Contents

Affective reflections and refractions within the BrainMind

Jaak Panksepp

The characteristic affects such as anger, fear, loneliness, desire, love and playful joy make emotions so important in our lives, and perhaps the lives of many other animals. Still, affect is such a slippery brain process, more easily discussed from first than third person perspectives, that there is little agreement on how to create a solid science of affective experience. Science is much better positioned to study objective entities of the world as opposed to subjective entities of the brain. Only because of advances in brain research, as highlighted in this issue, is progress finally being made on that slippery topic. (*Netherlands Journal of Psychology*, 64, 128-131.)

Keywords: affect; biology; emotion; motivation; neuroscience

Emotion science has been flourishing in psychology for almost a quarter of a century. Affect science is gradually catching up. Why make the distinction? Because affects, the valenced feeling aspects of certain brain states, are just a subset of the neurophysiological and psychological complexities that accompany all emotional and motivational states. It is common for emotions to be parsed into behavioural, physiological, cognitive and affective components, with the affective components being most difficult to clarify in any scientific depth. Indeed, without affective feelings, there would be little of substance left to the concept of emotions—the behavioural, physiological and cognitive components can never hang together as a coherent description of emotions. However, affect science remains burdened by sterile controversy (Ortony & Turner, 1990; Panksepp, 1992). Many remain excessively committed to the classic Wundtian dimensions of valence and arousal as being the most coherent ways to talk about affects (Barrett, 2006). Others do not deny the empirical utility of such approaches, but advocate evidence-based visions of the brain being an evolved bee-hive of many distinct affects, ranging from anger to hunger, from fear to thirst, from joy to disgust, from grief to love (Denton, 2006; Panksepp, 1998, 2007a). How is one to make sense of such divergent views? Clearly, controversy currently outweighs agreement (Barrett et al., 2007; Izard, 2007; Panksepp, 2007b, 2008a).

Perhaps some clarity can be had through conceptual analyses (Ekman & Davidson, 1994). Affects come in various flavours: Some are strictly sensory, such as the delight of honey on the tongue and the excruciating ache of gouty joints. Some are clearly linked to very specific visceral

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bodily states, from hunger pangs to the dreadful dehydration that can fill the mind with excruciating thirst; others are of a more nebulous variety, not well understood, such as bodily exhilaration and fatigue. Yet others, although modulated by bodily states, appear to be affects that arise largely from within intrinsic BrainMind dynamics, such as our capacity to experience various emotional arousals and the associated feelings (Panksepp, 2008b). Clearly, the menagerie of basic emotional feelings is smaller than the full complement of valenced affects that the brain can engender from bodily dynamics operating in highly variable worlds.

There are also levels of control within each affective neural system. The foundational, primary-process levels of control are built into the MindBrain as genetically provided tools for living. Others are derived from secondary and tertiary processes, ranging from simple forms of learning (classical conditioning) to culture (based on our capacity to think about our place in complex social groups). Superb brain-body mechanistic work can be done at subcortical primary and secondary process levels, while the tertiary process levels, concentrated in neocortex, are so much more variable that mechanistic work on general principles is much harder to pursue, almost impossible in animal models. Indeed, such emotional complexities emerge as organism mature, making developmental landscapes and epigenetic processes critical dimensions for the eventual emergence of our higher affective complexities.

Those higher levels of emotionality, where interactions with cognitive processes abound, will be harder to understand than the foundational issues that are more tightly tethered to our evolutionary heritage. This self-evident hierarchical view may be troublesome for purely psychological approaches that have little interest in and access to the lower, subcortical, initially objectless' affective foundations of the mind. Psychology has traditionally been more comfortable discussing the firmament of the cognitive mind, whose complexity is tethered to the availability of neocortex—brain tissue that is as close to a general-purpose *tabula rasa* as one can find in the BrainMind. And the more of this random-access, pluripotent brain tissue organisms have, the more perceptually acute, cognitively intelligent, emotionally sophisticated, and affectively variable will organisms become.

Despite the opinions of many evolutionary psychologists, there are no genetically predetermined functional modules up there in the neocortical stratosphere. Please note that young mice whose future visual cortex is removed before birth still develop totally functional visual systems in the cortex (Sur & Rubenstein, 2005). Early damage to subcortical regions is not followed by comparable plasticity, leading to lasting changes in mental abilities (Merker, 2007). Indeed, all of the neocortical cognitive functions can only operate if they remain connected to the functionally dedicated subcortical circuits that decisively mediate our basic attentional, emotional and motivational abilities.

Indeed, the neocortex alone does not have the right stuff to sustain consciousness (Watt & Pincus, 2004). The sub-neocortical regions are quite adept at supporting primitive affective forms of consciousness. Even human children born anencephalic—essentially without any neocortex—retain the capacity of simple perceptual and affective experiences (Shewmon, Holmse, & Byrne, 1999). And when we surgically decorticate young animals, they retain emotional 'normalcy'. They eat, drink, fight, fornicate and take adequate care of their offspring (albeit in untidy nests). To our surprise, they also retain ludic urges, playing as effectively as their neurologically intact littermates (Panksepp et al., 1994).

This may lead to a troublesome conclusion for many psychologists interested in emotions. Even though emotional feelings and cognitive strategies seem inextricably entangled in the higher reaches of the MindBrain, they are sufficiently distinct entities that it is wise to envision cognitions and affects as mental capacities that can be scientifically distinguished within the lowest, primary-process regions of the brain. Even at higher levels, where affects and cognitions highly interpenetrate, they probably remain as physiologically distinct, and as functionally intertwined, as kidneys and heart. Thus, affects and cognitions can be teased apart despite their intimate interactions within the intact MindBrain. If we are not willing to dissect the dissectible, we may never understand what emotional feelings and cognitions really are.

Of course, such dissections do a great injustice to the whole BrainMind. But as we come to understand the critical dimensional parts of emotional wholes, we can develop better visions of how to diminish needless disagreements (e.g., Barrett, 2006; Barrett et al., 2007; Panksepp, 2007b, 2008a). Many distinct levels of control exist within intact BrainMinds. With better clarity about one's own level of analysis, we can better recognise what our favoured strategies can solve and what they cannot. Thereby sterile controversy can be minimised, and the various levels of control within the MindBrain can be better integrated.

My own strategic aspiration has been to understand the *primary-process* affects of basic emotional arousals. Although I remain most interested in the nature of basic emotional feelings in humans, I surmised early in my career that cogent experimental tactics did not exist if I restricted my research to human beings. I needed access to the lower reaches of the brain. Thus, I took Darwin's evolutionary lessons to heart. We humans are inheritors of many basic animalian processes, including a variety of basic emotions (certainly primal forms of anger, fear, desire, loving care and playfulness). I accepted that such emotional, instinctual networks are built into every mammalian species, and that the anatomical and neurochemical *principles* learned from other animals would also apply to human beings and our emotional disorders (Panksepp, 1998, 2004).

However, the study of animals would not tell us much about the way basic emotions interpenetrate with human capacities for complex emotional information-processing, for deep thoughts and complex cultures. Those abilities are permitted by expansive neocortical dynamics that achieve their cognitive power partly by inhibiting the primary-process power of the basic emotional and motivational urges (Liotti & Panksepp, 2004). Might it not be useful for all investigators to envision how their research efforts fit in within hierarchically layered Mind-Brain complexities? At the lowest levels of control, there are *primary-process* emotional networks, encoded by genes about which little is known. This perspective is based on the robust fact that we can artificially evoke instinctual emotional actions and various positive and negative feeling states by stimulating, either electrically or chemically, the same subcortical locations in every species of mammal so far studied. The modest amount of evidence in our own species only confirms the general principle that raw emotional affects arise from homologous subcortical networks.

As a result of animal brain research, it is now well known how basic emotions interact with primal learning mechanisms such as classical and instrumental conditioning. The best-studied network mediates learned fearfulness within lateral and central zones of amygdala (LeDoux, 1996). However, such studies of *secondary-process* emotions tell us little about the *primary-process* of fear. The 'unconditioned instinctual responses' continue to be neglected in preference for the easier study of 'conditioned responses.' This is regrettable since raw affective experiences, primitive forms of sentience, arise from the primary-process substrates as variants of affective consciousness (Panksepp, 2007c).

Animal models are largely impotent for revealing how *tertiary-process* cognition-emotion interactions operate. Most of this work must be done in humans, where the subtlety of mentation can be monitored in the context of varying environmental and cultural dynamics. Only in humans can we monitor how affects promote complex cognitive plans and ruminations, where the focus of attention can turn inward toward the neuro-psychodynamics of the mind. Such work cannot be done in animals. However, to understand the whole, we must integrate all levels of analysis, and dispense with the hubris that one level of analysis can prevail over another (Barrett et al., 2007).

And so, how shall we construct a lasting Mind-Brain science from the affective experiences of humans and our mammalian relatives? The edifice of scientific understanding must be created one experimental brick at a time. An understanding of the 'whole' can only be obtained by a scientific understanding of the 'parts'. The fine contributions of this special issue, focusing on both higher and lower processes, highlight rigorous efforts from which a thorough understanding of emotional-affective processes and the nature of personality must eventually arise.

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Incorporating motivational intensity and direction into the study of emotions: implications for brain mechanisms of emotion and cognition-emotion interactions

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Contemporary dimensional models of emotion regard the positive to negative valence dimension as an important organising principle. This principle has been used to organise empirical observations of the relationship between left vs. right (asymmetrical) frontal cortical activations and positive vs. negative emotional experience and expression. This affective valence organising principle has also been used in research concerned with how emotions affect cognition, and much research has suggested that positive affects have different effects on cognition than negative affects. In this paper, we review recent research that questions the utility of the affective valence dimension in understanding the functions of asymmetrical frontal cortical activity and in understanding the effects of emotions on cognition. We will show that the incorporation of motivational direction as a separate dimension from affective valence will benefit understanding of brain mechanisms involved in emotions as well as emotion-cognition interactions. (*Netherlands Journal of Psychology*, 64, 132-142.)

Keywords: affective valence; cognition; emotion; frontal cortex; lateralisation; motivation

Contemporary dimensional models of emotion regard the positive to negative valence dimension as an important organising principle (Lang, 1995; Watson, 2000). Over the last three decades, this principle has been used to organise empirical observations of the relationship between left vs. right (asymmetrical) frontal cortical activations and emotional experience and expression. In this body of research, positive affect has been found to relate to relatively greater left than right frontal cortical activity, whereas negative affect has been found to relate to relatively greater right than left frontal cortical activity. This affective valence organising principle has also been used in research concerned with how emotions affect cognition, and much research has suggested that positive affects have different effects on cognition than negative affects. In this paper, we will review research that questions the utility of the affective valence dimension in understanding the functions of asymmetrical frontal cortical activity and in understanding the effects of emotions on cognition. We will show that the incorporation of motivational direction

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as a separate dimension from affective valence will benefit understanding of brain mechanisms involved in emotions as well as emotion-cognition interactions.

Affective valence, motivational direction, and asymmetrical frontal cortical activity

The interest in the relationship between asymmetrical frontal brain activity and emotional valence was sparked in part by systematic observations that damage to the left frontal cortex caused depression, whereas damage to the right frontal cortex caused mania (see review by Robinson & Downhill, 1995). Following closely after these observations, research demonstrated that both trait and state positive affect was associated with increased left frontal cortical activity, whereas trait and state negative affect was associated with increased right frontal cortical activity (see review by Silberman & Weingartner, 1986). Conceptually similar results have been obtained using a wide variety of neuroscience methods, including lesion studies (Robinson & Downhill, 1995), repetitive transcranial magnetic stimulation (rTMS; van Honk, Schutter, d'Alfonso, Kessels, & de Haan, 2002), positron emission tomography (PET; Thut et al., 1997), functional magnetic resonance imaging (fMRI; Canli, Desmond, Zhao, Glover, & Gabrieli, 1998), event-related brain potentials (ERPs; Cunningham, Espinet, DeYoung, & Zelazo, 2005), and electroencephalographic activity (EEG; Coan & Allen, 2003). Moreover, these effects have been observed in nonhuman and human animals (Berridge, España, & Stalnaker, 2003).

Until the late 1990s, all studies examining the relationship between asymmetrical frontal cortical activity and emotion confounded affective valence (positive vs. negative affect) with motivational direction. That is, all positive affective states/traits (e.g., joy, interest) that had been empirically examined were approach motivating, whereas all negative affective states/traits (e.g., fear, disgust) were withdrawal motivating. To understand whether these asymmetrical frontal cortical activations were due to affective valence or motivational direction (approach vs. withdrawal), we needed to examine an emotive state that avoided this confound of valence and motivational direction. To do so, we began investigating the relationship of anger with asymmetrical frontal cortical activity, because past social psychological and animal behaviour research suggested that anger is a negative emotion that evokes approach motivational action tendencies. If asymmetrical frontal cortical activity relates to motivational direction, then *anger should relate to greater left than right frontal activity*, because anger is associated with *approach motivational direction*. On the other hand, if asymmetrical frontal cortical activity relates to affective valence, then *anger should relate to greater right than left frontal activity*, because anger is associated with *negative valence*.

Testing competing hypotheses: motivational direction vs. emotional valence

In 1997, two studies observed that trait approach motivation was related to greater left than right frontal activity at resting baseline, as measured by electroencephalographic (EEG) alpha power activity (Harmon-Jones & Allen, 1997; Sutton & Davidson, 1997). Trait approach motivation was assessed using Carver and White's (1994) behavioural activation and behavioural inhibition scale. Sample items from the BIS scale include: 'I worry about making mistakes' and 'I have very few fears compared to my friends (reverse scored).' Sample items from the BAS include: 'It would excite me to win a contest', 'I go out of my way to get things I want'; 'I crave excitement and new sensations'. The scale was based on Gray's (1987) theory of motivation, which posits that a behavioural activation system (BAS) and behavioural inhibition system (BIS) motivate and guide behaviour. BAS is posited to be a motivational system sensitive to signals of conditioned reward, nonpunishment, and escape from punishment. Its activation causes movement toward goals. BIS is hypothesised to be sensitive to signals of conditioned punishment, nonreward, novelty, and innate fear stimuli. It inhibits behaviour, increases arousal, prepares for vigorous action, and increases attention toward aversive stimuli.

