions of Air Induction

Condition	R^2	Temperature change	Familiarity
Cool air	.12	−.35	.06
Oregano	.31	−.29	.51*
Warm air	.36*	−.69**	.19

* $p < .02$. ** $p < .01$.

and familiarity. As previously, the standardized beta coefficients for the relation between liking and temperature change were significant, and in the case of warm air, in which the most pronounced temperature change occurred, they were quite substantial.

Subjects' predictions as to whether smelling a particular scent for a prolonged period of time would be more likely to put them in a good mood or in a bad mood yielded similar results. Of the 20 subjects, 17 reported that the "scent," which they ostensibly smelled when warm air was introduced would induce a bad mood, departing significantly from chance ($p < .05$). In contrast, only 7 of the 20 subjects in both the cool-air and oregano trials suggested that this scent would result in a bad mood. If our assumptions are correct, these results may now be interpreted to mean that if facial efference results in subjective affective reactions, it does so by virtue of its influence over brain temperature. This is so because, in the absence of facial movement, the direct physical manipulation of the temperature reaching the cavernous sinus also results in affective changes, with cooling being felt positively and warming being felt negatively. Thus, Study 5 shows temperature once again to be a measure capable of discriminating between hedonic polarities.

General Discussion

It appears, therefore, that muscular facial actions may have an independent influence over the individual's subjective feeling state. To the extent that pronouncing the phoneme *ü* constricts angular and ophthalmic veins and reduces air intake into the nasal cavity, cooling by the cavernous sinus is impeded and the blood entering the brain is not sufficiently cooled. Such a state is felt as discomfort, and subjects, in turn, rate the phoneme *ü* negatively. On the other hand, the more open phonemes *ah* and *e* do not restrict venous flow to the cavernous sinus and enhance free passage of ambient air (which, of course, is considerably cooler than venous blood) into the nasal cavity, thus cooling the venous blood in the ophthalmic veins that feed the cavernous sinus. In fact, *e* requires some distension of the nostrils. The uttering of the phoneme *e*, as in *cheese*, has a great topographical similarity to the muscular movement of a smile inasmuch as both require the contraction of the major zygomatic muscle. There is no reason to doubt that muscular movements elicited in the course of emotional episodes have similar effects. And the similarity of the phoneme *ah* to the facial actions often seen in delight and pleasant surprise, would lead one to expect low temperatures and positive subjective ratings for that phoneme as well.

The mediating role of cerebral temperature in the link between facial efference and subjective state is supported by a variety of facts. First, we did obtain a significant correlation between blood temperature and liking—the less the item was liked, the higher was the subject's rise in forehead temperature. A similar relation between temperature and emotion has been found in other contexts. Cohen, Izard, and Simons (1986) recently found forehead temperature to differentially track heart rate changes in 4½-month-old infants expressing sadness or anger. Ekman et al. (1983) used finger temperature to distinguish between fairly specific emotions. Finger temperature, moreover, is commonly used as a cue in biofeedback treatment of migraine headaches, which are typically associated with cerebral vascular disturbances (Mathew et al., 1980).

But there is also another line of research that has a bearing on the link between brain temperature and emotion and that can benefit from the concepts of VTEE. The metaphors *hothead, boiling mad, hot under the collar,* and *cool as a cucumber* are not altogether accidental, and the present study is not the first to measure head temperature change in response to an emotional episode. More than 100 years ago, Lombard (1879) made just such measurements. More recently, extensive research has shown that aggression and negative affect occur more readily when ambient temperature is high (Baron, 1977). For example, one study demonstrated that when placed in high ambient temperature, subjects reported feeling more aggressive and rated a stranger in more hostile terms (Griffitt, 1970; Griffitt & Veitch, 1971). Significantly, aggression in the form of rape, murder, and assaults was also found to increase with elevated ambient temperature (Anderson & Anderson, 1984; Cotton, 1981; Harries & Stadler, 1988; Rotton & Frey, 1985). Reifman, Larrick, and Fein (1988) have found that in major-league baseball, the batter's likelihood of being hit by a pitched ball increases with ambient temperature. These studies simply assert that a relation exists between elevated temperature and negative affect, but they do not explain why. The concepts of VTEE that implicate the role of the cavernous sinus offer a plausible explanation.

