Brain function, emotional experience and personality

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One objective of this article has been to develop a taxonomy of 'sensations', 'feelings' and 'basic emotions', and to distinguish these from personality traits. A second objective has been to clarify the relationship between emotional experience and personality and to describe how neurological differences can cause differences in the dynamics of emotional experience, either directly or as a consequence of a bias in learning, which are manifest as differences in personality or temperament, and in extreme cases as neurotic disorders. It is suggested that bias in emotional experience initiated by individual differences in the natural frequencies and damping ratios of thalamocortical oscillators is perpetuated and augmented by biased learning. (*Netherlands Journal of Psychology*, 64, 152-167.)

Keywords: anger; anxiety; brain; depression; EEG; emotions; feelings; moods; personality; septohippocampal system; sensations; thalamocortical system

The nature of mental experience

It seems fitting to begin this article with some thoughts about the fundamental nature of mental experience. In fact, one might be so bold as to assert that we can begin with some facts. The first and most fundamental fact, underpinning all normal human experience, is that it derives from the elementary 'sensations' we experience when there is highly localised stimulation of neurons in the primary sensory receiving areas of the cerebral cortex. *Stimulation of sub-cortical neurons does not result in any kind of mental experience unless this stimulation eventually causes the activation of cortical neurons* (Guyton and Hall, 2005). I should immediately qualify this statement by pointing out that there are point-to-point connections between the topographically organised neurons of the cortex and thalamus so that the thalamocortical system is composed of billions of thalamocortical loops or circuits that produce the 'alpha band' oscillating scalp electrical potentials commonly referred to as brain waves (Robinson, 2006). Thus, it is more correct to state that we experience elementary sensations when there is local stimulation of *thalamocortical* circuits in the primary sensory receiving areas.

The second important fact is that the elementary sensations we feel are numinous qualities

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that can only be experienced by individual people. Sensations such as 'redness', 'pain' and 'pleasure' cannot be directly observed by the methods of science nor can they be explained by the theories of science. No reference to scientific knowledge can explain how the physical and chemical processes of neural activity could cause a sensation of 'redness' to occur: Nor can we even begin to suggest the essential nature of such experiences. In short, sensation is something that lies totally beyond the pale of science. It is not a quality or property of any known substance or material; nor is it something that can be explained by the processes mediating evolution. It is something so mysterious that it is utterly beyond human comprehension. All we know is that sensation is the most elementary manifestation of conscious experience and that it is uniquely associated with life itself. Indeed, it should be evident to all that if we could not experience sensations we would not exist as conscious living entities.

A third important fact is that all available neurological and psychological evidence indicates that there is a perfect correlation between the activity of thalamocortical neurons and the experience of sensation during the normal waking state. As already noted, there is no basis in science for claiming that this correlation indicates causation nor is there any basis for ruling out the possibility that sensations can be experienced in the absence of neural activity. There is in fact a 'ghost in the machine' (Koestler, 1967) and there is no scientific or rational basis for ruling out the possibility that, in some special circumstances, this ghost may become detached from the machine.

All we can say with certainty is that in normal circumstances there appears to be a perfect correlation between the activity of thalamocortical neurons and mental experience. Also, since this is the case, we can understand quite a lot about the meaning of experience in general, and about the more strongly motivating kinds of mental experience that are of special interest in this article. That is to say, the manner in which thalamocortical neurons are activated and organised provides information about the organisation of mental experience and about how this relates to external circumstances and to the structure and function of body processes and brain processes.

Table 1 lists the different kinds of sensations that are experienced by point stimulation of different locations in the primary thalamocortical receiving areas with the qualification that the more ancient part of the cortex known as the 'hippocampus' is connected to the septum rather than the thalamus. Thus, strictly speaking one should refer to both septohippocampal and thalamocortical circuits in order to embrace all of the elementary sensations. However, for convenience, I will usually only refer to thalamocortical circuits. I should also note in passing that animal studies give undue emphasis to the septohippocampal system when seeking to explain emotional experience (Robinson, 1986). This is at least partly due to the fact that the phylogenetically older structures of the cortex and limbic system are associated with the more appetitive and noxious sensations caused by the stimuli used to motivate animals in learning experiments. However, these experiments tend to obscure the fact that *learning is a continuous internal brain process through which all forms of sensation can become connected to cause complex mental experiences*. This continuous process of association through learning only requires contiguous activation of

Table 1 **Different kinds of elementary sensation.**

Mental experience	*Correlate of the mental experience*	*Definition of sensations*
Colour	Light frequencies	Sensations are defined as the most elementary units of mental experience evoked by point stimulation in the primary sensory receiving areas of the thalamocortical system. Behaviour is only caused or motivated by combinations of these basic sensations determined by either genetic endowment or as a consequence of learning mediated by interaction of a genotype with its environment
Sound	Mechanical vibration	
Taste	Chemical properties of liquids	
Smell	Chemical properties of gases	
Heat	Heat energy	
Tactile	Mechanical pressure	
Visceral	Visceral state	
Proprioceptive	Muscle, tendon, joint state	
Pain	Tissue damage	
Pleasure	Life sustaining processes	

the corresponding thalamocortical neurons and it need not result in any overt behaviour (Robinson, 2006).

As is well known, there are predetermined structural features of body processes and neural processes so that fixed and predetermined patterns of thalamocortical activation and sensation can occur without the agency of associative learning. For example, when blood sugar levels are low there are 'hard-wired' neural processes originating in the hypothalamus that will cause stimulation of those parts of the thalamocortical and septohippocampal systems that give rise to the experience of hunger. In addition, there will be a priming or lowering of the thresholds for patterns of pleasant sensations associated with 'food' odours and tastes, as well as increased activation of all those systems that prepare the body for increased activity, and prepare the brain so that it can support enhanced awareness of the external environment (Guyton & Hall, 2005).

Apart from the complex processes activated to prepare the body and brain for 'foraging activity', behaviour is given direction by the motivation provided by enhanced sensitivity to pleasant odours and tastes, on the one hand, and by the unpleasant sensation of hunger on the other. Ultimately, these hard-wired patterns are extended through interaction with the environment. With the steady and continuous progression of learning, there is a constant linking of thalamocortical sensation points to form new patterns of mental experience. The analogy here is of an artist mixing the primary colours to create an infinity of different hues. Similarly, humans can acquire the ability to distinguish an extraordinarily diverse set of food-related mental experiences and these experiences cut across all sensory modalities.

It is easy to see that a distinction can be made between the elementary 'sensations' listed in Table 1 and 'feelings' such as hunger. The mental experience that we describe as a 'feeling of hunger' derives from fixed and predetermined patterns of sensation which relate to the monitoring and regulation of internal body states. A list of such feelings is provided in Table 2 and henceforth the word 'feeling' will be used to refer to this particular class of mental experiences even if we are obliged to continue using the word in the broader sense of normal usage. Each of the listed feelings is experienced by everyone, and they can be readily distinguished in terms of the well-defined circumstances of their occurrence. In addition, comparison of our individual subjective experiences indicates that each of the feelings has a distinct quality and that different people have similar experiences. It should be evident from simple inspection of this table of feelings that the purpose is to motivate behaviours that serve basic needs of the body – needs that are essential for survival of the individual and for the propagation of life. These feelings deter us from damaging our bodies, they motivate us to eat and drink at appropriate times, they suggest what is good to eat and drink and what is bad, they motivate us to stop eating and drinking after adequate consumption, and they motivate us to rest or sleep when this is necessary. They also encourage us to engage in health giving activities and in reproductive activities.