These studies suggested that asymmetrical frontal cortical activity could be associated with motivational direction instead of affective valence, even though BIS and BAS were also mostly associated with negative and positive affect, respectively (Carver & White, 1994). That is, past research had essentially confounded emotional valence (positive, negative affect) with motivational direction (approach, withdrawal motivation), and researchers were claiming that relatively greater left than right frontal cortical activity reflected greater approach motivation and positive affect, whereas relatively greater right than left frontal cortical activity reflected greater withdrawal motivation and negative affect. These claims fit well into dominant emotion theories that associated positive affect with approach motivation and negative affect with withdrawal motivation (Lang, 1995; Watson, 2000).

However, other, older theories suggested that approach motivation and positive affect are not always associated with one another. Anger, for example, is a negatively valenced emotion that evokes behavioural tendencies of approach (e.g., Darwin, 1872; Ekman & Friesen, 1975; Plutchik, 1980; Young, 1943). For instance, anger is associated with attack, particularly offensive aggression (e.g., Berkowitz, 1993; Blanchard & Blanchard, 1984; Lagerspetz, 1969). Offensive aggression, associated with anger, can be distinguished from defensive aggression, associated with fear. Offensive aggression leads to attack without attempts to escape, whereas defensive or fear-based aggression leads to attack only if escape is not possible.

Other research also suggested that anger was associated with approach motivation (e.g., Izard, 1991; Lewis, Alessandri, & Sullivan, 1990; Lewis, Sullivan, Ramsay, & Alessandri, 1992). More recent studies examined whether trait behavioural approach or BAS related to anger-related responses. In two studies, trait BAS, as assessed by Carver and White's (1994) scale, was positively related to trait anger at the simple correlation level, as assessed by the Buss and Perry (1992) aggression questionnaire (Harmon-Jones, 2003; see also, Smits & Kuppens, 2005). Carver (2004) also found that trait BAS predicts state anger in response to situational anger manipulations. BAS sensitivity has been found to predict aggressive inclinations even more strongly when approach motivation was first primed (Harmon-Jones & Peterson, 2008). Other research found that BAS predicted vigilance to angry faces presented out of awareness, consistent with the idea that attention toward angry faces is the first step in an approach-based dominance confrontation (Putman, Hermans, & van Honk, 2004).

Because of the large body of evidence suggesting that anger is often associated with approach motivation (see Carver & Harmon-Jones, in press, for a review), my colleagues and I examined the relationship between anger and relative left frontal activation to test whether the frontal asymmetry is due to emotional valence, motivational direction, or a combination of emotional valence and motivational direction.

Asymmetrical frontal cortical activity and anger

Because much past research from a variety of empirical approaches suggests that anger is associated with approach motivational tendencies, we proposed that by assessing the relationship of anger and asymmetrical frontal cortical activity, we would be better able to determine whether asymmetrical frontal cortical activity related to motivational direction or affective valence. If asymmetrical frontal cortical activity relates to motivational direction, then anger should relate to greater left than right frontal activity, because anger is associated with approach motivational direction. In contrast, if asymmetrical frontal cortical activity relates to affective valence, then anger should relate to greater right than left frontal activity, because anger is associated with negative valence.

Trait anger

In one of the first studies testing these competing predictions, Harmon-Jones and Allen (1998) assessed trait anger using the Buss and Perry (1992) questionnaire and assessed asymmetrical frontal activity by examining baseline, resting regional EEG activity (alpha power) in a four-minute period. In this study of adolescents, trait anger related to increased left frontal activity and decreased right frontal activity. In addition, a subset of this sample was comprised of adolescents in a psychiatric inpatient unit for impulsive aggression. Even among these individuals, trait anger related positively with greater left than right frontal activity (see also, Rybak, Crayton, Young, Herba, & Konopka, 2006). Asymmetrical activity in other regions did not relate with anger. The specificity of anger to frontal asymmetries and not other region asymmetries has been observed in all of our studies. Thus, we focus our review on asymmetrical frontal activity.

Other research addressed an alternative explanation for the observation that relative left frontal activity related to anger (Harmon-Jones, 2004). The alternative explanation suggested that persons with high levels of trait anger might experience anger as a positive emotion, and this positive feeling or attitude toward anger could be responsible for anger being associated with relative left frontal activity. After developing a valid and reliable assessment of attitude toward anger, a study was conducted to assess whether resting baseline asymmetrical activity related to trait anger and attitude toward anger. Results indicated that anger related to relative left frontal activity and not attitude toward anger. Moreover, further analyses revealed that the relationship between trait anger and left frontal activity was not due to anger being associated with a positive attitude toward anger.

State anger

To address the limitations inherent in correlational studies, we conducted experiments in which we manipulated anger and measured its effects on regional brain activity. In Harmon-Jones and Sigelman (2001), participants were randomly assigned to a condition in which another person insulted them or to a condition in which another person treated them in a neutral manner. Immediately following the treatment, EEG was collected. As predicted, individuals who were insulted evidenced greater relative left frontal activity than individuals who were not insulted. Additional analyses revealed that within the insult condition, reported anger and aggression were positively correlated with relative left frontal activity. Neither of these correlations were significant in the no-insult condition. These results suggest that relative left-frontal activation was associated with more anger and aggression in the condition in which anger was evoked.

More recent experimental evidence has replicated these results and also revealed that state anger evokes both increased left and decreased right frontal activity. In addition, when participants were first induced to feel sympathy for a person who insulted them, this reduced the effects of insult on left and right frontal activity (Harmon-Jones, Vaughn-Scott, Mohr, Sigelman, & Harmon-Jones, 2004). This suggests that the reason experiencing sympathy for another individual reduces aggression toward that individual (e.g., see review by Miller & Eisenberg, 1988) may be because sympathy reduces the relative left frontal activity associated with approach-oriented anger.

Independent manipulation of approach motivation within anger

In the experiments just described, the designs were tailored in such a way as to evoke anger that was approach oriented. Although most instances of anger involve approach inclinations, it is possible that not all forms of anger are associated with approach motivation. To manipulate approach motivation independently of anger, Harmon-Jones, Sigelman, Bohlig, and Harmon-Jones (2003) performed an experiment in which the ability to cope with the anger-producing event was manipulated. Based on past research that has revealed that coping potential affects motivational intensity (Brehm & Self, 1989) it was predicted and found that the expectation of being able to take action to resolve the anger-producing event would increase approach motivational intensity relative to expecting to be unable to take action. That is, angered participants who expected to engage in approach-related action evidenced greater left frontal activity than angered participants who expected to be unable to engage in approach-related action. Moreover, only within the action-possible condition did greater left frontal activity in response to the angering event correlate directly with greater self-reported anger and more approach-related behaviour.

The research by Harmon-Jones, Sigelman et al. (2003) suggests that the left frontal region is most accurately described as a region sensitive to approach motivational intensity. That is, participants only evidenced the increased relative left frontal activation when anger was associated with an opportunity to behave in a manner to resolve the anger-producing event. The effect of approach motivation and anger on left frontal activity has recently been produced using pictorial stimuli that evoke anger (Harmon-Jones, Lueck, Fearn, & Harmon-Jones, 2006). In this experiment, participants low in racial prejudice were shown neutral, positive, and fear/disgust pictures from the International Affective Picture System (Lang, Bradley, & Cuthbert, 2005). Mixed among those pictures were pictures depicting instances of racism and hatred (e.g., neo-Nazis, Ku Klux Klan). Prior to viewing the pictures, half of the participants were informed that they would write an essay on why racism is immoral, unjust and unfair at the end of the experiment. This manipulation served to increase their anger-related approach motivation. Results revealed that participants showed greater relative left frontal activity to anger pictures than other picture types only when they expected to engage in approach-related behaviour. A second study revealed that individuals who scored lower in racial prejudice evidenced even greater relative left frontal activation to the anger-evoking racist pictures in the approach motivation condition.

The above findings may suggest that relatively greater left frontal activity will occur in response to an angering situation only when there is an explicit approach motivational opportunity. However, it is possible that an explicit approach motivational opportunity is not necessary for increased left frontal activity to anger to occur, but that it only intensifies left frontal activity. In other words, other features of the situation or person may make it likely that an angering situation will increase approach motivational tendencies and activity in the left frontal cortical region. For example, individuals who are chronically high in anger may evidence increased left frontal activity (and approach motivational tendencies) in response to angering situations that would not necessarily cause such responses in individuals who are not as chronically angry. This prediction is based on the idea that angry individuals have more extensive angry associative networks than less angry individuals, and that anger-evoking stimuli should therefore activate parts of the network more readily in these angry individuals (Berkowitz, 1993).

In the study, participants were exposed to anger-inducing pictures (and other pictures) and given no explicit manipulations of action expectancy. Across all participants, a null effect of relative left frontal asymmetry occurred. However, individual differences in trait anger related to relative left frontal activity to the anger-inducing pictures, such that individuals high in trait anger showed greater left frontal activity to anger-producing pictures (controlling for activity to neutral pictures; Harmon-Jones, 2007). These results suggest that the explicit manipulation or opportunity for approach motivated action may potentiate the effects of approach motivation on relative left frontal activity, but may not always be necessary.

Manipulation of frontal cortical activity and anger processing

Other research is consistent with the hypothesis that anger is associated with left frontal activity. For example, d'Alfonso, van Honk, Hermans, Postma, & de Haan (2000) used slow repetitive transcranial magnetic stimulation (rTMS) to inhibit the left or right prefrontal cortex. Slow rTMS produces inhibition of cortical excitability, so that rTMS applied to the right prefrontal cortex decreases its activation and causes the left prefrontal cortex to become more active, while rTMS applied to the left prefrontal cortex causes activation of the right prefrontal cortex. They found that rTMS applied to the right prefrontal cortex caused selective attention towards angry faces whereas rTMS applied to the left prefrontal cortex caused selective attention away from angry faces. Thus, an increase in left prefrontal activity led participants to attentionally approach angry faces, as in an aggressive confrontation. In contrast, an increase in right prefrontal activity led participants to attentionally avoid angry faces, as in a fear-based avoidance. Conceptually similar results have been found by van Honk and Schutter (2006). The interpretation of these results concurs with other research demonstrating that attention toward angry faces is associated with high levels of self-reported anger and that attention away from angry faces is associated with high levels of cortisol (van Honk, Tuiten, de Haan, van den Hout, & Stam, 2001; van Honk, Tuiten, van den Hout, Koppeschaar, Thijssen, & de Haan, 1998; van Honk, Tuiten, Verbaten, van den Hout, Koppeschaar, Thijssen, & de Haan, 1999), which is associated with fear.

We recently extended the work of van Honk, Schutter, and colleagues by examining whether a manipulation of asymmetrical frontal cortical activity would affect behavioural aggression. Based on past research showing that contraction of the left hand increases right frontal cortical activity and that contraction of the right hand increases left frontal cortical activity (Harmon-Jones, 2006) we manipulated asymmetrical frontal cortical activity by having participants contract their right or left hand. Participants then received insulting feedback ostensibly from another participant. They then played a reaction time game on the computer against the other ostensible participant. Participants were told they could give the other participant a blast of 60 to 100 dB of white noise for up to 10 seconds if they were fastest to press the shift key when an image appeared on the screen. Results indicated that participants who squeezed with their right hand gave significantly louder and longer noise blasts to the other ostensible participant than those who squeezed with their left hand (Peterson, Shackman, & Harmon-Jones, 2008).

Incorporating motivation into the study of positive affect

The consideration of motivational direction as independent from affective valence assisted in elucidating the psychological and behavioural functions of asymmetrical frontal cortical activity. Given this independence of motivational direction and affective valence, we began to consider how incorporating the motivational dimension into positive affect might add to the relatively new interest in positive affect. For much of psychology's history, the study of positive affect had been neglected relative to the study of negative affect. However, with the spawning of the positive psychology movement, scientists have become more interested in the study of positive affect. In the midst of this explosion of interest in positive affect, Fredrickson (2001) postulated that all positive affects expand attentional and cognitive resources. This expansion or broadening of cognition and attention is predicated on the idea that all positive affects suggest a stable and comfortable environment, and thus cause individuals to be more creative, categorically more inclusive, and increase attentional breadth.

Indeed, much research has found that positive affect creates a broadening of cognitive processing in categorisation (Isen & Daubman, 1984), unusualness of word association (Isen, Johnson, Mertz, & Robinson, 1985), social categorisation (Isen, Niedenthal, & Cantor, 1992), and recalling memory details (Talarico, Berntsen, & Rubin, 2008). In these studies, positive affect was manipulated by having participants receive a gift (Isen & Daubman, 1984; Isen et al., 1992), watch a funny film (Isen et al., 1985; Isen, Daubman, & Nowicki, 1987), recall a pleasant memory (Schwartz & Clore, 1983; Murray, Sujan, Hirt, & Sujan, 1990), or remember a positive life event (Gasper & Clore, 2002; Talarico et al., 2008).