The question about the role of facial efference in the experience of emotion, which is a fundamental problem for a theory of emotions, can now be better answered. There is now clearer evidence that facial movement *alone* is capable of inducing changes, albeit small, in the subjective feeling of the individual. And there is some suggestive information about how such effects are generated, which means that we are beginning to understand some of the processes underlying the experience of positive and negative affect.

To be sure, the process postulated here is complex, and many of its components remain to be investigated. But the theory is falsifiable, and the direction of future research is clear. Specific questions both at the behavioral and at the neurochemical level can be readily formulated. We assume that the process whereby emotional efference generates changes in subjective feeling state is essentially the same as one that we observe in more elementary phonetic action. We further assume that it consists of two links. First, muscular activity in uttering different phonemes changes brain blood temperature. Second, this change in temperature is sufficient to alter the individual's subjective state, which is probably due to the effects of changed temperature on neurochemical activity of the brain.

Each of these two links has an unknown probability of being true. The results of our experiments suggest that these probabilities are decidedly greater than zero. It is indeed somewhat of a surprise that muscular movement and nasal breathing can affect temperature to an extent sufficient to produce a subjectively felt affective reaction. The internal carotid carries a large volume of blood to the brain, and it carries it at a considerable rate. A significant drop in its temperature would require, it would seem, a large ambient change. Cabanac (1986) concluded that the cavernous sinus can keep the hypothalamus 1 °C or more below trunk temperature. The data of Kluger and

D'Alecy (1975) show systematic changes in hypothalamic temperature when the cavernous sinus is not cooled by air breathed through the nose—changes that have very short latencies. Our data show similar changes. Ekman et al. (1983) observed a 0.15 °C rise in finger temperature with emotional expression of anger held for only 10 s. Thus, the link between facial movements and brain temperature is now more than a mere hypothesis. But it requires more direct evidence.

The second assumption that temperature changes in the brain cause subjective changes is also supported (Stellar, 1982). The further supposition that the subjective changes derive from neurochemical effects brought about by brain temperature change is clearly speculative. There is considerable evidence, however, that neurochemical activity has dramatic effects on temperature (Brown, 1982; Clark & Bernardini, 1982; Hawkins & Avery, 1983; Kavaliers, 1982; Lee & Lomax, 1983; Lin & Pivorun, 1986; Morley, Elson, Levine, & Shafer, 1982; Thornhill & Saunders, 1984; Yehuda & Sheleff, 1985). For example, neurotensin, a peptide found primarily in the anterior hypothalamus—a structure important in thermoregulation—and in the nucleus accumbens—a structure implicated in emotional reactions—has pronounced hypothermic effects. A dose of 30 μg neurotensin was found to reduce rectal temperature in mice by as much as 17 °C (Bissette, Nemeroff, Loosen, Prange, & Lipton, 1976). Note that neurotensin is known to produce excitation and, when injected centrally, to reduce aversion to painful stimuli (Cooper, Bloom, & Roth, 1986). Thus, because neurotensin produces both hypothermia *and* affective consequences, it is quite reasonable to suppose that the manipulation of hypothalamic temperature, achieved by any method, might also have affective consequences.

Because, according to the Q_{10} law, a 10 °C drop reduces the rate of reactions threefold, such a profound temperature change must have widespread biochemical consequences. Systematic knowledge about temperature effects on neurochemical activity is scant, but not altogether absent. It has been demonstrated, for instance, that the adrenergic system is temperature dependent (e.g., Corwin, Malvin, Katz, & Malvin, 1984; Gandhi & Ross, 1987; U'Prichard & Snyder, 1977), as are some peptides (Zachary & Rosengurt, 1987). Often, the effects require very minimal changes in temperature (see Jampel et al., 1983, and Miller & Clem, 1984). Bode and Molinoff (1988) have found very substantial changes in the plasma membranes of cells with small temperature changes. The finding is important because the physical properties of cell membranes control neurotransmitter activity across the synapse.