There is a clear distinction between the 'feelings' listed in Table 2 and the 'emotions' listed in Table 3 since the feelings are mostly related to the state of the body's internal environment. This includes the hormone levels that regulate sexual feelings and motivate sexual behaviours.

Table 2 **Feelings related to different internal body states.**

Mental experience	*Correlate of the mental experience*	*Behaviour motivated by mental experience*
Hunger	Lack of nutrients	Food seeking
Thirst	Lack of water	Water seeking
Satiation	Satisfaction of need	Cessation of related behaviour
Nausea (disgust)	Ingestion of toxins	Rejection of food
Weariness	Need for sleep	Resting, sleeping
Fatigue	Need to rest muscles	Cessation of related behaviour
Suffocation	Lack of oxygen	Struggle
Pain	Tissue damage	Damage limitation or avoidance behaviours
Pleasure	Life sustaining processes	Life sustaining or propagating behaviours

Unlike the emotions, feelings are not *in the first instance* initiated by external objects or events. It is also clear that the feelings have their origins in the very early stages of phylogenetic development and that they relate to the most fundamental life support and procreation systems. Thus, in this respect also, they can be distinguished from other kinds of motivating mental experiences that have yet to be discussed.

The emotions and mood states

While acknowledging and emphasising the ultimate complexity of emotionally toned mental experience the author suggests that the specific emotional experiences listed in Table 3 can be considered basic emotions. This is not inconsistent with the fact that sensations are considered more elementary or primary than the emotions since one can distinguish *degrees of complexity within the domain of emotions*. The essential basis for classification as a basic emotion, and for inclusion in Table 3, is that despite some understandable looseness in definition and usage the word emotion normally refers to a particular kind of mental experience. That is to say, it is most often used to refer to mental experiences with strongly motivating subjective qualities akin to the basic sensations of either pleasure or pain. They are also initiated by some particular objects or events, real or imagined, and they tend to motivate particular kinds of behaviour as illustrated later in Tables 5 and 6. According to these criteria, one can make a clear distinction between the 'emotions' in Table 3 and the 'sensations' and 'feelings' already discussed.

An additional criterion that could justifiably be employed in order to identify the *basic* emotions is that these should be experienced by all normal individuals and should be described in similar terms by different people. This criterion would exclude the last four pairs of emotions in Table 3 since there are marked differences in the extent to which these are experienced by different people. Thus, in terms of these four pairs of opposed emotions some people would be typically proud, generous, sympathetic and loving whereas others would be typically guilt-ridden, avaricious, cruel and disposed to hatred. From this it should be evident that these 'emotions' cross the boundary between what might be considered the most basic emotions and those more complex and differentiated emotional experiences that belong to the domain of personality traits.

Despite this consideration, it is the author's opinion that any list of basic emotions would seem odd and incomplete if the last four pairs of emotions were not included. However, despite inclusion in Table 3 these will eventually be listed as personality traits. It seems inevitable that some degree of ambiguity must be accepted when seeking to classify mental experiences that gradually become more complex and differenti-

Table 3
Eleven pairs of positive and negative emotions.

KIND OF EMOTION	POSITIVE EMOTIONS	NEGATIVE EMOTIONS
EMOTIONS RELATED TO OBJECT PROPERTIES	**Interest,** curiosity	**Alarm,** panic.
	Attraction, desire, admiration.	**Aversion,** disgust, revulsion.
	Surprise, amusement.	**Indifference,** familiarity, habituation.
FUTURE APPRAISAL EMOTIONS	**Hope**	**Fear**
EVENT RELATED EMOTIONS	**Gratitude,** thankfulness.	**Anger,** rage.
	Joy, elation, triumph, jubilation.	**Sorrow,** grief.
	Relief	**Frustration,** disappointment.
SELF APPRAISAL EMOTIONS	**Pride** in achievement, self-confidence, sociability	**Embarrassment,** shame guilt, remorse.
SOCIAL EMOTIONS	**Generosity**	**Avarice,** greed, miserliness, envy, jealousy.
	Sympathy	**Cruelty**
CATHECTED EMOTIONS	**Love**	**Hate**

ated across individuals; and where there is no abrupt transition in nature from basic emotions to personality traits.

In the first instance, the actual content of Table 3 derives from consideration of the mental experiences classed as emotions in the thirteen theories reviewed by Ortony and Turner (1990) and listed in Table 4. Some of these putative emotions do not meet the classification criteria stated in the last paragraph and hence they do not appear in Table 3. Additional emotions were identified based on the recognition of what appears to be a fundamental principle, and an additional emotions criterion, namely, that for every basic emotion there appears to be an emotion that is opposite in terms of the positive or negative quality of subjective experience, in terms of the events or objects triggering the emotion, and in terms of the behavioural consequences of the emotion. Thus, 'gratitude' is included as the emotion that is opposite to 'anger' where anger is a subjectively unpleasant mental experience evoked by the real or imagined harm done to an individual, or what an individual values, and where this emotion disposes an individual to exact retribution by means of vengeful behaviour directed towards the source of their injury. In contrast, gratitude is a warm and pleasing experience that occurs when one receives some benefit from others and it motivates behaviours that seek to reciprocate the benefit received.

It is evident from inspection of Table 3 that some of the emotions listed are more basic than others. More specifically, 'interest' and 'alarm' may occur without the mediation of learning and without the formation of the beliefs and attitudes and the 'cognitive appraisal' that is required in order to experience 'hope' and 'fear'. The naming of subsets of emotions in Table 3 draws attention to some of the distinctions that can be made within this set of basic emotions and to make the point, already noted, that some are more basic than others.

The greater manifestation of individual differences in association with the more complex basic emotions should not be surprising since individual differences are bound to become more evident as the influence of learning increases,

Table 4 **Basic emotions and frequencies across thirteen theories reviewed by Ortony and Turner (1990).**

Positive emotions		*Negative emotions*	
Hope	1	Fear	9
		Anger	7
Desire	2	Aversion (1), Disgust (6)	7
Joy (5), Elation (1)	6	Sadness (3), Sorrow (1), Grief (1)	7
Love	3	Hate	1
		Anxiety	2
Surprise	5		
Interest	3		
Wonder	2		
Happiness	3	Dejection (1), Despair (1)	2
Pleasure	1	Pain	1
		Shame	2
		Guilt	1
		Subjection	1
Tender-emotion	1		
Courage	1		
Expectancy (1), Anticipation (1)	2		
Total positive	**30**	**Total negative**	**40**

Table 5 Eleven positive emotions and their causes and consequences.