Positive affect and broadening of attention

More recently, the concept of cognitive broadening within positive affect has been investigated using measures of global (broad) and local (narrow) attention. Global as compared with local attentional processing can be likened to seeing the forest (global) vs. the trees (local). Global-local attentional focus has been measured in a variety of ways. The most common measures involve using a figure with both global and local features. Participants are asked to identify or compare features of the figure. For example, Kimchi and Palmer (1982) developed a task where individuals make similarity judgements. In the task, three global figures (large triangles or squares) each composed of local elements (small triangles or squares) are presented. The standard figure is positioned on top and the two comparison figures are positioned below. One of the comparison figures has local elements that match the standard, whereas the other comparison figure has a global configuration that matches the standard. Individuals can make similarity judgements based on either the global configuration or local elements of the standard figure. Similarity judgements based on global configurations indicate a global attentional focus, while judgements based on local elements indicate a local attentional focus.

Another prominent measure of global or local attention is the Navon (1977) letters task. In the task, pictures of a large letter composed of smaller letters are presented. The large letters are made up of closely spaced local letters (e.g., an *H* made of small *F*s). Individuals are asked to respond to particular individual letters throughout the task (e.g., *T* or *H*). If the response letters were T and H, global targets would be those in which a *T* or an *H* is composed of different smaller letters. Local targets would be those where a large letter is composed of smaller *T*s or *H*s. Faster responses to the large letters indicate a global focus, whereas faster responses to the small letters indicate a local focus.

In one experiment examining the effect of positive affect on attentional focus, Gasper and Clore (2002) compared a positive with a negative affect manipulation on global-local bias. Individuals were assigned to recall a pleasant, neutral, or negative memory. Then, they completed the Kimchi and Palmer (1982) global-local attention measure. Results indicated that positive as compared with negative affect produced a more global bias. However, no differences occurred between positive and neutral affects.

In 2005, Fredrickson and Branigan used the same measure of attention to investigate the attentional broadening effects of discrete positive emotions of amusement and contentment. Using film clips to evoke these discrete positive emotions, the authors found that relative to neutral emotion states, positive emotional states of amusement and contentment broadened attentional focus. More recently, Rowe, Hirsh, and Anderson (2007) found positive moods, as opposed to neutral moods, elicited by music resulted in broadened visual-spatial processing. The view that positive affect broadens attention has been the dominant view of the positive affect literature for over 20 years. Current research continues to operate under the theoretical assumption that all positive emotions are the same and that all positive emotions expand attentional breadth. The view that positive affect creates attentional and cognitive broadening, while negative affect creates narrowing, is widely accepted.

Positive affects vary in approach motivational intensity

This previous work on the attentional and cognitive consequences of affect focused on the valence dimension, that is, whether the emotion, mood, or affect was positive or negative. Another important and relatively neglected dimension of emotion is motivational direction: whether the emotion motivates the organism to approach or avoid a stimulus. All past research on the broadening effects of positive affect could be said to have used positive affects that evoked low intensity approach motivation. Positive affects, however, vary in the degree to which they are associated with approach motivation. Some positive affective states are low in approach motivation (e.g., feeling content, serene, or tranquil), whereas others are relatively high in approach motivation (e.g., feeling enthusiastic, excited, or desirous). The studies to be described have sought to examine the varied consequences of positive affective states that differ in the intensity of motivation.

Our work is predicated on conceptual models of emotion that emphasise emotions' motivational functions (Frijda, 1986) and that consider emotion to involve subjective, expressive, and physiological components. For example, Lang, Bradley, and Cuthbert (1990) proposed a dimensional model of emotion, with two orthogonal dimensions, valence and arousal. According to this conceptual view and its large empirical base, strong approach motivation is associated with stimuli that are positive and arousing, whereas strong avoidance motivation is associated with stimuli that are negative and arousing. Stimuli that reliably elicit approach are photos of erotica and food, whereas photos of mutilations and threat reliably elicit avoidance (Lang, 1995).

Positive affects vary in motivational intensity, and may have different effects on attention and cognition. Indeed, Lang and colleagues' programme of research has revealed that the processing of pleasant stimuli varies in approach motivation, and this processing affects autonomic, reflexive, and electro-cortical responses (Lang, 1995). Given the importance of approach-motivated positive affective states to biologically important outcomes such as reproduction and the ingestion of food and water, it seems likely that such states would not be associated with increased attentional and cognitive broadening. Broadening of attention and cognition might cause distraction and hinder acquisition of basic biological necessities. In contrast, approach-motivated positive affective states should be associated with attentional narrowing, as organisms shut out irrelevant perceptions and cognitions while they approach and attempt to acquire the desired objects.

Research has suggested that appetitive and consummatory components of reward processes relate to different types of positive affect. While seeking out and obtaining a reward, high approach pregoal positive affect occurs, whereas consummatory responses after obtaining a reward are associated with low approach positive affects such as satisfaction (Knutson & Wimmer, 2007). Neurobiological differences exist between pregoal and postgoal attainment positive affect in the prefrontal cortex, nucleus accumbens and other structures (Davidson & Irwin, 1999; Knutson & Peterson, 2005; Knutson & Wimmer, 2007).

Also, intrinsically motivated interest in a given task may arouse approach-oriented positive affects that attentionally narrow one's focus rather than broaden it. The narrowing of attention and cognition as one is engaged in goal pursuit is likely to assist in the goal-directed action and increase the chances of success. Such a process has been noted in research on action orientation (vs. state orientation) and implemental mindsets. Implemental mindsets increase approach-motivated positive affect and increase the likelihood of goal accomplishment (Brandstätter, Lengfelder, & Gollwitzer, 2001) as well as increase left frontal cortical activity (Harmon-Jones, Harmon-Jones, Fearn, Sigelman, & Johnson, 2008).

Research examining attentional consequences of approach-motivated positive affect

Past work on the cognitive consequences of positive affects has studied only low intensity approach-motivated positive affect, leaving the area of approach-motivated positive affect unexplored. Consequently, we have begun a programme of research aimed at examining the consequences of approach-motivated positive affect on attention and the neurophysiological underpinnings associated with these states.

Comparing the attentional effects of low vs. high approach-motivated positive affect

Our first experiment compared the attentional effects of high approach positive affect to low approach positive affect (Gable & Harmon-Jones, 2008a), using methods similar to those used in previous studies. Participants first viewed a neutral film. Then, they viewed either a low approach positive affect film (cats in humorous situations) or a high approach positive affect film (delicious desserts). After this film, participants completed Kimchi and Palmer's (1982) global-local visual processing task to assess breadth of attention (Fredrickson & Brannigan, 2005; Gasper & Clore, 2002). Then, participants rated how they felt during the film.

Results indicated that the cat film caused more global attentional focus than the dessert film. Also, the dessert film evoked more desire than the cat film, while the cat film evoked more amusement than the dessert film. These results provide initial support that high approach-motivated positive affect (desire) decreases attentional broadening as compared with low approach-motivated positive affect (amusement).

Investigating attentional narrowing of high approach positive affect relative to a neutral state

One caveat of the initial investigation is that it did not include a neutral comparison condition, making it difficult to know whether approach-motivated positive affect decreased attentional broadening as compared with a neutral condition. That is, approach-motivated positive affect may reduce broadening to the same level as neutral affect. Study 2 of Gable and Harmon-Jones (2008a) tested whether high approach positive affect reduced attentional breadth relative to a neutral condition.

Participants viewed either dessert or neutral pictures (rocks). After each affective/neutral picture, a Navon (1977) letter was presented to assess attentional breadth. As predicted, reaction times to global targets were slower after dessert pictures than after rock pictures. In contrast, reaction times to local targets were faster after dessert pictures than after rock pictures. Picture ratings revealed that food pictures were more pleasing and arousing, and caused more desire than neutral pictures. This second study revealed that high approach positive affect reduced broadening of attention.

Relating trait approach motivation to reduced attentional breadth

To provide further evidence that approach motivation was responsible for the effects of positive affect manipulations on reduced attentional broadening, Study 3 investigated whether individual differences in approach motivation would relate to attentional responses following appetitive stimuli. Carver and White's (1994) BIS/BAS questionnaire was used to measure trait approach motivation and the Navon letters task was used to measure attentional breadth following appetitive pictures (desserts and baby animals).

Results indicated individuals higher in trait approach motivation responded with less broad attention following approach-motivating stimuli (controlling for responses to neutral pictures). This study provided further evidence to support the hypothesis that the reduced attentional broadening caused by appetitive stimuli is due to approach motivation, as individuals high in BAS showed greater reductions in attentional broadening following appetitive stimuli.

Manipulating approach motivation within high approach positive affect

To test whether approach motivation mediates the reduction in attentional broadening following appetitive stimuli, intensity of approach motivation needed to be experimentally manipulated. Study 4 of Gable and Harmon-Jones (2008a) did this by varying the expectancy to consume desserts viewed in pictures. Past research has suggested that the expectancy to act increases motivational intensity generally (Brehm & Self, 1989) and approach motivation in approach-oriented contexts (Harmon-Jones et al., 2006). Participants were (1) shown dessert pictures and told they could expect to consume them, (2) shown dessert pictures without this expectancy, or (3) shown neutral pictures and told they could expect to take some of the neutral objects. Following the picture viewing, attentional breadth was measured using the Navon letters task.

Participants who viewed dessert pictures and expected to consume desserts were the least attentionally broad, followed by participants who simply viewed the dessert pictures, and finally participants who viewed neutral pictures. Participants reported increasingly more excitement and enthusiasm from the neutral to the dessert and then to the expectancy-dessert condition. It is important to note that in all of our studies on positive affect and attention, we have not observed our positive affect manipulations to cause any negative affect. Results of this study strongly supported the hypothesis that high approach-motivated positive affect causes attentional narrowing.

Linking left frontal activation to high approach positive affect with attentional narrowing

Given previous research showing that approach-motivated positive affect is associated with increased left prefrontal cortical activation (Gable & Harmon-Jones, 2008b), we investigated whether greater left frontal activation associated with high approach-motivated positive affect would relate to attentional narrowing (Harmon-Jones & Gable, in press). The study was predicated on research showing that left frontal activation is associated with approach motivation (Harmon-Jones, 2003), and research showing that left hemispheric activation is associated with attentional narrowing (Volberg & Hübner, 2004).

Specifically, we examined whether neural activations associated with approach motivation would relate to the effect of approach-motivated positive affect on narrowed attention. Also, we examined whether individual differences in approach motivation would relate to attentional narrowing.

Results showed that individual differences in approach motivation (time since eaten) related to local attentional bias following dessert pictures. Also, relative left frontal-central activation predicted this local attentional bias.

These results demonstrated that greater narrowed attention induced by appetitive stimuli is driven by neurophysiological activations associated with approach-motivational processes. The present study integrated research on approach-motivated positive affect, attentional focus, and their associated neural processes. Thus, it suggests approach motivation engages the same neural circuitry that drives local attention in general, and the approach-motivated activation of this circuitry biases local attention even more.

Conclusion

Approach-related emotions such as anger or desire involve several brain regions, but the reviewed research establishes the importance of the left prefrontal cortex in approach motivation independent of affective valence. Often in discussions on the functions of the prefrontal cortex (PFC), scientists suggest that the PFC is involved in higher level cognitive functions, such as working memory and inhibitory processes. Part of the reason scientists reserve the PFC for higher-level cognitive processes is because it is a region that is much larger in humans than nonhuman animals. The logic continues that if the PFC were a relatively recent development in evolution, then it must be the source of those psychological processes that separate us from other animals. This logic is likely to be at least partially correct, but not foolproof. For example, recent single-cell research with rats has revealed that the PFC is involved in aggression and most of the cells activated are not inhibitory cells (Halász, Tóth, Kalló, Liposits, & Haller, 2006).

The PFC is a vast territory and is likely involved in a number of psychological processes. Moreover, structures that are involved in certain psychological/behavioural processes in nonhuman animals may be involved in different processes in human animals. For instance, many of the anatomical details of components of emotional response circuits are different in rodents and primates. The organisation, connectivity, and some functions of amygdala nuclei (Amaral, Price, Pitkanen, & Carmichael, 1992), prefrontal cortex (Goldman-Rakic, 1987), and anterior cingulate (Bush, Luu, & Posner, 2000) differ between rodents and primates. In addition, evidence suggests that areas throughout the brain are activated during a variety of mental processes, rather than processes being localised in just one brain area. The size, complexity, and activity of the human PFC suggest that it is integrated in many processes.

The approach and withdrawal processes implemented by left and right frontal cortices have been observed in rhesus monkeys (e.g., Kalin, Shelton, Davidson, & Kelley, 2001) and humans as early as 2-3 days of age (Fox & Davidson, 1986). In addition, damage to these regions of frontal cortex cause depression vs. mania (Robinson & Downhill, 1995), and rTMS manipulations of left vs. right cortical regions affect mood and attentional processing in manners consistent with the idea that asymmetrical frontal cortical activity is involved in motivational direction (d'Alfonso et al., 2000; van Honk & Schutter, 2006). Finally, research with organisms as simple as toads has revealed that approach and withdrawal processes are lateralised in a manner similar to that observed in humans (Vallortigara & Rogers, 2005). However, these lateralisations probably involve more structures than the frontal cortex, as amphibians lack such. It is possible that subcortical structures are lateralised for approach and withdrawal motivational processes in amphibians, reptiles, and birds but that these lateralisations are preserved and elaborated into the frontal cortices of primates. Future research will need to explore connections between subcortical and cortical structures in approach and withdrawal motivation.

Greater left than right frontal cortical activity is associated with approach motivation and not positive affect per se. Research has demonstrated that unlike other negative emotions, anger is often associated with approach-motivational tendencies. Consequently, major dimensional theories of emotion will need to be modified to incorporate the idea that not all negative affects are associated with withdrawal motivation. Also, our recent research on the intensity of approach motivation within positive affect suggests that positive affect high in approach motivation causes a reduction in attentional breadth, a finding that is opposite to that obtained with low approach positive affect. This research provides further evidence suggesting that emotions of the same valence can have very different consequences for attention and cognition. Furthermore, it integrates the areas of motivation, attentional focus, and their associated neural processes. In sum, these findings broaden theorising about the relationship between emotions and motivation. Moreover, they add to a growing literature focused on the examination of motivational intensity and direction within emotions.