One can certainly question the likelihood that differences in temperature as small as we obtained may have neurochemical effects and ensuing subjective influences.[3] Two observations apply here. First, the temperature changes were measured on the skin of the forehead as proxies for brain temperature changes, which may be considerably greater. Similar procedures resulted in greater changes in tympanic membrane temperature in our calibration and validation tests. Second, one would not expect strong neurochemical effects with small temperature changes if one takes as an anchor studies based on animal models. In these studies the effects are observed on the basis of gross behavioral output. However, the effects we observed are in the form of subjective reports and are considerably more sensitive to even slight differences than are gross behavioral measures. Thus, both assumptions have substantial probabilities of being true, and each is readily falsifiable. More important, if correct, they lead to very important implications.

The link between temperature change and the release of neurochemicals is not necessary for our purposes, inasmuch as the only part of the assumption required is that temperature change be capable—by any process—of altering hedonic tone. Nevertheless, it is a supposition that is highly plausible, given the systematic dependence of biochemical processes on temperature, and it is a supposition that for many reasons would be worthwhile to substantiate empirically.

It is significant that we did not obtain lateral differences in forehead temperature in any of the studies. These lateral differences have been repeatedly found (Fox & Davidson, 1986), although the hypothesis that the hemispheres perform distinct functions does not enjoy complete consensus (LeDoux, 1982). Absence, in the present research, of lateral differences in forehead temperature may be due to the communication between the left and the right supratrocheal veins through the transverse nasal arch before each drains into the supraorbital vein. The cavernous sinuses that form the circular sinus are also joined. The VTEE would thus not predict lateral differences, whereas a subcortical explanation of the results would suggest lateral differences. This, again, should not be construed to mean that, in general, subcortical processes play no role in the subjective experience.

It should be clear that we do not regard the vascular mechanisms that mediate subjective states to be unique or to act alone. Certainly, other physiological processes and systems are equally capable of influencing them. The amygdala has been demonstrated to play a major role in the elicitation of emotion by integrating sensory inputs (see Aggleton & Mishkin, 1986; Geschwind, 1965; LeDoux, in press; Rolls, 1986, for other hypotheses about the origin of the subjective experience). The bulk of theoretical and empirical work in the neurobiology of emotion indicates that *isotelesis*—the principle that any one function is served by several structures and processes—applies to emotion as it applies to thermoregulation, for example (Satinoff, 1982).

Universality of Emotional Efference

Charles Darwin regarded his work on emotional expression as a crowning achievement of the theory of evolution. For, if emotional expression is subject to the forces of natural selec-

[3] The results we obtained here can be readily verified by the reader on the occasion of a mild headache. When such a headache arises, simply relax in a chair for a few seconds. Take 10 slow, deep breaths through the nose, and exhale through the mouth. Relax for 2 min. Take 5 breaths through the nose, exhaling through the mouth. A noticeable relief will be felt. We have administered the procedure to 50 headache sufferers. Except for severe sinus and migraine cases, the procedure was effective in reducing the discomfort by a considerable degree, and it acted much faster than aspirin—virtually in an instant. For control purposes, the reader may try inhaling and exhaling through the mouth. One could speculate that the hedonic effects obtained here may be mediated or accompanied by an analgesia coming from the action of endorphins that might be released more readily in lower brain temperatures.

tion, then the laws of evolution are even more general than one would originally expect. Now, it could be said that these laws apply not only to morphological character and physiological process, but to behavior as well. Darwin's theoretical argument on the evolutionary origins of emotional expressions was based on their adaptive value. His empirical argument was based on their universality among cultures and among species. It was this universality of emotional expressions that Darwin (1896/1955) used as proof that "man evolved from some lower animal form" (p. 365). And it should be noted in this context that Darwin's principal interest was probably more in marshaling new evidence for the theory of evolution than in explicating the emotions. His contemporary Piderit (1888, pp. 7–8), a scholar chiefly dedicated to the study of emotions, wrote "Darwin ne cherche içi, comme dans tous ses autres travaux, qu'à découvrir de nouveaux documents en faveur de sa théorie de l'évolution" (Here, as in all of his other studies, Darwin is only searching for new evidence to support his theory of evolution).