Mental experience	*Correlate of the mental experience*	*Behaviour motivated by mental experience*	*Putative significance for survival*
Interest, curiosity	Novel stimulation of moderate or low intensity and no mismatch with expectations	Orienting reflex, moderate behavioural arousal, exploration	Attracts to new experiences that might aid survival
Attraction, desire, admiration	Signals of good environmental conditions, nutritional value and health giving properties and absence of genetic defects indicating good reproductive outcomes	Acceptance of contact. Seeking to establish and maintain contact	Ingestion of healthy food, selection of healthy environments, promotion of reproductive success
Surprise, amusement	Mismatch between experience expected and experience that occurs	Attention, laughter or behavioural immobility depending on the degree of mismatch	Stimulates interest but may also induce caution to allow time for cognitive appraisal
Hope	Expectation of a positive outcome	Behaviours consistent with a positive outcome	Responding to signals previously associated with positive outcomes
Gratitude, thankfulness	Acts of kindness, mercy, assistance and co-operation done by another	Reciprocal acts of kindness and assistance	Development of social bonds and friendship
Joy, elation, triumph, jubilation	Successful performance of genetically predetermined life sustaining and propagating behaviours but ultimately the moment when hopes are realised and success achieved	Life sustaining and propagating behaviours and the achievement of objectives	Continuation of life sustaining and propagating behaviours and repetition of successful behaviours
Relief	Success when failure expected or confirmation that an aversive event will not occur	Cessation of behavioural inhibition	Encourages behaviour that reduces threat
Pride in achievement, self-confidence, sociability	Pleasant thoughts that derive from the execution of behaviours that are in accordance with personal beliefs and values	Behaviours consistent with personal beliefs and ideas about 'right' and 'wrong' Behaviours designed to enhance feelings of self-satisfaction	Rational control of behaviour in a social context
Generosity	Benevolent thoughts about others	Behaviours designed to assist others by sharing possessions	Enhances survival of community
Sympathy	The vicarious experiencing of the feelings, thoughts and attitudes of others. Empathy which derives from the intellectual capacity to understand the mental life of others	Kind, compassionate and caring behaviours that help other people	Emotional support of community members and the promotion of social harmony
Love	A complex set of emotionally toned ideas that cause strong feelings of affection and attachment to other people and sometimes also to animals, objects and even ideas	Motivates people to cherish each other and sometimes to sacrifice life itself in order to protect what is perceived to be beautiful and good	Forms strong and affectionate bonds between people and motivates the altruistic service of society

mental experiences become more complex, and there is the possibility that emotional experience begins to reflect the development of belief systems and attitudes that will be biased by any factors that can influence the unique character of each person's history of learning.

The important question of individual differences will be addressed in due course and it remains to point out that, for the sake of simplicity, Table 3 does not take account of differences in the intensity of experienced emotion nor of any fine distinctions that can be made in the character of emotions so that, for example, 'embarrassment', 'shame', 'guilt' and 'remorse' are all lumped together as a single basic emotion. The lumping together of dissimilar emotions is most evident in the case of 'avarice' where no distinction is made between 'greed' and 'miserliness' or between 'jealousy' and 'envy'. The logic here is that 'avarice' does contrast with 'generosity' but it is recognised that ultimately one must distinguish between the two forms of 'avarice' and the basis for such a distinction will be introduced in the section dealing with individual differences.

Tables 5 and 6 provide a more detailed account of the nature of the emotions listed in Table 3. The Tables are self-explanatory and the only point worthy of additional comment is that wherever possible an attempt has been made to highlight the infra-human origin of the emotions and to draw attention to their evolutionary significance. Despite the necessarily provisional nature of Table 3, and of the related Tables 5 and 6, the author believes that this list of basic emotions has greater validity than other lists that have been published. A detailed critique of other putative lists of the basic emotions cannot be undertaken in this article. However, it is important to point out that all of these lists suffer from the lack of any adequate criteria for deciding what is an emotion and what is not. From Table 4, one can see that the list of emotions derived from the thirteen theories reviewed by Ortony and Turner (1990) is painfully inadequate and that there is a definite bias towards the 'negative' emotions. The reason for this is that most of these theories focus on the relatively small number of emotions that are medically relevant. Since the date of the Ortony and Turner review some additional lists of emotions have been published. However, here also the lack of adequate criteria results in the omission of some emotions, or in the confounding of emotions with mood states and personality traits (e.g., Ortony, Clare, & Collins, 1990; Lazarus, 1991; Lazarus & Lazarus, 1994; Goleman, 1995; Ekman, 2003).

Before concluding this section it is appropriate to mention the important article by William James (1884) entitled 'What is an emotion?' James begins by noting that the analyses of empirical psychology had divided the mind into its 'perceptive and volitional' parts while ignoring the *aesthetic* aspect with its longings, its pleasures and pains, and its emotions. If he were writing his article today he might well have made similar comments. Perhaps for this reason, his article is still one of the best accounts of the emotions that has ever been published. According to James:

. . . the entire circulatory system, forms a kind of sounding-board, which every change of our consciousness, however slight, may make reverberate. Hardly a sensation comes to us without sending waves of alternate constriction and dilation down the arteries of our arms. The blood vessels of the abdomen act reciprocally with those of the more outward parts. The bladder and bowels, the glands of the mouth, throat, and skin, and the liver are known to be affected gravely in certain severe emotions, and are unquestionably affected transiently when the emotions are of a lighter sort. That the heart-beats and the rhythm of breathing play a leading part in all emotions whatsoever, is a matter too notorious for proof. And what is equally prominent, but less likely to be admitted until special attention is drawn to the fact, is the continuous co-operation of the voluntary muscles in our emotional states. Even when no change of outward attitude is produced, their inward tension alters to suit each varying mood, and it is felt as a difference of tone or of strain. In depression the flexors tend to prevail; in elation or belligerent excitement the extensors take the lead. And the various permutations and combinations of which these organic activities are susceptible, make it abstractly possible that no shade of emotion, however slight, should be without a bodily reverberation as unique, when taken in its totality, as is the mental mood itself.

All of this is consistent with current knowledge and one can see that although cognitive appraisal may trigger or modify an emotional response these responses all involve different and exceedingly complex symphonies of widespread bodily activity. Symphonies orchestrated by 'hard-wired' systems; and with each one triggered in the first instance by its own particular stimulus object or event. As James describes it, each emotion is unlocked by its own particular key 'that is sure to be found in the world . . . as life goes on'. Cognitive processes can only trigger emotions through the associative learning that connects the memory of real-world triggers with the appropriate emotional system.

James is acknowledged as the first to realise that the mental experience of an emotion is 'nothing but' the activation of ordinary sensorial processes 'variously combined'. This is how the mental experience of an emotion was explained in the initial pages of this account so there is complete agreement with James on this fundamental question. However, one cannot agree with James when he goes on to conclude that 'we feel sorry because we cry, angry because we strike, and afraid because we tremble'. The rationale for this conception of the emotions is that the mental experience of an emotion is, as already proposed, nothing more or less than the concurrent activation of a particular combination of sensation points in the thalamocortical system. Thus, as James notes, the totality of the mental experience of anger must embrace sensa-

Table 6 Eleven negative emotions and their causes and consequences.