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Our main fields of interest are emotion, motivation, and social processes, and the neural processes underlying these psychological constructs.

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Watch the face and look at the body!

Reciprocal interaction between the perception of facial and bodily expressions

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Human emotion processes are traditionally investigated in the laboratory by using facial expressions. However, information from other sources, such as the emotion of the voice, the body or the surrounding context, seems to influence the way we perceive the face. In the current experiment compound stimuli consisting of faces and bodies expressing fear or happiness, with the same (congruent) or different (incongruent) emotion, were presented. Participants had to judge either the emotion of the face or the body. Our data clearly show that face and body expressions influence each other. Accuracy was negatively influenced by the incongruent emotion of the bodily expression, but only when the target face expressed a happy emotion. When a fearful or happy body had to be judged, both incongruent face emotions affected the accuracy similarly. The same pattern was observed for the reaction times for judgement of the body emotion, while no influence of the body was observed when the emotion of the face had to be judged. Our results indicate that face and body expressions influence each other but that the way the one biases the perception of the other is dependent on the specific emotion and on which the attention is focused. (*Netherlands Journal of Psychology*, 64, 143-151.)

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Faces do not appear to us to be completely isolated from other sources of information that may be helpful to recognise and react to their emotional expression. However, traditionally the study of how humans process emotional signals has focused on the underlying perceptual and neurophysiological processes of perceiving facial expressions without taking these other sources of information into consideration.

Many studies indicate that the face and its expression might comprise a special perceptual

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category processed by the brain in a specialised manner and involving dedicated brain regions. Given our evolutionary background in which detection of threat was of utmost importance for survival, this is not entirely surprising.

The fusiform gyrus has been put forward as the region dedicated to the perception of faces and their expressions. This is witnessed by a larger activity for faces than for other objects (Haxby, Horwitz, Ungerleider, Maisog, Pietrini, & Grady, 1994; Kanwisher, McDermott, & Chun, 1997; Sergent & Signoret, 1992) and an increase in activity when the face contains an emotion (e.g., Morris, de Gelder, Weiskrantz, & Dolan, 2001; Rotshtein, Malach, Hadar, Graif, & Hendler, 2001).

Similarly, the N170 event-related potential with as possible source the fusiform gyrus (Herrmann, Ehlis, Muehlberger, & Fallgatter, 2005; Pizzagalli, Lehmann, Hendrick, Regard, Pascual-Marqui, & Davidson, 2002, but see Henson, Goshen-Gottstein, Ganel, Otten, Quayle, & Rugg, 2003), is larger for faces than for other objects (Bentin et al., 1996) and is sensitive for the expression of the face (Batty & Taylor, 2003; Caharel, Courtay, Bernard, Lalonde, & Rebai, 2005; L. M. Williams et al., 2006).

A possible feedback mechanism (see Breiter et al., 1996; Morris, Öhman, & Dolan, 1998; Sugase, Yamane, Ueno, & Kawano, 1999) between the fusiform gyrus and the amygdala might explain the emotion sensitivity of the first region (and possibly of the N170, see Righart & de Gelder, 2006). Furthermore, patients with amygdala lesions are impaired in the recognition of facial expressions (Adolphs, Tranel, Damasio, & Damasio, 1994, 1995; Young, Aggleton, Hellawell, Johnson, Broks, & Hanley, 1995; Young, Hellawell, van de Wal, & Johnson, 1996). Moreover, faces containing an emotion are more easily detected (Hansen & Hansen, 1988) and reduce inattention in visual extinction and neglect patients (Tamietto, Latini Corazzini, Pia, Zettin, Gionco, & Geminiani, 2005; Vuilleumier & Schwartz, 2001).

As an expression can sometimes be ambiguous, additional sources of information have to be taken into account, such as tone of voice or the bodily expression. In those cases, recognition can be improved, but when the additional source is incongruent with the primary source, i.e. displaying a different emotion, reaction times are slowed down and judgement becomes more erroneous. In the study by Meeren, van Heijnsbergen, and de Gelder (2005) fearful and angry facial expressions were recognised faster and more accurately when the concurrently presented bodily expression was the same (congruent) rather than different (incongruent). The amplitude of the P1 event-related potential appeared larger for incongruent than congruent pairs. Van den Stock, Righart, and de Gelder (2007) showed that facial expressions, ranging on continuum from fear to happiness, were more frequently judged as expressing happiness when a happy instead of fearful bodily expression was shown concurrently.

Adopting the approach of these two previous studies, Aviezer et al. (2008) obtained similar results and showed the extent to which the perception of the facial expression was influenced by the expression of the body. The effect was modulated by the similarity between the emotion of the target face, and the emotion of the accompanying body (in descending order of influence: anger, sadness and fear).

Furthermore, activity of the amygdala and fusiform gyrus (Dolan, Morris, & de Gelder, 2001) and the amplitude of the N170 (Righart & de Gelder, 2006, 2008a) are influenced by the complementary affective information that accompanies the facial expression (emotional voice: Dolan et al., 2001; emotional scene: Righart & de Gelder, 2006, 2008a).

Whether the primary source of affective information is liable to influence is sometimes dependent on its own specific emotion and that of the additional source. Righart and de Gelder (2008a, 2008b) showed that the perception of a fearful face was not negatively influenced by the happiness-inducing context, but if a happy face had to be categorised, the fear-inducing context slowed down the response (Righart & de Gelder, 2008a, 2008b) and participants made more errors (Righart & de Gelder, 2008b). Using only (emotional) faces, Fenske and Eastwood (2003) and Hansen and Hansen (1988) reported similar results. In the first study, reaction times of emotional categorisation of the target face were negatively influenced by the negative faces that flanked the target if the target face itself contained a positive emotion. When the target contained a negative emotion and the flankers a positive emotion, no influence on reaction times was observed. In the second study, the influence of the angry distractor faces on the happy target face was larger than that of happy distractor faces on the angry target face. Negative emotions may hold attention if the target exhibits the negative emotion (Fox, Russo, Bowles, & Dutton, 2001), or may attract attention to the secondary source when the latter contains the negative affective information (Hansen & Hansen, 1988) and may thereby interfere with target processing.

These studies might suggest that the facial expression is taken as the primary source of information. However, when the other person is standing far away, the bodily expression is better visible than the face and might show an advantage. Furthermore, the special status of the face has been put in a more modest perspective recently. Bodies are also encoded rapidly (Meeren, Hadjikhani, Seppo, Hämäläinen, & de Gelder, submitted), the fusiform gyrus is also activated by images of bodies (Peelen & Downing, 2005) and modulated together with the amygdala by affective information of the body (de Gelder, Snyder, Greve, Gerard, & Hadjikhani, 2004; Hadjikhani & de Gelder, 2003; van de Riet, Grèzes, & de Gelder, in press). Just like faces, bodies capture attention (Downing, Bray, Rogers, & Childs, 2004), reduce attention deficits of neglect patients (Tamietto, Geminiani, Genero, & de Gelder, 2007), and are processed outside of awareness by patients with striate cortex lesions (de Gelder & Hadjikhani, 2006).

We recently investigated the influence of additional affective information on the processing of bodily expressions (van den Stock, Grèzes, & de Gelder, 2008). Emotion judgements of dynamic bodily expressions of fear and happiness were biased to the emotion of the concurrently presented fear and happiness-inducing vocalisations produced by humans or animals.

No studies so far have investigated the influence of facial expressions on the perception of body language. All the aforementioned studies investigated the influence of the body on the face (Meeren et al., 2005; van den Stock et al., 2007) or of the affective vocal expressions on the body (van den Stock et al., 2008).

In the current experiment, we studied this question by presenting emotionally congruent and incongruent face-body compounds, with the face or body expressing fear or happiness. The emotion of either the face or the body had to be categorised.
Based on prior studies, we hypothesised that emotional categorisation of the target (face or body) might benefit from the presence of a congruent context emotion (body or face) in comparison with an incongruent emotion with slower and/or less accurate responses for incongruent pairs. We predicted that this (in)congruency effect is dependent on the emotion of target and context. A target expressing happiness will be negatively influenced by the incongruent fearful context expression, while no effect will be seen of the incongruent context when the target expresses fear.

Methods

Participants

Eighteen right-handed healthy undergraduates were tested. They received course credits for participation in the experiment. All participants had normal or corrected-to-normal vision and declared having no history of neurological of psychiatric disorders. They all gave written consent and the study was in accordance with the Declaration of Helsinki.

Stimuli

Each stimulus consisted of greyscale pictures of faces and bodies with either a fearful or a happy expression resulting in four (2 x 2) possible stimulus combinations. Four male and four female face and body identities were used, each identity displaying a fearful or happy expression. Face and body pictures were taken from the Ekman and Friesen database and from our own database, respectively, and were previously validated (faces: Ekman & Friesen, 1976; bodies: van de Riet et al., in press) and included when they were recognised correctly more than 75% of the time.

Faces were fitted inside a grey oval shape, which masked all external aspects. Body stimuli were cut out, removing all background. The faces of the body pictures were covered with a grey mask that made the internal facial features invisible. Faces and bodies were scaled to the same height (300 pixels) and superimposed on each other, similar to the stimulus construction procedure as used in Boutet, Gentes-Hawn, and Chaudhuri (2002). This deviates from the procedure used in Meeren et al. (2005) and van den Stock et al. (2007) in which face-body compounds were constructed by positioning the head on top of the body. In the current procedure there is no clear advantage of one stimulus category over the other, as differences in eye movements are

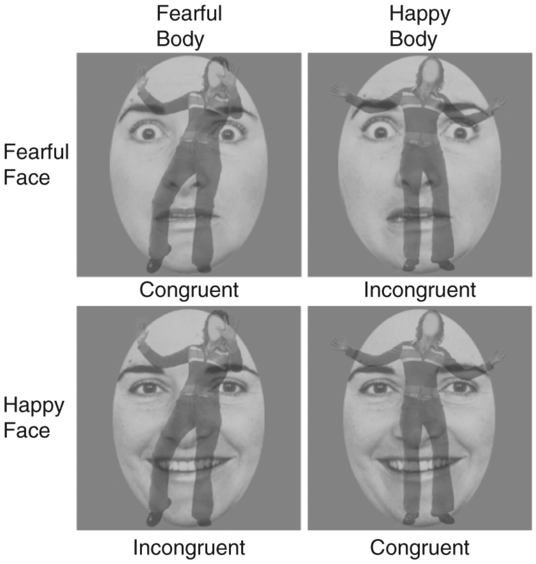

Figure 1
Examples of the compound stimuli presented during the experiment. A fearful facial expression was coupled to a fearful (congruent) or happy (incongruent) bodily expression. A happy facial expression was coupled to a fearful (incongruent) or happy (congruent) bodily expression.

avoided and both parts occupy the same position in the visual field.

Design and procedure

Participants were instructed on a trial-by-trial basis to judge the emotion of either the face or body. Before each compound stimulus was shown, participants were instructed whether to categorise the emotion of the face or the body by the word FACE or BODY appearing on the screen. This instruction screen stayed on for 1000 ms. A fixation cross appeared for 400 ms after which the compound stimulus was shown for 40 ms. Participants had to respond within the time frame of the subsequent grey screen (1200-1400ms) and fixation cross (400 ms). See Figure 2 for the trial sequence.

In previous studies in which the focus of attention was on the face or on the additional stimulus, emotion effects were present in designs in which trial types were presented randomly (Anderson, Christoff, Panitz, De Rosa, & Gabrieli, 2003; Vuilleumier, Armony, Driver, & Dolan, 2001), while absent when presented in a block design (Pessoa, McKenna, Gutierrez, & Ungerleider, 2002). We therefore chose the current design type, as in a block design, participants may have enough time to actively suppress the unattended stimulus (see M.A. Williams, McGlone, Abbott, & Mattingley, 2005).

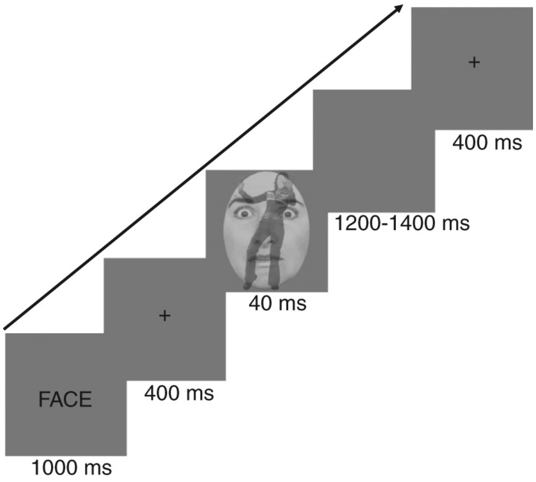

Figure 2
Sequence of the various parts of the trial and their duration. Participants were alerted by the instruction screen whether to judge the emotion of the face or the emotion of the body before presentation of the compound stimulus. Responses had to be made before offset of the fixation cross which succeeded the grey screen.

To avoid ceiling effect, we increased task difficulty by presenting the stimulus very briefly and limited the time frame in which the participants were supposed to respond.

Participants were sitting facing the monitor in a soundproof experimental boot and responded with the right index and middle finger. Ascription of each finger to each response category was counterbalanced over participants. E-prime (Schneider, Eschman, & Zuccolotto, 2002) was used for presentation of the stimuli and the registration of responses and reaction times. In each of the five blocks, the stimulus set of 64 different images was presented in a randomised order with a short break of two minutes between blocks. The experiment was preceded by a short practice session using different compound stimuli than the experimental ones.