The evolution of emotional expression was based on their function. The language of Darwin's (1896/1955) entire volume leads one to view emotional expression as having for its *primary* function the broadcasting of information about the animals' internal states. By displaying their internal states—their fears, their appetites, and their intentions—animals communicate to others the probabilities of incipient behaviors—a process that has an important adaptive value. The universality of emotional expressions was documented to some extent by Darwin, and later research has shown him to be quite right (e.g., Ekman, 1972; Ekman & Friesen, 1971). However, not until the closing pages of his book does Darwin disclaim, albeit partially, the evolutionary primacy of expression (Adelmann & Zajonc, 1989). He stated explicitly, although belatedly, that "there are no grounds, as far as I can discover, for believing that any muscle has been developed or even modified exclusively for the sake of expression" (Darwin, 1896/1955, p. 354). It is interesting that Darwin implicated the respiratory and the vascular system. He said, in fact, that "If the structure of our organs of respiration and circulation had differed in only a slight degree from the state in which they now exist, most of our expressions would have been wonderfully different" (p. 363). Note that he only disallows the evolutionary primacy of particular morphological features as having been selected for expressive functions. But there is no doubt that he thought of expressive behavior as having been selected for its communicative value. This is clear from the fact that he regarded expression as a genetically transmitted "serviceable associated habit" (p. 28) that has "evolved like an instinct" (p. 30).

Darwin (1896/1955) does not consider seriously the possibility that facial actions might have direct hedonic consequences. For if they did, such consequences would promote their repeated occurrence and hence exert selective influence in their own right. It is in this sense that the evolutionary theory of emotional expression and VTEE differ. The VTEE proposes that facial muscular movements, above all else, serve a restorative function: that they help regulate blood flow to the brain and brain temperature. Only as a secondary, fortuitous bonus might they be used to communicate internal states. In this sense, they are no different from sneezing, which too serves a restorative function in the respiratory organs (and fortuitously broadcasts to others that there is a respiratory obstruction), or vomiting, which has a gastric restorative function (and reveals unambiguously that there are some problems of the digestive tract). Sneezing evolved primarily to serve the respiratory system, and vomiting, the gastro-intestinal system. Both are universally understood among humans and probably among animals as well. But people don't sneeze or vomit to inform those around them of their internal difficulties. At a formal level, one would be hard put to distinguish sneezing and vomiting from a pain grimace made in response to a stomach ache, which might indeed be classified as an expression of emotion. And more relevant to the present studies, piloerection and shivering, for example, serve both thermoregulation and emotional expression. In fact, the parallels may be even more striking: The effector mechanisms that serve cooling (panting, sweating, vasodilation) are very often those that are also associated with positive emotional experiences such as sexual excitation, whereas those that serve warming (shivering and vasoconstriction) are often associated with negative emotional experiences, such as fear or anger. Fusco, Hardy, and Hammel (1961) cooled and heated the anterior hypothalamus of dogs obtaining vasoconstriction and shivering, or vasodilation and panting, respectively, under unchanged ambient temperature. It is a matter for further empirical research to demonstrate that an appropriate stimulation of the amygdala that is assumed to control emotional expressions would also produce similar effector outputs without changes in hypothalamic temperature.