Mental experience	*Correlate of the mental experience*	*Behaviour motivated by mental experience*	*Putative significance for survival*
Alarm, terror, panic	Unlearned signals of immediate and extreme danger, such as very intense stimulation	Orienting reflex, defence reflex, strong behavioural arousal, fight, flight	Self preservation
Aversion, disgust, revulsion	Signals of bad environmental conditions, contagious toxicity and genetic defects indicating poor reproductive outcomes	Rejection of contact or seeking to avoid contact	Avoidance of life-threatening objects and environments, promotion of reproductive success
Indifference, familiarity, habituation	Habituation or inhibition of familiar sources of stimulation that have no significance	None	Blocking attention to sources of stimulation that did not signal pain or pleasure in the past
Fear	Expectation of a negative outcome	Behaviours consistent with a negative outcome	Avoiding dangers signalled by prior associative learning
Anger, rage	Physical pain inflicted by an attacker or psychological pain caused by thoughts about real or imagined harm done by another	Fight or other forms of aggressive behaviour	Genetically programmed defence of territory. Harm to object, vengeance, retribution
Sorrow, grief	The death of a loved one, usually a family member or close friend, but may also occur due to the damage or loss of any valued object or relationship	Weeping and other behaviours indicating distress	Indicates the need for emotional support and may have its origin in infant 'separation distress'
Frustration, disappoint-ment	Failure when success expected or confirmation that a pleasant event will not occur	Discontinuation of related behaviour	Cessation of unsuccessful behaviours
Embarrassment, shame, guilt, remorse	Painful thoughts about real or imagined public failure to meet social standards and/or self-criticism that derives from failure to behave in accordance with personal beliefs and values	Avoiding social contact and public places. Behaviours consistent with personal beliefs and ideas about 'right' and 'wrong'. Behaviours designed to assuage painful thoughts	Rational control of behaviour. Social conformity
Avarice, greed, miserliness, envy, jealousy	Resenting another's success. Coveting their possessions or the attention they receive. Or guarding and hoarding own possessions	Spiteful and malicious behaviour Selfish behaviour	Rivalry. Seeking personal advantage at the expense of others
Cruelty	Sadistic thoughts associated with the desire to hurt others or with gloating over the misfortune of others. Lack of empathy that causes social conflict and alienation	Behaviours designed to avenge real or imagined wrongs and to hurt, torment or torture others into subjugation and submission	Harm to others and subjugation of others through intimidation and punishment. Domination in a social hierarchy
Hate	A complex set of emotionally toned ideas that cause strong feelings of hostility and alienation.	Motivates people to seek to destroy what is believed to be evil and to risk their lives in a fight against evil	Destruction of what threatens self or communal well being

tions associated with the activation of body processes during the experience of anger – which would include sensations associated with respiratory changes, changes in heart-rate, changes in muscle activity and so on – and even those patterns of sensation generated by actual fighting.

If this were the whole story, then one would have to agree with James that the sensations generated by the preparation and execution of fighting activity creates the mental experience of anger and that we do indeed *feel angry because we fight* as distinct from *fighting because we feel angry*. However, the fatal flaw in the argument presented by James is that *prior to any fighting behaviour, and even prior to the body's preparation for fighting behaviour, there are sensations that have been generated by the harmful events that trigger the fight response*. It is these initial sensations that first and foremost correspond to the emotional experience of anger, not the sensations, or not primarily, the sensations generated by the body's preparation for fighting or by actual fighting. Since it is self-evident that the James-Lange theory is incorrect, and since it leads to such a serious misunderstanding of the well-springs of human nature and human behaviour, it should not be given the emphasis it currently receives in psychology text books.

In the concluding paragraphs of this section it is appropriate to consider the mood or arousal states mentioned from time to time in the discussion of emotions. In the first instance, these states can be distinguished from the basic emotions since they do not normally relate to specific objects or events nor are they usually related to any very specific classes of behaviour. Another important distinction is that while the basic emotions relate to relatively transient changes in states of activation or arousal the mental experiences described as 'moods' involve more prolonged changes in arousal states.

From the preceding paragraphs it should be evident that all of the emotions involve widespread changes in the activity levels of different neural and somatic systems. This is a well-established fact already noted in the account provided by James. Thus, in making a distinction between the basic emotions and other 'feeling' states, in terms that emphasise the activation or arousal of biological systems, it is important to emphasise that the basic emotions as well as moods are all defined by the thalamocortical (and septohippocampal) sensations associated with the arousal or activation of neural and somatic systems. However, as already stated, an important difference between the basic emotions and the mood states *is the duration of the periods of activation*.

One cannot refer to some simple and undifferentiated dimension of global arousal or activation since there are different ways in which neural and somatic systems can be activated (Lacey, 1967) and even different ways in which the thalamocortical system can be activated. The reader is reminded that the quality of all mental experience depends on the particular patterns of activity occurring in the thalamocortical and septohippocampal systems. However, these patterns of activation can be altered by axons from brain-stem nuclei that project widely throughout the thalamocortical system to release acetylcholine, adrenalin, dopamine and serotonin; while also sending projections to other structures such as the hypothalamus. The main effect of all of these neurotransmitters is to increase thalamocortical activation. However, this activation can have either a positive or negative hedonic tone that seems to depend on the relative influence of the different transmitter substances and, for example, on their selective activation of different parts of the limbic system and selective activation of the sympathetic and parasympathetic divisions of the autonomic nervous system.

We have already had an interesting example of the contrast between depression and two forms of excitement when James referred to the fact that 'in depression the flexors tend to prevail; in elation or belligerent excitement the extensors take the lead.' One way of thinking about the influence of the brain-stem nuclei is that they change the mode of operation of the thalamocortical system so that there can be optimal functioning in a range of different circumstances. In normal individuals these changes are associated with states of mind that persist for periods longer than those associated with the emotions but not for the extended periods associated with psychiatric disorders.

One should not conclude from this account that moods are just a consequence of different levels of thalamocortical activation. In normal individuals these different levels of activation, and the sustained changes that can occur from time to time, are the result of a complex psychological process that is influenced by genetic endowment, life-long learning experience, and the current circumstances of life. This is one reason why abnormally severe or prolonged states of depression and anxiety cannot be cured by simply administering drugs that alter thalamocortical arousal levels. Drugs can be of great help in the shorter term but there are grounds for believing that drug therapy must be accompanied by a process of therapeutic relearning. Insofar as these problems may be caused or aggravated by lifestyles, and the circumstances of life, there are grounds for suggesting that changes in lifestyle and in the circumstances of life would also assist recovery.

As this account has moved to progressively more complex but still structured levels of mental experience there have been several references to the emergence of individual differences in the character of mental experience. An important objective in the final pages of this article is to offer a neurological explanation for systematic and structured individual differences in the

mental experiences that have been classified as 'feelings', 'basic emotions' and 'moods'; and to show how these individual differences predispose particular individuals to emotional disorders. The fact that there are differences in the way that people think, feel and act is known to all. Less obviously, but still apparent from everyday experience, these personality differences persist throughout life despite the progression of learning and the cumulative influence of experience. This alone is enough to suggest that any explanation must refer to individual differences in brain function.