Data analysis

Data (Reaction times and Accuracy) were analysed using two 2 x 2 repeated measures analyses of variance (ANOVAs) with the main factors Emotion Face (two levels: Fearful and Happy), Emotion Body (two levels: Fearful and Happy) for Judging Emotion Face and for Judging Emotion Body separately.

Interaction effects between Emotion Face and Emotion Body can indicate that congruent compounds are recognised better and/or faster than incongruent pairs. As we expect these congruency effects to be dependent on the emotion of target and context, for each emotion of the target, the congruent and incongruent emotions of the context were compared with separate paired-sample t-tests (see Righart & de Gelder, 2008a, 2008b).

Percentage correct responses were calculated by dividing the number of correct responses by the number of responses.

Results

Accuracy

Face Judgement
There was a main effect of Emotion Body ($F(1, 17) = 5.268, p = 0.035$), with better accuracies for happy than fearful bodies (see Figure 3, for graphs of the accuracy rates and the reaction times). The interaction between Emotion Face and Emotion Body almost reached significance ($F(1, 17) = 4.258, p = 0.055$). This congruency effect was dependent on the emotion of the face. Happy faces in the context of a happy instead of a fearful body ($t(17) = 2.961, p = 0.009$) were recognised better, while no difference was observed between a fearful face in the context of a fearful or a happy body ($t(17) = 0.825, p = 0.421$).

Body Judgement
There was an interaction effect between Emotion Face and Emotion Body ($F(1, 17) = 10.094, p = 0.006$). This congruency effect was not dependent on the emotion of the face or body. Fearful bodies were better recognised with a fearful than

happy face ($t(17) = 2.143$, $p = 0.047$), while happy bodies were near-significantly better recognised in the context of a happy than a fearful face ($t(17) = 2.056$, $p = 0.055$).

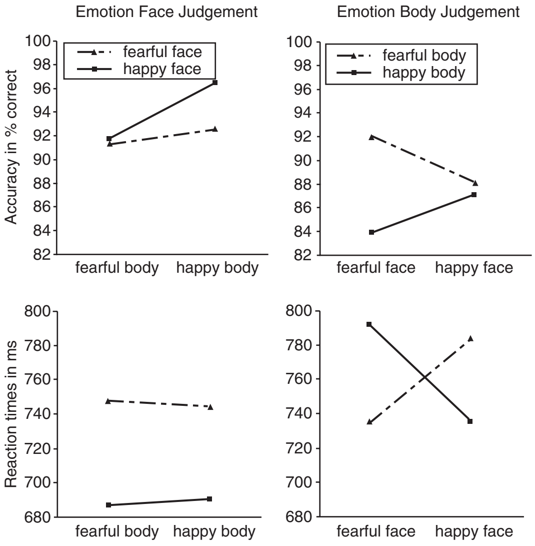

Figure 3
Accuracy for Face Judgement (left upper panel), accuracy for Body Judgement (right upper panel), reaction times for Face Judgement (left lower panel) and reaction times for Body Judgment (right lower panel).

Reaction times

Face Judgement

There was a main effect for Emotion Face, as happy faces were recognised faster than compounds containing fearful faces ($F(1, 17) = 17.709$, $p = 0.001$).

Body Judgement

There was an interaction between Emotion Face and Emotion Body ($F(1, 17) = 26.564$, $p < 0.001$). This congruency effect was not dependent on the emotion of the face or body. A fearful body with a fearful instead of a happy face ($t(17) = 4.161$, $p = 0.001$) and happy body with a happy instead of a fearful face ($t(17) = 3.190$, $p = 0.005$) were recognised faster than their incongruent counterparts.

Discussion

Our goal was to investigate the reciprocal influence between facial and bodily expressions of emotion as a function of the emotional expression displayed by each separately and the deployment of attention. Taken together, our data clearly show that face and body expressions influence each other. However, the specific pattern of reciprocal influence depends on the emotion displayed in the face and the body and whether the participants attend to either the face or the body.

Participants responded faster and more accurately to the emotion of the body when the emotion expressed by the face was the same (congruent) instead of different (incongruent). Less errors were made in judging the emotion of the face when it was coupled to a congruent bodily expression. This latter congruency effect was only present when a happy facial expression had to be categorised, indicating a negative influence of the incongruent fearful bodily expression. Happy faces were recognised faster than fearful faces, but this was not influenced by the emotion of the body.

First, faster reaction times for happy faces are in line with our previous results (van de Riet et al., in press) and those of other studies (Esteves & Öhman, 1993; Harrison, Gorelczenko, & Cook, 1990; Kirouac & Dore, 1983, 1984; Mandal & Palchoudhury, 1985; Righart & de Gelder, 2008a, 2008b; Stalans & Wedding, 1985). Second, our finding that congruence effects are a function of the emotion displayed is consistent with previous studies using face stimuli within a context consisting of other faces (Fenske & Eastwood, 2003; Hansen & Hansen, 1988) or paired with emotion-inducing scenes (Righart & de Gelder, 2008a, 2008b). Third, not all observed congruency effects were dependent on the emotion of the target and context. Fourth, contrary to Meeren et al.'s study (2005), reaction times for facial expression categorisation were not influenced by the emotion of the body.

These results clearly show that the face and the body do not exert the same influence on each other. A few explanations might be opted for this effect. First, there are face-body differences in stimulus size. The face stimulus is relatively larger, hence its larger influence. Second, face-body recognition differences are present. The facial expression is better recognised and is therefore more dominant. Third, face-body emotion differences in processing give rise to the observed differences.

Face-body differences in stimulus size

Although the face and the body were equal in height, they were not equal in width, with the face occupying larger parts of the visual field than the body. The size of an affective stimulus can have an effect on accuracy and speed of judgement, with higher ratings for arousal and valence (Codispoti & De Cesarei, 2007), shorter response times and higher accuracies (De Cesarei & Codispoti, 2006) for larger stimulus sizes. These effects might be due to a larger retinal size, indicative for a shorter distance between stimulus and observer (Loftus & Harley, 2005) and thereby prompting immediate action, or alternatively due to larger visibility of fine-grained details (De Cesarei & Codispoti, 2008).

In the current study, the face is possibly perceived as nearer to the observer and as more detailed than the body while in Meeren et al.'s experiment (2005) both face and body appear at equal distance, with a visibility advantage for the latter. Relative dominance in the percept might therefore be biased toward the emotion of the face in the current experiment while to the body in Meeren et al.'s study (2005).

Face-body emotion recognition differences

The claim we put forward before (de Gelder, 2006), that emotional body language is a less ambiguous signal than the expression of the face, seems to be in conflict with the current data and previous results, in which facial expressions presented in isolation were recognised better than (van de Riet et al., in press) or similar to (Meeren et al., 2005) bodily expressions.

Emotional body language might not, however, have the typical one-to-one relationship with specific emotions that has been assumed for basic facial expressions (e.g., Ekman, Friesen, & Ellsworth, 1972). In the current experiment, the actors expressing happiness were given a scenario that they were meeting an old friend after a long time. It is clearer from the body language than from the facial expression that someone is engaged in this kind of situation. However, as multiple bodily expressions can signify happiness, detecting happiness in a bodily expression becomes more difficult than detecting this emotion in the face, especially as cues such as movement are absent.

Face-body emotion processing differences

We did not see clear differences in emotional modulation (comparing fear and happiness) between face or body for the amygdala or fusiform gyrus in our former experiment (van de Riet et al., in press). This finding is corroborated by various other studies that show that the amygdala is not only activated more by fearful than neutral faces (Morris et al., 1998; Rotshtein et al., 2001) but similarly also more by fearful than neutral bodies (de Gelder et al., 2004; Hadjikhani & de Gelder, 2003). In addition, Sprengelmeyer et al.'s study (1999) showed that a patient with amygdala damage was not able to recognise fear expressed by face and body, while her performance for both the happy facial and bodily expressions was at ceiling.

However, Atkinson, Heberlein, and Adolphs (2007) showed that two amygdala lesion patients were not impaired in categorising static and dynamic pictures of fearful bodies and additionally, Peelen, Atkinson, Andersson, and Vuilleumier (2007) showed that emotional modulation of amygdala activity was present for happy but not for fearful dynamic bodily expressions.

Similarly, Stekelenburg and de Gelder (2004) also point to inherent differences as the amplitude of the N170 was modulated by the emotion of the face but not by the emotion of the body. However, it should be noted that these emotional face-body differences are more apparent than real. Similarly, for modulation of the N170 amplitude by facial expressions some studies do find effects (Batty & Taylor, 2003; Caharel et al., 2005; L.M. Williams et al., 2006), while others do not (Eimer & Holmes, 2002; Eimer, Holmes, & McGlone, 2003; Holmes, Vuilleumier, & Eimer, 2003; Schupp et al., 2004).

Whether the observed differences in the current data are due to differences between face and body in stimulus size, recognisability or processing by the brain needs to be further clarified. It is, however, clear from the present study that additional affective information is taken into account when the emotion of the face or the body has to be judged. Of interest, it seems that multiple factors can be instrumental in determining the relative weight of facial and bodily expressions in the whole percept. An issue, worth considering in further research.

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Brain function, emotional experience and personality

David L. Robinson

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

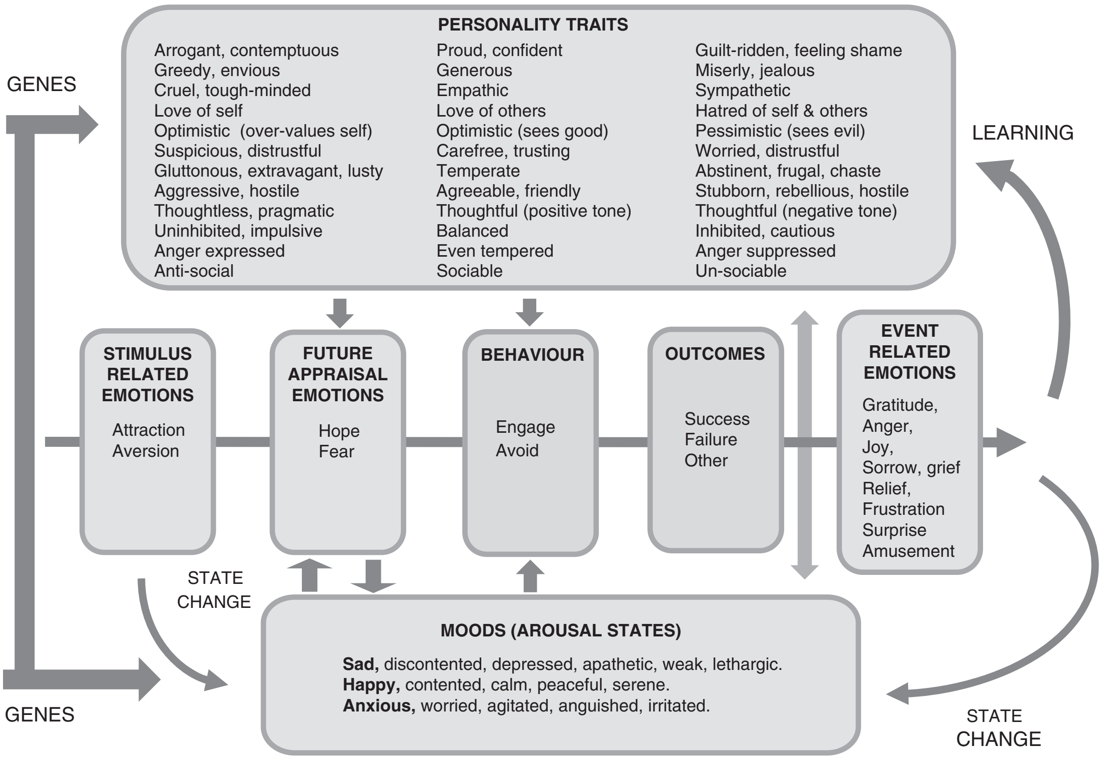


Figure 1
A general model for the dynamic interaction of basic emotions, mood states and personality traits.

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 succession 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.