Darwin (1896/1955) formulated the problem of emotional expression by asking why is it that "different muscles are brought into action under different emotions; why, for instance, the inner ends of the eyebrows are raised, and the corners of the mouth depressed by a person suffering from grief or anxiety" (p. 3). It is now clear after 100 years of research that there is nothing particular in each of the expressions that would explain its topography as compellingly displaying one emotion rather than another. There are no a priori grounds to suppose that the corrugator muscle must be contracted in anger and the zygomatic in pleasure. The expressions are not onomatopoeic. The semantics of emotional expression are as arbitrary as the semantics of the verbal language. But we know that they are fairly universal and universally understood. Why? VTEE may offer an answer to Darwin's question by examining the particular vascular, thermoregulatory, and neurochemical consequences of a particular facial action. If these vascular/thermoregulatory/neurochemical patterns are systematically associated with particular subjective states, the answer will have been found, for they will indeed be in the same class as sneezing and coughing.

But with respect to emotional efference, there remains still the question of which function dominated selective pressures of the evolutionary process. If the evolution of emotional efference were in its later stages dominated by their communicative function, there would be as much variation in emotional expressions across cultures as there is in language. But the similarities among the members of completely diverse linguistic communities in the display of emotions are enormous (Ekman, 1980; Ekman et al., 1987). People from remote parts of the globe, who have no comprehension of each other's languages at all, can understand each other's emotions with great ease.

It is the case, of course, that the understanding and the expression of specific emotions as they are connected to their eliciting conditions, are influenced by learning and conditioning. This should not deter us from entertaining the idea that the facial actions themselves can act as restoratives and regulators of CBF and brain blood temperature, and as such, are no different than sneezing, coughing, yawning, or vomiting. Treating emotional expressions in the light of VTEE, as serving primarily restorative vascular functions, makes their evolutionary basis less Lamarckian, their universality better understood, and their ultimate origins considerably more plausible.

In light of the preceding discussion, it is quite clear that the processes that emerge in emotion are governed not only by isotelesis, but by the principle of *polytelesis* as well. The first principle holds that many functions, especially the important ones, are served by a number of redundant systems, whereas the second holds that many systems serve more than one function. There are very few organic functions that are served uniquely by one and only one process, structure, or organ. Similarly, there are very few processes, structures, or organs that serve one and only one purpose. Language, too, is characterized by the isotelic and polytelic principles; there are many words for each meaning and most words have more than one meaning. The two principles apply equally to a variety of other biological, behavioral, and social phenomena. Thus, there is no contradiction between the vascular and the communicative functions of facial efference; the systems that serve these functions are both isotelic and polytelic.

Effects of Facial Efference and Cognitive Appraisal

If we accept simple affective polarities as fundamental dimensions of emotions, then the evidence cited here shows that a prior cognitive appraisal is not a necessary condition for subjective emotional experience. In our experiments, neither an emotional stimulus nor a cognitive appraisal of that stimulus was a necessary condition for the observed changes in subjective feeling state. We can now more fully appreciate that preferences and aversions can emerge without and prior to cognitive activity (Zajonc, 1980), and how they can emerge without the person's awareness (Kunst-Wilson & Zajonc, 1980; Seamon, Brody, & Kauff, 1983a, 1983b). Of course, more complex emotional experiences, such as pride, disappointment, jealousy, or contempt obviously require extensive participation of cognitive processes. We would not expect someone who has just learned that he has cancer to turn his grief into joy by the mere contraction of the zygomatic muscle. Likewise, the complete emotion of fear must recruit a cognitive process of some form because it is elicited by a specific stimulus that needs to be encoded to a level sufficiently articulated so as to become integrated with other sensory associations that make that stimulus aversive. Anxiety, however, because it may not always need the participation of a specific eliciting stimulus, might be precognitive.

It is unlikely that all emotions have the same etiology, are characterized by the same affective and cognitive processes, exhibit the same sequencing of these component processes, or have the same underlying neuroanatomical structure and neurochemical action. Thus, certain subjective feelings emerge early and determine the ensuing course of the emotional process, whereas others develop much later. For some emotions, cognitive appraisal is a necessary precondition, whereas for others it is not necessary. LeDoux (1987) has shown that aversive reactions can be demonstrated as having identifiable correlates at the subcortical level. The careless child withdraws a burned hand before experiencing the aversive hedonic state. A subtle pun, on the other hand, may not be appreciated nor reacted to with laughter unless it has been extensively processed.