The emotions, personality traits and temperament types

Figure 1 illustrates the author's conception of relationships between the basic emotions, mood states, and some of the more fundamental personality traits. The basic emotions are characterised as transient emotional experiences that usually occur as an immediate consequence of the specific events that occur in our ongoing interaction with the environment; or are triggered by the memories or imagination of such events. However, it is also clear from the diagram that the way in which we respond will be modified by our mood state on a particular occasion and by our personality traits. The mood states are partly determined by genetic differences but are also due to the cumulative effect of events in the recent past that may, for a limited period of time, hours rather than minutes or days, selectively raise or lower the level of activity of the thalamocortical system and other brain systems. The personality traits are also partly determined by genetic differences and by the cumulative effects of prior experience. However, in this case the effect of prior experience is mediated by learning, it relates to all that has happened in the life of an individual, and it is relatively permanent.

The personality traits shown in Figure 1 subsume some of the 'emotions' mentioned in the theories and lists of emotions that did not qualify for inclusion in the list of basic emotions provided in Table 3. However, the Figure 1 traits come mainly from the domain of personality and from consideration of those traits that have an impact on the expression of emotions. For example, a pessimistic person is more likely to experience fear than to experience hope when considering the possibility of either a positive or negative outcome. An impulsive person is more likely than an inhibited person to engage rather than to avoid. It is not immediately obvious that impulsivity is related to emotional experience but it should be evident that 'engagement' has different emotional consequences than 'avoidance'.

The diagram helps to illustrate how traits differ from the basic emotions. Inspection of the traits also reveals that it has been possible to identify sets of opposed traits just as it was possible to identify sets of opposed emotions. When reference is made to traits, one cannot be both pessimistic and optimistic but the opposed traits

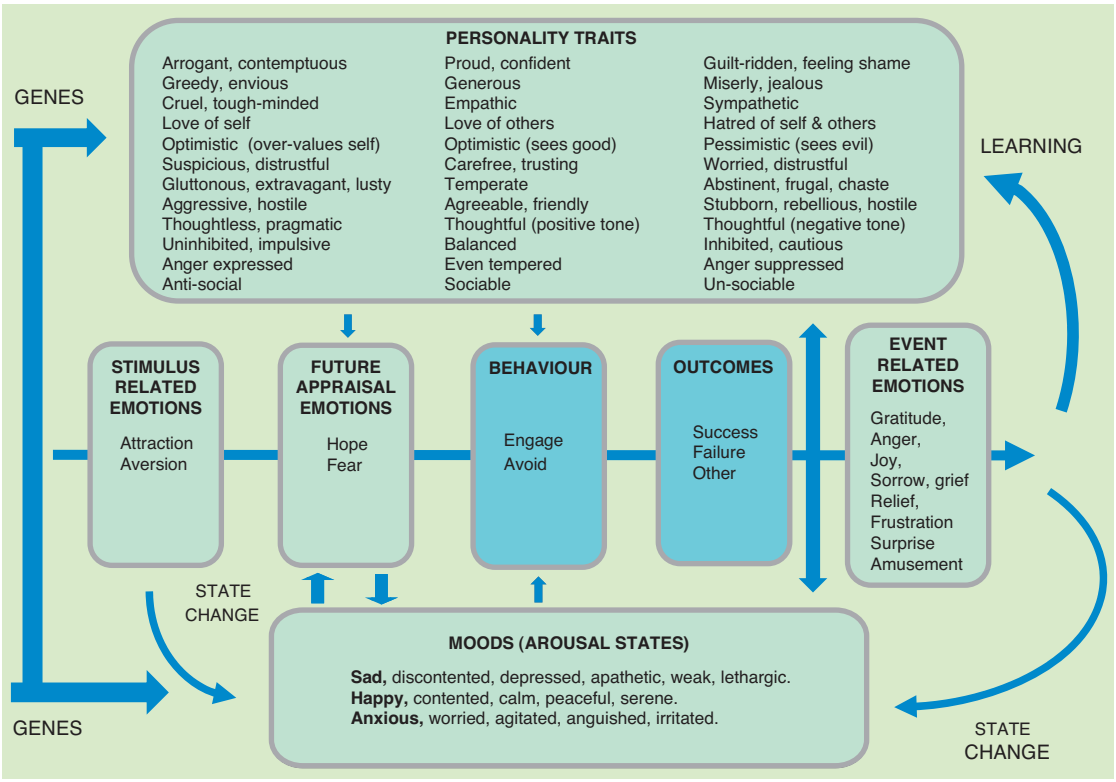

Figure 1
A general model for the dynamic interaction of basic emotions, mood states and personality traits.

are again a manifestation of structure. Another structural feature, not immediately evident from the diagram, is that the traits listed in the first column on the left tend to coincide in particular individuals. Also, in terms of the totality of personality or temperament, such individuals are in some but not all respects opposite to those who can be defined by coincidence of the traits listed in the third column on the right. Finally, one can see from the diagram that the last four 'basic emotions' listed in Table 3 now appear as personality traits in Figure 1.

One of the problems in the domain of personality is that the richly different personalities described by the traits on the left and right in Figure 1 would be reduced to a simple contrast in terms of the introversion-extraversion (E) and neuroticism (N) dimensions of personality (Eysenck and Eysenck, 1975). Thus, the traits on the left would be reduced to a high extraversion score in association with a high neuroticism score. Those on the right would be reduced to a low extraversion score, and again, a high neuroticism score. The traits in the central column have not yet been mentioned but these indicate extraversion in association with low neuroticism. According to conventional thinking, and the incorrect interpretation of results from factor analytic studies, the E and N dimensions are believed to be independent. However, their apparent independence is only an artefact imposed or created by the factor analytic procedure and they can only be conceived as arbitrary coordinates that must be used in conjunction with each other in order to identify real personalities (Robinson, 2001).

That is to say, the dimensions are like 'latitude' and 'longitude', the parameters of an extremely useful but entirely arbitrary coordinate system that allow us to specify exact locations on the surface of the planet. An infinite number of other coordinate systems could be devised that would perform the same useful task and nobody would dream of suggesting that either latitude or longitude relate to any particular physical phenomena. The same is true for systems of personality description and therefore it is not surprising to find that every personality 'theorist' comes up with a different system of personality description. There have been systems with 10 dimensions and 16 dimensions but it is currently fashionable to refer to the 'big five' personality dimensions. Again, one must refer to the arbitrary nature of the solutions provided by the factor analysis procedure and point out that this allows extraction of an infinite number of factors. In essence, one can carve the cake up into as many slices as one might wish for but it is still the same cake.

Thus, when appropriate methods are employed it is possible to demonstrate that the 'big five' dimensions are providing very little information about *real personalities* that is additional to the information provided by the two E and N dimensions (Maraun, 1997; Becker, 1999). If latitude or longitude are used in isolation it is impossible to specify any actual physical location. In the same way the extraversion and neuroticism scales cannot specify any actual personality when used in isolation from each other. Nor can scales that purport to measure 'behavioural inhibition', 'conscientiousness' and so forth since all of these individual scales will confound different personality types. If different personality types are confounded the scales in question can have little predictive power since different personality types will respond in different ways despite having similar scores on a specific personality scale. Ironically, when the two E and N scales are used in conjunction with each other, and we consider the traits associated with the four combinations of high and low scores, it is evident that these dimensions confirm the ancient doctrine of the four temperament types.