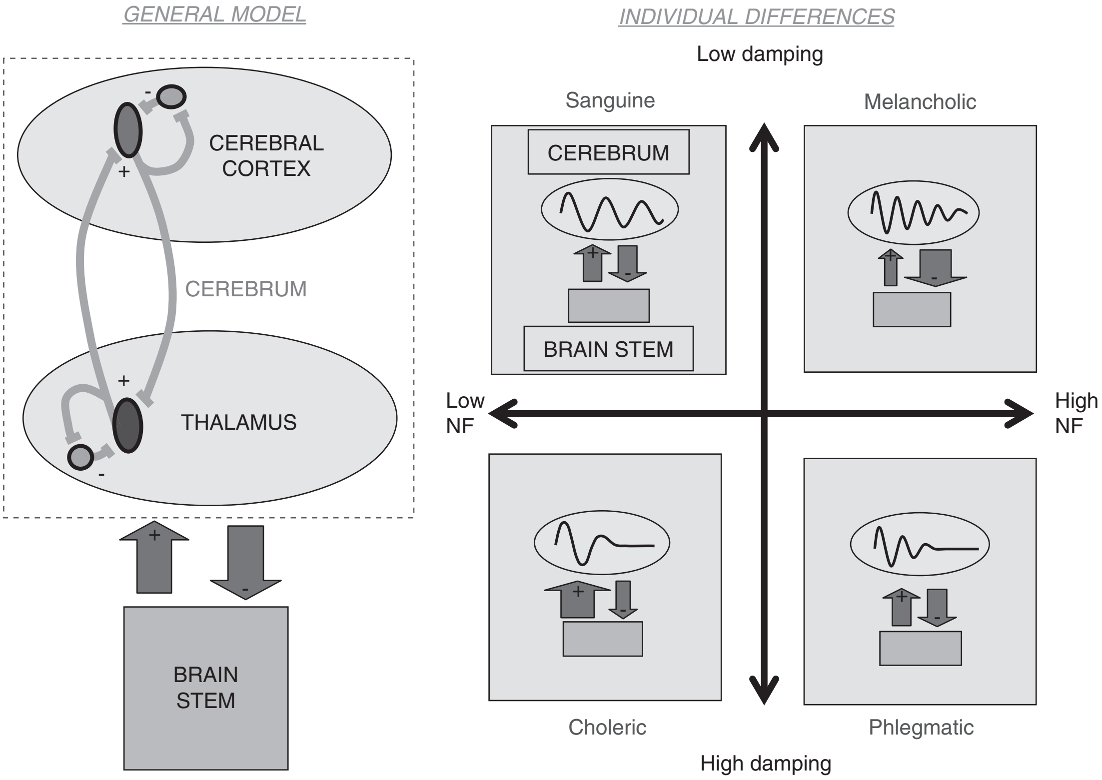
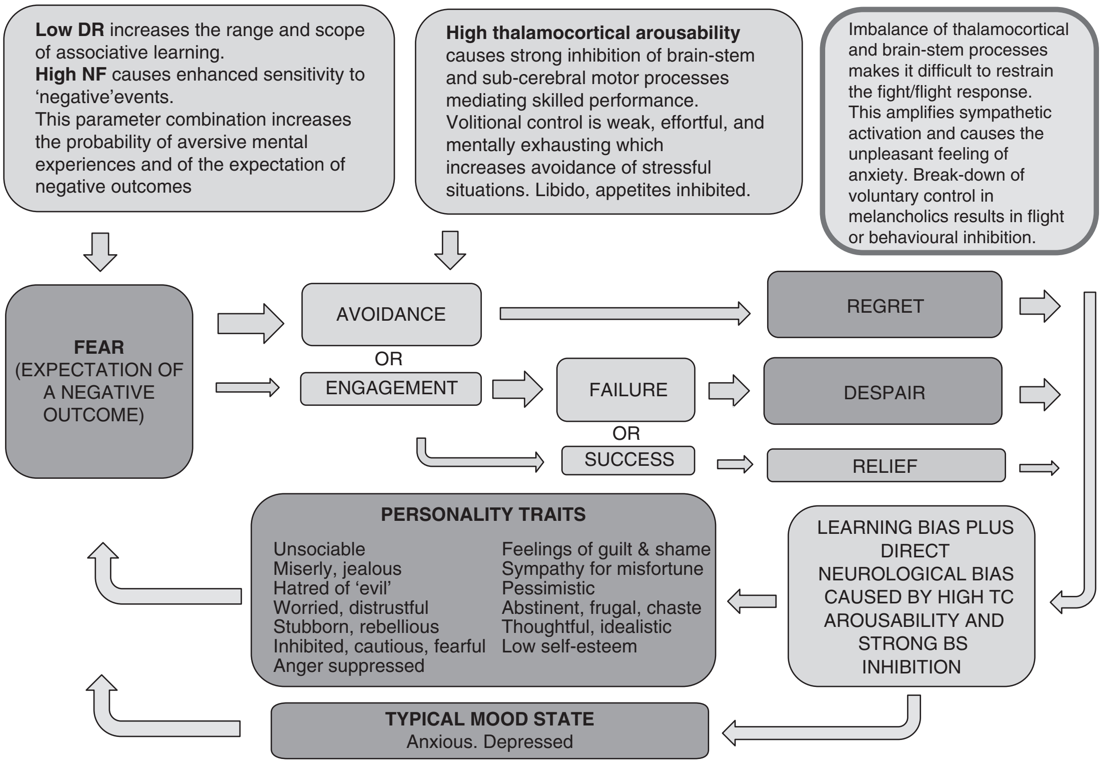


Figure 2
Differences in global brain function that result from differences in the natural frequencies and damping ratios of thalamocortical circuits.

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-



Low DR increases the range and scope of associative learning.
High NF causes enhanced sensitivity to ‘negative’events.
This parameter combination increases the probability of aversive mental experiences and of the expectation of negative outcomes

High thalamocortical arousability causes strong inhibition of brain-stem and sub-cerebral motor processes mediating skilled performance. Volitional control is weak, effortful, and mentally exhausting which increases avoidance of stressful situations. Libido, appetites inhibited.

Imbalance of thalamocortical and brain-stem processes makes it difficult to restrain the fight/flight response. This amplifies sympathetic activation and causes the unpleasant feeling of anxiety. Break-down of voluntary control in melancholics results in flight or behavioural inhibition.

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-

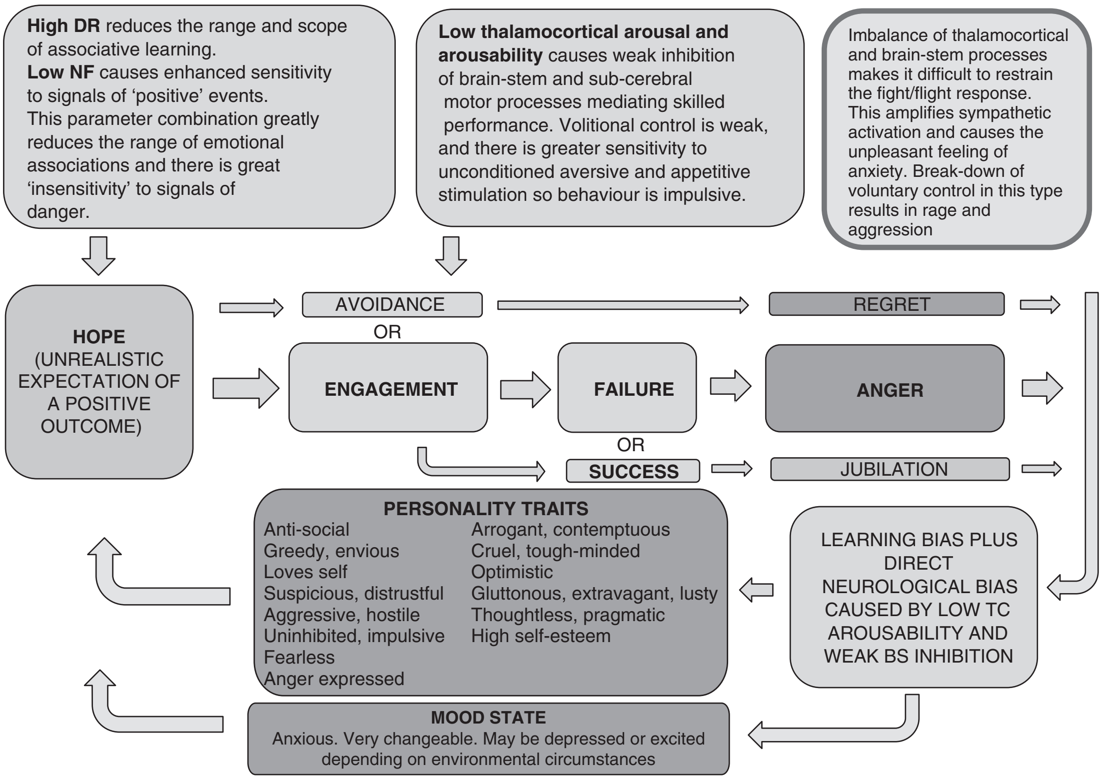


Figure 4

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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Processing of pleasant information can be as fast and strong as unpleasant information: implications for the negativity bias

Ingmar H.A. Franken, Peter Muris, Ilse Nijs and Jan W. van Strien

Several theoretical accounts state that negative or unpleasant information is processed 'faster' and activates more attentional resources than neutral and positive information. This notion is confirmed by several experimental studies. However, these studies did not employ equal values of emotional salience and arousal for positive and negative stimuli. In the present study we examine whether positive stimuli (erotic bodies) are processed as fast and strongly as negative information (mutilated bodies) when equally arousing, biologically relevant stimuli are used. Electrophysiological correlates of the processing of biologically relevant high-arousing emotional stimuli are studied using Event-Related Brain Potentials (ERPs). Results showed that both pleasant and unpleasant stimuli are processed fast and preferentially in the brain, within 100-200 ms after stimulus onset. These studies indicate that, on the electrophysiological level, pleasant stimuli are processed as 'fast and strongly' as unpleasant stimuli if arousal values of the stimuli are high. Implications of these findings for theories of emotion and psychopathology are discussed. *(Netherlands Journal of Psychology,* 64, 168-176.)

Keywords: emotion; negativity bias; ERP; attentional bias; emotional processing

Selective processing of emotional stimuli is a basic feature of our brain which is necessary to signal relevant stimuli in our environment. Once a relevant stimulus has been noticed it can be processed further, and behaviour can be adapted if necessary. The processing of emotional stimuli has been addressed in several studies using behavioural and physiological measures. For example, behavioural studies employing cue-target paradigms (Posner, 1980) show that emotional stimuli are able to capture attention automatically (e.g., Koster, Verschuere, Crombez, & Van Damme, 2005; Mogg & Bradley, 1998). In addition, Event-Related Potential (ERP) studies show that emotional stimuli are processed preferentially above non-emotional stimuli (e.g., Ito, Larsen, Smith, & Cacioppo, 1998; Schupp, Stockburger, Codispoti, Junghofer, Weike, & Hamm, 2007). Further, fMRI studies (Morris, Öhman, & Dolan, 1998) in which fearful stimuli are pre-

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sented at subliminal levels show that the processing of fearful stimuli in the brain can be executed very quickly. All these results are in line with theories suggesting that emotional stimuli automatically capture attention in a very fast and automatic way (Lang, Bradley, & Cuthbert, 1990; Öhman, 1997; Vuilleumier, 2005). Although there is a general consensus that emotional stimuli are processed preferentially above non-emotional stimuli, there are several important issues that need further investigation.

The first issue, and most relevant for the present study, is that several studies report that negative (unpleasant) stimuli are processed faster and 'stronger' than positive stimuli (pleasant stimuli; Baumeister, Bratslavsky, Finkenauer, & Vohs, 2001) and as such they are thought to have more impact on the brain (Ito et al., 1998), a phenomenon that has been labelled as the negativity bias (Crandall, 1975). From an evolutionary point of view, this makes sense: There must be an evolutionary preparedness for the very fast processing of threat stimuli (LeDoux, 1998; Öhman, 1997). It seems plausible that it would be more important to signal a threatening stimulus immediately (in order to make an avoiding motor reflex; e.g. the fast withdrawal of the foot when a snake is signalled in the woods) than to signal a pleasant stimulus (e.g., a sexual partner or food) very quickly. Although it is extremely important from an evolutionary point of view to signal and respond to pleasant stimuli, in most cases there is no necessity to do this within a fraction of a second.

Several ERP studies that make a comparison between the processing of pleasant versus unpleasant stimuli indeed suggest that the human brain has a selective sensitivity towards negative stimuli above positive and neutral stimuli (Carretie, Mercado, Tapia, & Hinojosa, 2001; Delplanque, Silvert, Hot, Rigoulot, & Sequeira, 2006; Ito et al., 1998; Smith, Cacioppo, Larsen, & Chartrand, 2003; Yuan et al., in press). Similarly, there is also some behavioural research examining the attentional processing of negative stimuli as compared with positive stimuli. For example, Pratto and John (1991) employed an emotional Stroop paradigm that included negative as well as positive words. In keeping with the above-described ERP studies, the results demonstrated an attentional bias for negative words, but no such effect for positive stimuli. Although all these studies seem to indicate that negative stimuli have more impact on the brain than positive stimuli, there are several caveats that should be studied in more detail before this notion can be generalised. First of all, it can be argued that prioritised processing of negative stimuli is primarily due to the typically low arousal levels that are associated with positive cues. Interestingly, Tipples and Sharma (2000) used a dot probe task to investigate attentional bias for affective stimuli and demonstrated that high-arousing pleasant stimuli do result in an attentional bias, which resembles the enhanced processing phenomenon as observed for negative, unpleasant stimuli. To summarise, most studies documenting the enhanced processing of negative relative to positive stimuli only use unpleasant stimuli and have not taken arousal levels of various stimuli into account. This research may typically have employed stimuli with low arousability features, which might explain the finding of the negativity-bias effect.

Further, it should be noted that the pleasant stimuli as used in previous research possess different contents to the pleasant stimuli that are typically employed. More precisely, whereas negative stimuli mainly consisted of biologically relevant threat pictures (attack situations, mutilations), positive stimuli seem to represent less biologically relevant themes (rollercoaster, sport cars or flowers). As there is clear evidence that biologically relevant stimuli result in enhanced neurophysiological processing and attentional biases in healthy subjects, and are differentially processed in distinct neural networks as compared with non-biologically relevant stimuli (Anokhin, Golosheykin, Sirevaag, Kristjansson, Rohrbaugh, & Heath, 2006), it seems important to take this feature into account in studies comparing the processing of negative and positive stimuli.

The second issue pertains to the question whether the selective processing of emotional stimuli is only a feature of clinical patients or whether it is also present in normal populations. Of course, attentional biases are a hallmark of anxiety psychopathology, and there are many studies showing that patients with an anxiety disorder such as spider phobia, social phobia or post-traumatic stress disorder display a preferential processing of threat-related stimuli (Bar-Haim, Lamy, Pergamin, Bakermans-Kranenburg, & van Ijzendoorn, 2007; McNally, 1998). However, there is also research suggesting the presence of a processing bias in healthy subjects, but only in persons displaying high levels of trait anxiety (Koster et al., 2005). In contrast, when looking at research that goes beyond behavioural measures, such as ERP and fMRI studies, it becomes clear that an enhanced processing of emotional stimuli is a common feature which is also present in healthy subjects.