The answer to the question of where in the chain of emotional links lies the subjective state, therefore, is that it can be pre- as well as postcognitive. A theory of emotion needs to be a theory of emotions. Such a theory will need to classify the sequential topography of the various emotional patterns, describe the transitional contingencies, and specify the conditions that produce them. Moreover, it would appear that a taxonomy of the emotions cannot at this time designate any one set of criteria as primary, be they muscular patterns, linguistic labels, forms of cognitive appraisal, introspective accounts of subjective states, or autonomic, peripheral, or subcortical reactions. There is no theory thus far developed that has procedures for identifying boundaries between emotions that are consistent across the above criteria, and the correlations between these criteria are disappointingly low. According to Russell and Bullock (1986), emotions are best described as "fuzzy concepts" occupying overlapping regions of a two-dimensional space, whose axes are pleasure–displeasure and arousal–quiescence. The boundaries between emotions must, therefore, be explored by empirical methods that look for convergence of the diverse emotional correlates and indicators, and a focus on the one dimension about which there is general consensus—hedonic polarity—might well be the most fruitful research strategy at this time.

Vascular Theory of Emotional Efference and Facial Feedback

It could be argued that the muscular patterns associated with the phonemes are far removed from typical emotional expressions, and hence the present results have little bearing on the facial feedback hypothesis. This argument, however, must be taken in the light of the criticism of facial feedback theories that facial movement has no subjective consequences whatsoever. Because we found subjective consequences with muscular action that resemble emotional efference, actions that are implicated in *actual* emotional experiences should have even better chances of having significant subjective consequences.

The present studies, together with the conjectured theoretical explanation, go beyond facial feedback conceptions of the nature and antecedents of subjective feelings in emotions. They are consistent with the facial feedback theory and its weak version, that is, that facial movement has generalized and polarized affective impact, differentiated at the level of the positive–negative or approach–avoidance polarity. As such, these studies are among the few that show a clear discrimination by a physiological measure between positive and negative affect.

Nevertheless, nothing in the present study precludes the possibility of more specific affective effects that are produced by emotion-free facial movements, be they spontaneous or deliberate. It is entirely possible that more specific and identifiable dynamic patterns of temperature change and affective feelings might be associated with different facial patterns, and that some of these patterns fall within the range of emotional expressions distinguished by Ekman and Friesen's (1978) FACS or Izard's (1979) MACS classification systems. Perhaps there exist some phonetic patterns, consisting of two or three phonemes, that resemble quite closely some specific emotional facial action patterns. An investigation of the subjective reactions following these patterns together with other physiological measures, including not only hypothalamic temperature but measures of the activity of the autonomic nervous system, such as heart rate or GSR, will generate more precise information about the role of facial movement in the emotional experience.

The relations that we have found and theorized about in this article prompt several conclusions. First, the vascular system, especially the one that supplies the face and the brain, must play an important role in generating the subjective feeling state. Second, facial action is not a process that serves only or even primarily the display function; rather it is a process that, among other processes, participates in the maintenance and regulation of the vascular system of the head and of its thermoregulation. It follows that more knowledge about the relation between subjective feeling states and facial action can be gleaned with a stronger focus on vascular processes. Third, thermoregulation of hypothalamic blood offers a significant clue to the study of emotion, for it bridges peripheral processes to brain neurochemistry. Fourth, it is unlikely that emotion specificity is to be found at all levels of emotion analysis—the subjective, behavioral, and physiological. Given existing knowledge, close interrelations among these three aspects of emotional processes may be found only if distinctions among emotions do not go beyond hedonic polarities. Fifth, forehead temperature is a reliable psychophysiological measure found to discriminate reliably between positive and negative hedonic experiences.

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Mineka Appointed Editor of *Journal of Abnormal Psychology,* 1990–1995

The Publications and Communications Board of the American Psychological Association announces the appointment of Susan Mineka, Northwestern University, as editor of the *Journal of Abnormal Psychology* for a 6-year term beginning in 1990. As of January 1, 1989, manuscripts should be directed to

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