At this juncture, it is important to point out that there is one non-arbitrary feature which determines the outcomes of the factor analytic procedures used to 'identify' personality dimensions. Thus, in the first instance, *these procedures are designed to produce a factor that will account for the maximum amount of covariance in the responses to questionnaire items*. If one accepts the wisdom of the ages, namely, that there are four main temperament types, the outcome is entirely predictable. A factor will be created that contrasts the maximum number of individuals with the greatest number of coincident and opposed personality traits. Thus, *the first 'unrotated' factor will always be an introversion-extraversion or neuroticism factor because these are the two factors that contrast the two 'extraverted' temperament types with the two 'introverted' types or, alternatively, the two 'high neuroticism' temperament types with the two 'low neuroticism' temperament types*. If introversion-extraversion appears as the first unrotated factor then neuroticism will appear as the second unrotated 'orthogonal' factor in order to provide a complete account of the trait covariance caused by the existence of the four temperament types. Since these two factors account for most of the trait covariance any solutions producing a greater number of factors are only splitting the same covariance into a greater number of factors. However, these factors will have a narrow and essentially arbitrary emphasis on particular traits or subsets of traits.

Most of the traits on the left in Figure 1 would occur in individuals that, in former times, would be described as having the choleric temperament; the central column of traits coincide in individuals with the sanguine temperament; and most of the traits on the right would coincide in individuals with a melancholic temperament. For the sake of simplicity and clarity, traits associated with the phlegmatic temperament are not shown but are discussed elsewhere (Robinson, 1996, 2001). The main task for personality research is not to produce a never ending succes-

sion of 'new' but entirely arbitrary personality dimensions but to explain the structure revealed by the opposition of some traits and the coincidence of others, or in other words, to explain the occurrence of different personality or temperament types, to study these types, and to study the consequences of temperament differences.

In the author's theory of personality (Robinson, 1982, 1983, 1985, 1986a, 1986b, 1987, 1989, 1996, 2001, 2006), the fact that personality traits such as 'optimism' and 'empathy' do not usually change during the life-span, *and seem impervious to the influence of learning experience*, is attributed to genetic differences that bias the learning process so that a *bias in learning* contributes to the development of relatively stable personality traits and *will even accentuate these traits as learning proceeds*. However, that is not the whole story since one can identify neurophysiological differences, attributable to the same genetic differences, *but not in any obvious manner related to learning*, that have a direct and immediate effect on the processing of sensory information, on the character of mental experience, and on the motor processes that control behaviour.

In the author's theory the dimensional structure of personality and intelligence that is revealed by statistical studies is to a large extent caused by just two major dimensions of neurological variation. These dimensions of neurological variation define four neurological types and there are unequivocal empirical findings which demonstrate that these four neurological types correspond to the four temperament types (Robinson, 1996, 2001). One of the neurological dimensions is determined by the relative influence of thalamocortical processes of inhibition and excitation mediated by the neurotransmitters GABA and glutamate, respectively. The second dimension, partly related to the first, is determined by the relative influence or balance of the thalamocortical and brain-stem systems.

It would be inappropriate and counterproductive to undertake any detailed description of the author's theory in this article but it is important to point out that it is the only theory that accounts for both personality and intelligence within the same explanatory framework. It is also the only theory that is supported by clear and unequivocal empirical evidence derived from physical, neurologically and psychologically meaningful analyses of the oscillatory activity of the thalamocortical system. The reader may judge the validity of these claims by referring to the references given in the preceding paragraph. These references will confirm that the relations currently being discussed are empirical as well as theoretical. In particular, that the highest degree of thalamocortical arousability, with greatest inhibition of the brain-stem, is associated with the melancholic combination of E and N scores. And that a very low degree of thalamocortical arousability, with least inhibition of the brain-stem is usually associated with the choleric combination of E and N scores.

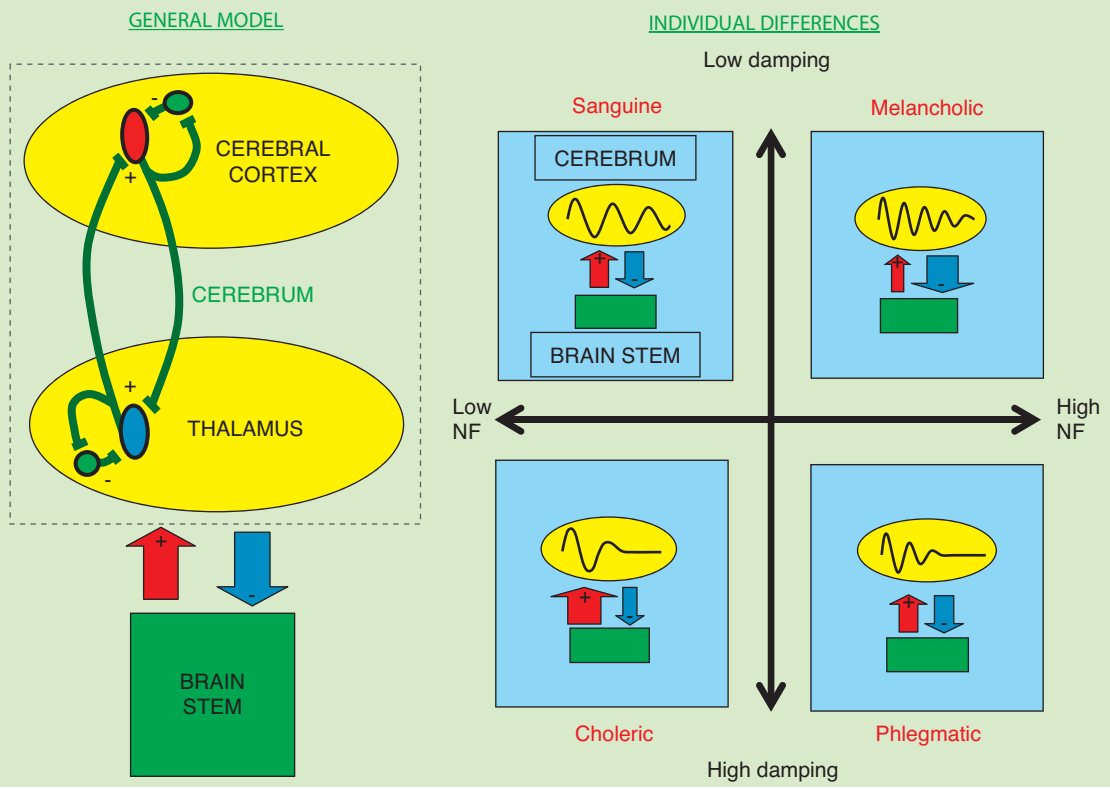

Figure 2
Differences in global brain function that result from differences in the natural frequencies and damping ratios of thalamocortical circuits.

The word 'usually' is employed in the last sentence because there is a very abrupt and dramatic reduction of E scores when thalamocortical arousability reaches the lowest limit so that there is again a melancholic combination of E and N scores. The author's findings indicate that it is only in this exceptional circumstance that there is any indication of ambiguity in the neurological significance of the combinations of E and N scores that define the temperament types. One interpretation is simply that when the subjective experience associated with the choleric temperament type becomes extremely unpleasant their E scores are depressed. Another possibility is that a very high degree of damping impairs associative learning to such an extent that stimulation is stripped of meaning and that this 'disconnects' an individual from the environment in a way that reduces extraversion scores. An important implication is that when thalamocortical arousability is very low it would require only a very small change in the value of the arousability parameters to produce a dramatic change in temperament. This would be consistent with the character of cyclothymia and bipolar affective disorder - as distinct from the dysthymic and monopolar affective disorders that the author attributes to very high thalamocortical arousability. It remains to point out that the two other temperament types, phlegmatic and sanguine, have an intermediate degree of arousability but differ in the way that an intermediate degree of arousability is determined.