In the present study we employed high-arousing pleasant stimuli (erotic bodies) and high-arousing negative stimuli (mutilated bodies), with both having biological relevance in order to keep aspects beyond valence as similar as possible. Note that these two categories have similar physical properties, both categories display humans in a social setting and display simple perceptual features: bodies or parts of bodies. Electrophysiological (ERP) indices will be employed in a population of healthy individuals to investigate the processing of pleasant and unpleasant stimuli.

ERPs are particularly suited to study the temporal characteristics of the selective processing and may reveal differences at various stages between emotional and neutral stimuli. In addition, because there is information on the localisation of specific ERP components, this methodology provides us with information on neural correlates associated with biased processing. In the present study we will investigate early stages of processing using the Early Posterior Negativity (EPN) component. It is known that emotional stimuli yield a negative-going potential at posterior regions starting 100-300 ms (EPN) after stimulus onset (reduced positivity), which is thought to originate from the extra-striate cortex (Pourtois, Thut, Grave de Peralta, Michel, & Vuilleumier, 2005; Schupp, Stockburger, Bublatzky et al., 2007). This EPN represents the perceptual encoding phase at which stimuli are selected for enhanced processing (Schupp, Stockburger, Codispoti et al., 2007). Later stages of stimulus processing are measured using the Late Positive Potential (LPP) which is a P3-like wave capturing the elaborative stimulus evaluation. This index of processing emerges 300-400 ms after stimulus onset and can stay present for several seconds (Cuthbert, Schupp, Bradley, Birbaumer, & Lang, 2000). Several studies show that both early and late ERP components can be modulated by attentional demands (Schupp, Stockburger, Codispoti et al., 2007). Research addressing the neural origin of this enhanced positive slow wave shows that it represents activity in a network of visual cortical structures such as the lateral occipital, inferotemporal, and parietal visual areas (Sabatinelli, Lang, Keil, & Bradley, 2007).

The main goal of the present study was to investigate whether pleasant and unpleasant information is processed in similar ways, on perceptual and elaborative processing levels. For this purpose, non-clinical subjects were exposed to high-arousing, biologically relevant positive and negative stimuli as well as neutral stimuli. It was expected that both negative and positive stimuli would be processed preferentially as compared with neutral stimuli.

Methods

Participants

Participants were 41 undergraduate students (25 females) from Erasmus University Rotterdam. The average age was 20.3 years (*SD* = 3.1). The participants received course credits for their participation.

Stimuli and experimental paradigm

Sixty colour pictures (20 neutral, 20 high-arousing pleasant, and 20 high-arousing unpleasant slides[1]) were selected from the IAPS (Lang, Bradley, & Cuthbert, 1999). Neutral pictures consisted mainly of household objects, unpleasant pictures consisted of mutilated bodies, and pleasant pictures consisted of erotic couples. Pleasant and unpleasant stimuli were selected on the basis of standardised valence and arousal ratings (Lang, Bradley, & Cuthbert, 1999). According to the normative data, mean arousal ratings of the neutral, pleasant and unpleasant stimuli were 2.4 (*SD* = 0.48), 6.4 (*SD* = 0.36) and 6.5 (*SD* = 0.59), respectively. An ANOVA demonstrated significant differences between the arousal ratings for each category, $F = 452.4$, $p < 0.001$. Bonferroni post-hoc tests indicated that there were no significant differences between the arousal ratings for the pleasant and unpleasant pictures ($p = 1.0$). As expected, both pleasant and unpleasant pictures yielded higher arousal ratings than neutral pictures ($p < 0.001$). Mean valence ratings of the neutral, pleasant, and unpleasant stimuli were 5.0 (*SD* = 0.25), 6.8 (*SD* = 0.33) and 1.7 (*SD* = 0.31) respectively. An ANOVA also revealed significant differences between the valence ratings for each category $F = 1487.6$, $p < 0.001$. As expected, pleasant pictures had higher valence scores than neutral pictures ($p < 0.001$), which in turn had higher valence scores than unpleasant pictures ($p < 0.001$). All pictures were presented for 1500 ms in blocks of five pictures per stimulus category, occupying about 5° of horizontal visual angle. Each block was presented twice, resulting in 120 stimulus presentations. Blocks were presented semi-randomly, with the restriction that no blocks of the same category were presented subsequently. The interstimulus interval was 2500 ms.

Procedure

Upon arrival, participants were instructed about the procedure and signed informed consent. After this, participants filled out the questionnaires. Subsequently, subjects were seated in a comfortable chair in a light- and sound-attenuated room. First, participants conducted a cognitive decision-making task (10 minutes; not reported in this paper). Then they performed the IAPS picture task. Stimuli were presented on a 21″ monitor 1.5 metres away from the participant. Participants were instructed to pay close attention to the pictures that would be presented. To be sure that they paid attention to the pictures they were told that questions about the pictures could be asked after the experiment. Approval was obtained from the local ethics

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[1] *The IAPS pictures were: Neutral: 7175, 7010, 7004, 7020, 7950, 7040, 7000, 7150, 7080, 7006, 7491, 7090, 7110, 7031, 7100, 7217, 5740, 7035, 7096, 7050; Pleasant: 4650, 4660, 4680, 4687, 4689, 4690, 4607, 4608, 4611, 4653, 4656, 4658, 4659, 4670, 4681, 4810, 4672, 4666, 4652, 4800; Unpleasant: 3000, 3010, 3030, 3051, 3060, 3061, 3062, 3063, 3064, 3071, 3080, 3130, 3150, 3168, 9253, 3100, 3102, 3110,3053, 3120.*

committee of the Institute of Psychology and the experiment was in accordance with international ethical guidelines.

Electroencephalographic (EEG) recording and signal processing

ERPs were recorded by means of a Biosemi Active-Two amplifier system from 64 scalp sites (10-20 system) using Ag/AgCl electrodes (active electrodes) mounted in an elastic cap. In addition, six additional electrodes were attached to the left and right mastoids, the two outer canthi of both eyes (HEOG), and the infraorbital and supraorbital regions of the eye (VEOG). Online signals were recorded with a low pass filter of 134 Hz. All signals were digitised with a sample rate of 512 Hz and 24-bit A/D conversion. Data were re-referenced off-line to an average reference. EEG and EOG activity was filtered off-line with a bandpass of 0.01-30 Hz (phase shift-free Butterworth filters; 24dB/octave slope). Data were segmented in epochs of 1300 ms (200 ms before and 1100 ms after response). After ocular correction (Gratton, Coles, & Donchin, 1983), epochs including an EEG signal exceeding ± 75 µV were excluded from the average. The mean 200 ms period before the stimulus presentation served as baseline. After baseline correction, average ERP waves were calculated for the neutral, pleasant and unpleasant stimulus conditions. The resulting ERP waves were visually inspected and appeared to correspond well with ERP waves usually reported in response to visual emotional stimuli (see Figures 1A and 2A). The mean number of artifact-free segments for the neutral, pleasant and unpleasant conditions was 29.3, 31.0, and 30.9 respectively (minimum = 18). Mean activity of the EPN (100-300 ms time window), and the LPP (400-1000 ms time window) were used as measures of early and late emotional processing, respectively. For the EPN, the effects were most pronounced at the O1 and O2 electrodes, and for the LPP at CPz1 and CPz2. This is in accordance with previous research (Schupp, Junghoefer, Weike, & Hamm, 2003b, 2004), and consequently these electrodes were selected for the statistical analysis.

Data analysis

First, we examined differences in emotional processing of the stimuli for each component (i.e., EPN and LPP) by means of a 3 (Emotion: neutral vs. pleasant vs. unpleasant) x 2 (Hemisphere: left vs. right) x 2 (Time window: early vs. late) repeated measures ANOVA. For the EPN the early time window was 100-200 ms and the late one was 200-300 ms (Figure 1B). For the LPP, the early time window was 400-700 and the late one was 700-1000 ms (Figure 2B). Significant effects were further analysed using Bonferroni-corrected post-hoc *t*-tests. Because we were only interested in Emotion-relevant interaction effects, we only report effects that included this factor.

Results

EPN

A main effect of Emotion was observed, $F(2, 80) = 32.6$, $p < 0.001$. Post-hoc tests revealed that pleasant ($M = 4.2$) and unpleasant stimuli ($M = 5.1$) yielded smaller (= larger EPN) amplitudes as compared with neutral stimuli ($M = 6.6$, both *p*s < 0.001). Furthermore, pleasant stimuli yielded larger EPN amplitudes as compared with unpleasant stimuli ($p < 0.05$). A significant interaction effect of Emotion x Time was also observed $F(2, 80) = 30.1$, $p < 0.001$. Post-hoc tests showed that during the first EPN time window (100-200 ms) there was a difference (neutral > emotional; suggesting a larger EPN for emotional stimuli) between neutral versus pleasant stimuli ($p < 0.001$), and a difference between neutral versus unpleasant ($p < 0.001$), with no difference between responses to pleasant and unpleasant stimuli. However, during the second time window (200-300 ms) pleasant stimuli yielded larger EPN amplitudes as compared with unpleasant stimuli ($p < 0.001$; see Figure 1B). In addition, an Emotion x Hemisphere x Time effect emerged, $F(2, 80) = 4.1$, $p < 0.05$. This effect was similar (for both hemispheres) to the Emotion x Time effect as described above, the only difference was that in the first time window (100-200 ms) unpleasant stimuli yielded larger EPN amplitudes as compared with neutral stimuli in the left hemisphere ($p < 0.001$), this effect was not present in the right hemisphere.

LPP

For the LPP, a main effect of Emotion was observed, $F(2, 80) = 69.1$, $p < 0.001$. Post-hoc tests revealed that pleasant ($M = 5.9$, $p < 0.001$) and unpleasant stimuli ($M = 5.5$, $p < 0.001$) yielded larger LPP amplitudes as compared with neutral stimuli ($M = 2.5$). No difference was observed between pleasant and unpleasant stimuli. In addition, an Emotion x Time interaction effect was observed $F(2, 80) = 5.5$, $p < 0.01$. However, post-hoc tests did not reveal a significant effect of time over and above the above-described effect of Emotion. Accordingly, the Emotion x Time effect of the LPP will not be discussed further.

Discussion

As expected, this study demonstrated that, in an early stage (100-300 ms), pleasant and unpleasant information is preferentially processed over neutral information. Moreover, pleasant stimuli yielded an enhanced EPN as compared with unpleasant stimuli in the second part of this stage

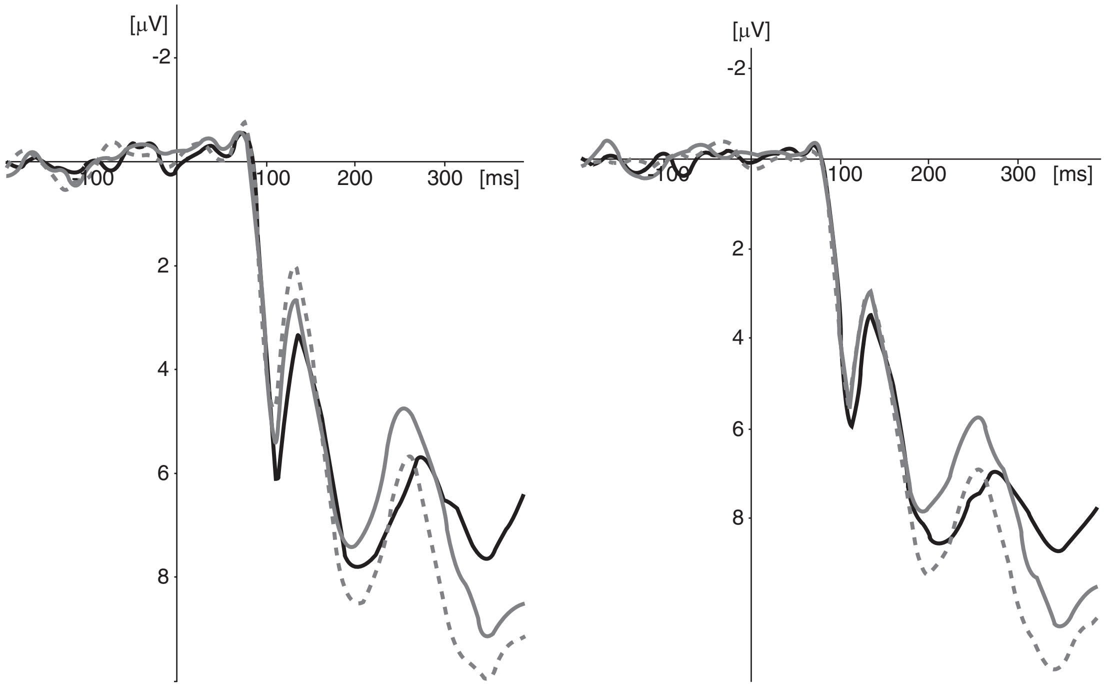

Figure 1A
EPN (100-300 ms) waves to neutral (black lines), pleasant (solid grey lines) and unpleasant pictures (dashed grey lines) at O1 (left panel) and O2 (right panel).