Figure 2 illustrates the kind of closed thalamocortical circuits that produce the alpha-band oscillatory activity of the EEG. Like other simple oscillators, these circuits tend to oscillate at their own 'natural frequency' which is determined by the properties of the oscillator elements. In this case, the relative excitability of the excitatory and inhibitory neurons that make up the thalamocortical circuits. Thus, by determining the natural frequency of thalamocortical oscillators one obtains an index of the ratio or relative influence of the excitatory and inhibitory processes in the thalamocortical system of a given individual. The only other way in which the response of one oscillator differs from another is in terms of the duration of oscillatory activity following any disturbance. Where the oscillator elements determine a low 'damping ratio' the oscillatory activity will continue for a longer period of time. The author has proposed that more or less persistence of the activity of thalamocortical oscillators determines differences in associative learning (Robinson, 2006). When damping is high oscillatory activity does not persist and this would exclude the possibility of lateral propagation to activate other parts of the neural network. There are important psychological correlates of differences in both natural frequency and damping but for present purposes the most important consideration is that these two pa-

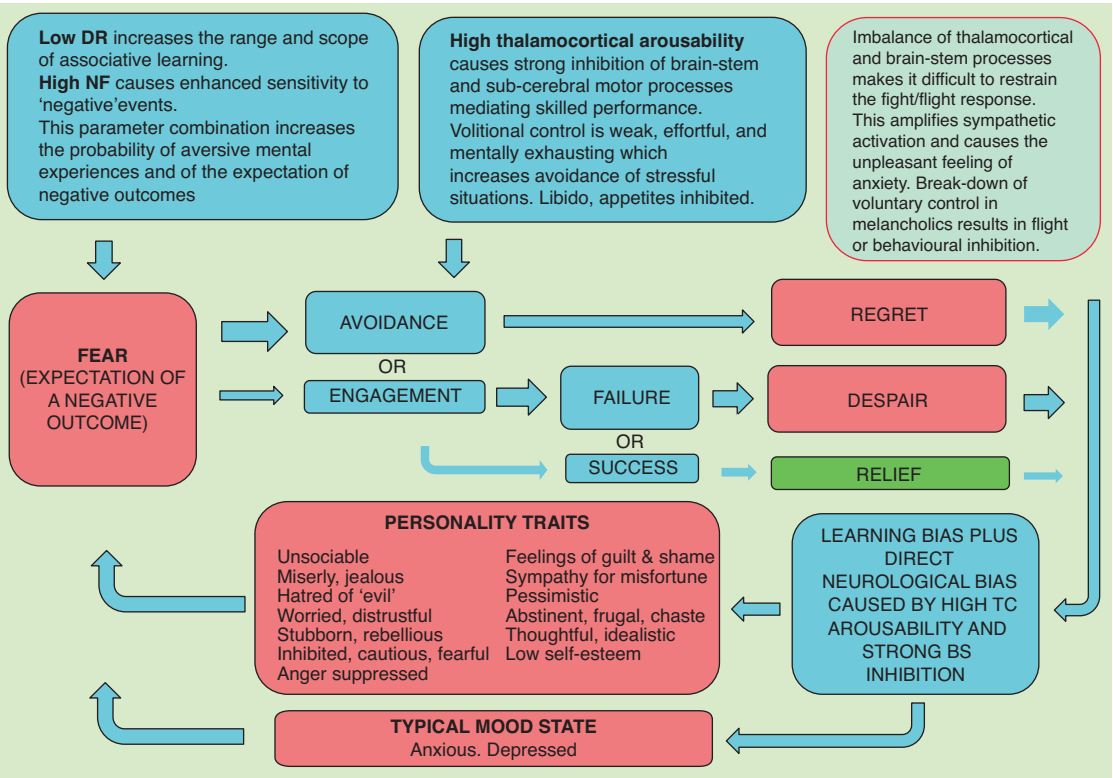

Figure 3
A model for the dynamic interaction of basic emotions, mood states and personality traits in the melancholic temperament type. The model also shows how this interaction is determined by high natural frequencies and low damping ratios in thalamocortical circuits.

rameters together determine differences in the overall arousability of the thalamocortical system. Since high thalamocortical arousability means that there is greater inhibition of brain-stem processes by the thalamocortical system, it should be evident that one can determine the relative balance or influence of thalamocortical and brain-stem processes. The neurological and psychological consequences of individual differences in natural frequency and damping ratio are summarised in Figure 2.

For present purposes it will be sufficient to consider the dynamic relationship between the basic emotions and the personality traits of the two temperament types that are determined by the highest and lowest degrees of thalamocortical arousability, namely, the melancholic and choleric types. However, it should be emphasised that there is considerable variation within a given temperament category and in this account it is the extreme cases that are considered. For example, the typical melancholic does not hate other people and the typical choleric is not cruel or anti-social. It is also worth noting that the typical melancholic and the typical choleric, despite a tendency to have lower IQ scores (Robinson, 1989, 1996) are likely to achieve more than the typical sanguine or phlegmatic individual precisely because anxiety is a powerful motivating force. For example, the author has unpublished data for a large population of medical students which shows that melancholic and choleric individuals tend to have better study habits than phlegmatic or sanguine individuals, that they tend to do better in examinations, and that they are less likely to have to repeat a year. With these important qualifications in mind, fear is shown in Figure 3 as the dominant basic emotion of melancholics when appraising the likely outcome of gain or loss situations.

However, fear is accentuated by the personality traits that in part are reflecting the history of past experience. Since the combination of high natural frequency and low damping determines the highest degree of thalamocortical arousability, there is also strong inhibition of the brain-stem and strong inhibition of the systems that mediate spontaneous or automatic skilled behaviour. Since voluntary control of behaviour is effortful and unskilled there are additional reasons why avoidance is more likely than engagement. If avoidance occurs this will eventually result in the experience of regret or guilt and across similar situations there will be a tendency to develop a depressed mood state and, through learning, a tendency to develop personality traits that mitigate against success in the future.

In the less likely event that engagement occurs failure will be more likely than success if only because there is an expectation of failure and poor motivation to succeed. Again, over time, the cumulative experience of failure tends to produce a depressed mood, low self esteem and the development of personality traits such as pessi-

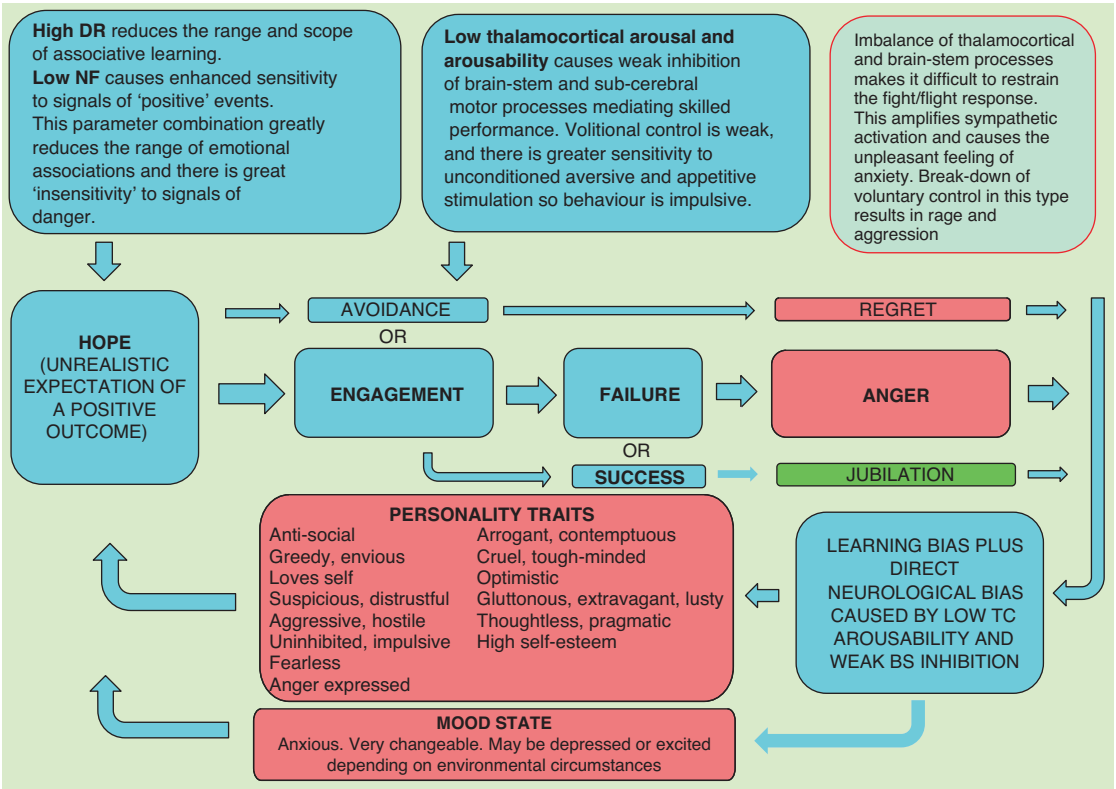

Figure 4
A model for the dynamic interaction of basic emotions, mood states and personality traits in the choleric temperament type. The model also shows how this interaction is determined by low natural frequencies and high damping in thalamocortical circuits.

mism. If success occurs it is only relief that is experienced rather than joy or elation. Notably, all or most of the personality traits that are listed can be attributed to either the direct effects of the arousability parameters or to the learning bias that is caused by these parameters.
In Figure 4 one can see the effects of low natural frequency in combination with high damping. This determines the lowest degree of thalamocortical arousability and least inhibition of brain stem processes. Here the appraisal emotion is more likely to be hope. First because the low natural frequency indicates predominance of thalamocortical inhibition over excitation. However, as before, this is reinforced by the prevailing mood state and by the personality traits of such individuals – not all due to learning. For example, in this case, the expectation of success is enhanced by increased libido due to disinhibition of the brain-stem. As well as having an unrealistic expectation of success there is also impulsivity - again due to low inhibition of the brainstem.

Hope of success and impulsivity both increase the likelihood of engagement but if engagement occurs failure is more likely than success because of the biased initial appraisal. The emotional response to failure is anger and resentment because success was expected and failure is not attributed to the individual's own flawed appraisal. If success does occur there is great joy and jubilation as distinct from the relief experienced by the melancholic. Notably, the negative consequences of failure do not result in personality traits that weaken the tendency to expect success but it is probable that a history of failure and conflict may increase anxiety and this will enhance the high neuroticism scores of such individuals.

Again it is emphasised that there are differences in the degree to which people are either choleric or melancholic. Most people in these categories must be considered healthy individuals if only because they represent such a large part of the general population. However, in the more extreme cases under consideration, cholerics are like Freud's 'hysterics' with a weak superego and a strong id. Melancholics are like 'dysthymics' with a strong superego and a weak id. It is hardly surprising that psychopathology should appear when there is an extreme functional imbalance of cerebral and brain-stem processes. It should also be self evident that despite their profound psychological differences melancholics and cholerics will both tend to have difficulties in their interaction with other people and the world in general.

Cholerics tend to overestimate their own worth and abilities and underestimate the difficulties associated with any enterprise in which they engage. In the more extreme cases their repeated failures are a constant source of frustration and anger. Their relationships with other people are spoiled by a demanding, intolerant and overbearing nature that is a source of continuous conflict. In contrast, melancholics tend to underestimate their own worth and abilities and overestimate the difficulties associated with any project. Again, in the more extreme cases, their lives are plagued by internal conflict, lost opportunities and a sense of hopelessness and despair that can result in social withdrawal. Both temperament types are prone to experience a state of uneasiness and distress that derives from the imbalance of thalamocortical and brain-stem processes, from their frustrated hopes and expectations, and from uncertainty about the future. In short, they are both prone to experience anxiety.

Here, it is noted that there are very high correlations between the Eysencks' neuroticism scale and measures of both depression and anxiety. Cholerics and melancholics both obtain high neuroticism scores despite the fact that melancholics are dominated by fear whereas cholerics are dominated by hope (Eysenck & Eysenck, 1975). Thus, it should be clear that anxiety is not the same as fear although the two words are often regarded as synonyms. Despite the fact that melancholics and cholerics are opposites in neurological terms, as well as in many psychological characteristics, the imbalance of thalamocortical and brain-stem processes lowers the threshold for activation of the stress cycle and of systems mediating the fight or flight defence reflexes. In the first instance the common experience of anxiety in melancholics and cholerics can be attributed to activation of the stress cycle and to the internal conflict that arises because of the difficulties they have in exercising voluntary control over behaviour. Finally, it should be evident that although a distinction has been made between mood states and personality traits, as shown in Figures 1, 3 and 4, it is also appropriate to describe individual differences in the occurrence and duration of these mood states as personality traits.

Conclusion

One objective of this article has been to develop a taxonomy of 'sensations', 'feelings', and 'basic emotions' and to distinguish these from personality traits. A second objective has been to clarify the relationship between emotional experience and personality and to describe how neurological differences can cause differences in the dynamics of emotional experience – either directly or as a consequence of a bias in learning – that are manifest as differences in personality or temperament, and in extreme cases as neurotic disorders. An important conclusion is that bias in emotional experience initiated by individual differences in the natural frequencies and damping ratios of thalamocortical oscillators is perpetuated and augmented by biased learning. Further research is needed to clarify and extend

our understanding of the full range of psychological differences that distinguish the temperament types and to clarify and extend our understanding of the dynamic relationship between emotions, mood states and personality traits. It would be particularly useful to achieve a better understanding of the biases in learning associated with different personality types and to examine how this contributes to the development of personality differences and in some cases also to psychopathology. Since learning is reversible, there is a theoretical basis for the further development and refinement of cognitive behaviour therapies that enhance patients' awareness of the dynamic relationship between behaviour, emotional experience and learning while also assisting them to identify and alter those beliefs and behaviours that contribute to the development of neurotic disorders.

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