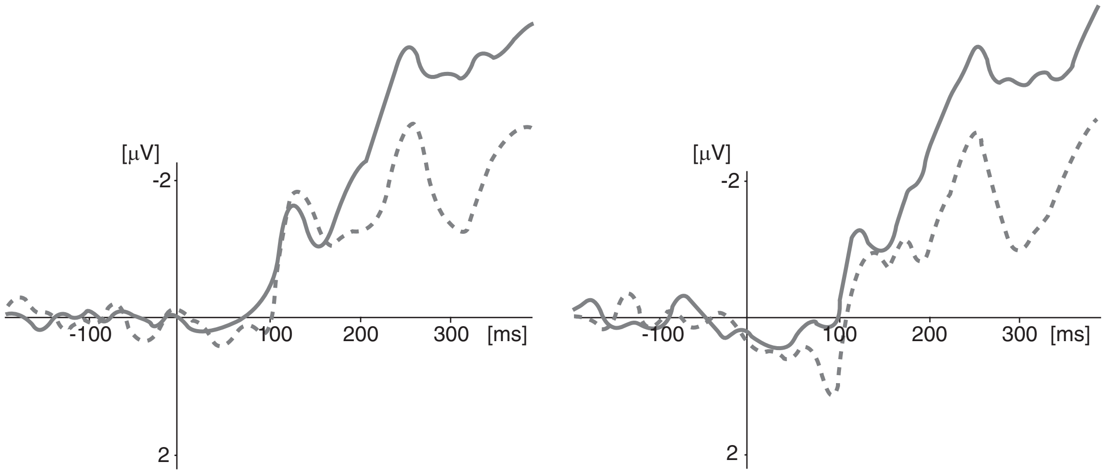

Figure 1B
EPN difference waves (emotional – neutral) to pleasant (solid grey lines) and unpleasant pictures (dashed grey lines) at O1 (left panel) and O2 (right panel).

(200-300 ms), suggesting that in this stage there is even a preferential processing of high arousing pleasant stimuli above high arousing unpleasant stimuli. Note that this difference is not the result of differences in arousability of the stimuli. According to the normative data of the IAPS, unpleasant and pleasant pictures had similar arousal ratings. As the EPN represents the perceptual encoding phase at which stimuli are selected for further processing, this result suggests that both high arousing pleasant and high arousing unpleasant information yields enhanced perceptual encoding and selection.

Further, analysis of the later ERP component, the LPP, revealed that pleasant and unpleasant information are preferentially processed above neutral information. As the LPP represents an elaborative stimulus evaluation, the results suggest that both high arousing pleasant and high arousing unpleasant stimuli are more extensively evaluated than neutral stimuli. This has been observed in several other studies (e.g., Schupp, Cuthbert, Bradley, Hillman, Hamm & Lang, 2004). Most importantly, the LPP to unpleasant pictures was not different from the LPP to pleasant pictures. This is not in keeping with the negativity bias theory which suggests that unpleasant stimuli have more impact on the brain than pleasant stimuli.

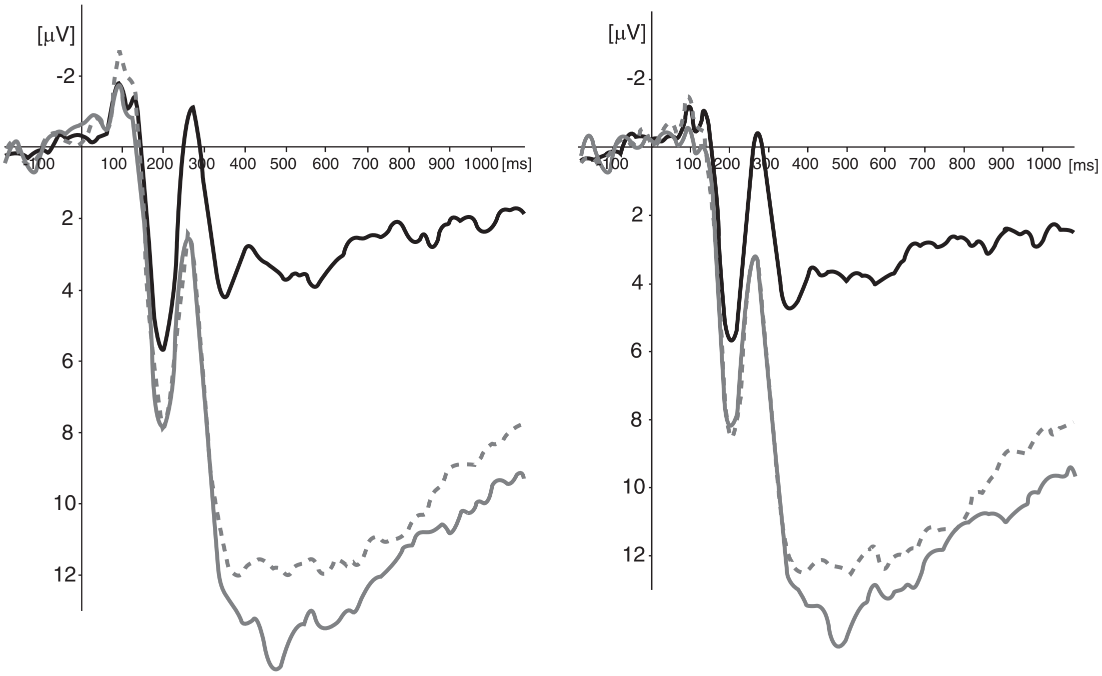

Figure 2A
LPP (400-1000 ms) waves to neutral (black lines), pleasant (solid grey lines) and unpleasant pictures (dashed grey lines) at CP1 (left panel) and CP2 (right panel).

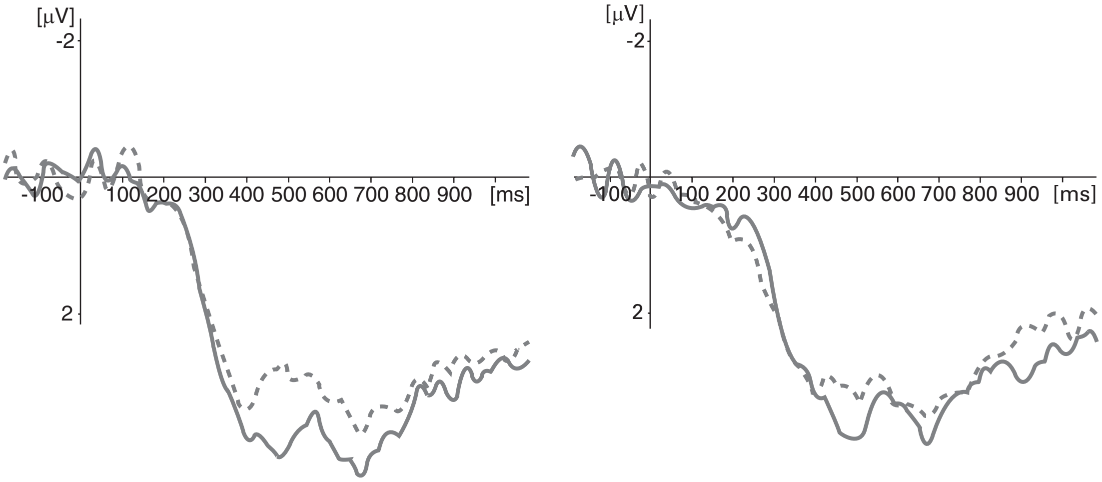

Figure 2B
LPP difference waves (emotional – neutral) to pleasant (solid grey lines) and unpleasant pictures (dashed grey lines) at CP1 (left panel) and CP2 (right panel).

This study suggests that during the early perceptual and attentional stages of processing, there is no preferential processing of negative information over positive information when one controls for arousal levels and biological relevance of the stimuli. As such, we did not find evidence for the 'negativity bias' notion which suggests that there is an evolutionary evolved mechanism in the human brain facilitating a rapid and intense response to aversive events. Instead, the present research suggests that high arousing pleasant and high arousing unpleasant information has equal impact on stimulus processing. Note that we do not suggest that there is no negativity bias in other psychological functions. We only demonstrated that the processing of high arousing pleasant information in the human brain at an initial, basic level is not different from the processing of high arousing unpleasant information. It might be that during later stages of processing, negative information is preferentially processed above positive information; for example, a recent study by Hajcak and Olvet (2008) found that at later stages of processes (>1000 ms) there was a persistence of increased attention (enhanced LPPs) after unpleasant compared with pleasant stimuli which is consistent with the existence of a negativity bias at later stages. Further, the present findings do not rule out the possibility for the presence of a negativity bias for low arousing stimuli.

Several studies have shown that one important neuroanatomical substrate of fast perceptual and attentional processing is the amygdala. There is strong support for the notion that the amygdala is involved in the affective enhancement of activation in the visual cortex (Vuilleumier, 2005; Vuilleumier & Driver, 2007). The present results are in line with the idea that the amygdala is involved in the processing of salient information, either positive or negative (Sander, Grafman, & Zalla, 2003). Several studies have demonstrated that the amygdala is involved in the processing of both unpleasant and pleasant information. Furthermore, the present results are in concordance with appraisal theories of emotion (e.g., Lazarus, 1991) which suggest a quick mechanism in which the brain distinguishes between neutral and emotional information, regardless of whether this information is positive or negative, and devotes more attentional resources to emotionally relevant information.

The present findings are also in concordance with previous studies using biologically relevant stimuli such as erotic and mutilated bodies (Schupp, Junghoefer, Weike, & Hamm, 2003a; Schupp, Stockburger, Codispoti et al., 2007). In these studies it was found that the early posterior ERP activity (the EPN component) was more pronounced for erotica than for mutilated bodies. In the later stage (LPP) Schupp et al. did not observe ERP differences between arousing pleasant and unpleasant stimuli, which is in agreement with the present findings. The observation that high-arousing pleasant stimuli elicit an early differential ERP activity which is larger than unpleasant stimuli is in contrast with the 'negativity bias' theories and as such undermines the notion that negative information is processed faster. Early posterior electrophysiological activity beginning 100 ms after stimulus presentation represents perceptual processing (VanRullen & Thorpe, 2001; Vuilleumier, 2005) and originates in the extrastriate cortex (Schupp, Stockburger, Bublatzky et al., 2007). It must be noted that the possibility cannot be ruled out that negative information such as subliminally presented fearful faces differentially activate neural structures even earlier (<100 ms) in the time course of visual processing (e.g., the amygdala, Morris et al., 1998; Vuilleumier, Richardson, Armony, Driver, & Dolan, 2004). To our knowledge, there have been no studies on whether high-arousing pleasant stimuli are also able to influence these very early (<100 ms) brain responses. Whether this is true for positive information awaits further research.

Concerning the lateralisation of the emotional processing, we observed largely the same results for left and right hemisphere. There was one exception, unpleasant stimuli yielded smaller amplitudes (= larger EPN) as compared with neutral stimuli in the left hemisphere. This effect was not present in the right hemisphere. This finding is difficult to explain since it has not been reported before as far as we know, and should be interpreted with caution since we also found an overall effect over both left and right hemisphere. The effect that was found in the left hemisphere just failed to reach significance in the right hemisphere. Therefore, we suggest that this finding needs replication before drawing firm conclusions.

The present finding that both pleasant and unpleasant stimuli are preferentially processed above neutral stimuli is also in line with studies that examined emotion processing at later processing stages (i.e. motor output systems). Using transcranial magnetic stimulation (TMS) and electromyography (EMG), Hajcak, Molnar, George, Bolger, Koola, & Nahas (2007) showed that viewing arousing stimuli, regardless of valence, increased motor cortex excitability. Also using TMS, Baumgartner and colleagues (2007) found no differences between Motor Evoked Potentials (MEPs) obtained during the presentation of emotional stimuli of different valence.

The present study has several limitations. First, we did not obtain self-reported valance and arousal values for the IAPS pictures. It might be that the self-reported ratings differ from the normative IAPS ratings. Although there might be some variation between self-reported data and normative data, it is unlikely that there are large differences between these two measures. Second we used only two categories of biological relevance: erotic and mutilated bodies. Other biologically relevant stimuli (e.g., social nonverbal communication, responding of others to threat cues) might be less straightforward than the stimuli we employed. Therefore, the results cannot be generalised to all biologically relevant stimuli. Third, it cannot be ruled out that the ERP findings are the result of differences in physical stimulus properties such as luminance differences or differences in colour; in particular the EPN is sensitive for these differences (Schupp, Flaisch, Stockburger, & Junghofer, 2006). However, we tried to keep the physical stimulus properties of pleasant and unpleasant stimuli as similar as possible by using human bodies on both occasions. Further, it is likely that small differences in physical stimulus properties such as luminance are randomly distributed in each category. Fourth, although it was not a goal of the present study, we were not able to examine gender differences because of the relatively low proportion of males in our sample. It is known that there are gender differences in emotional processing, and it would be interesting to examine these differences in future studies.

Overall, the results are in line with theories posing that individuals automatically pay attention to emotional stimuli, regardless of the valence of these stimuli (Lang, Bradley, & Cuthbert, 1990, 1997). This has implications for categorical explanations of psychopathology which state that an attentional bias is specific for clinical populations and threatening cues (Bar-Haim et al., 2007). All studies so far that employed high-arousing pleasant stimuli did show early processing preference of the brain for this category of stimuli. This suggests that attentional processing is a function of arousal properties of the stimulus and trait levels of emotional functioning of the subject.

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Sex differences in social and mathematical cognition: an endocrine perspective

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At the upper end of spectrums, males outperform females in mathematical cognition (i.e., processing information relevant for understanding the physical world) and females outperform males in social cognition (i.e., processing information relevant for understanding the social world). To be precise, sex differences in thinking about physical problems are observed in top-tier scientific environments, whereas sex differences in thinking about social problems are observed under more interpersonal, empathetic circumstances. One idea is that these differences are due to biologically based cognitive capacities that would differ between males and females. Here we would like to challenge this view and argue that biologically based motive drives principally underlie disparity in mathematical and social ability between the sexes. These motive drives are produced by the sexually dimorphic neuroendocrine system, and presently we highlight the role of the gonadal hormone testosterone. Testosterone is omnipotent in all sex differences in brain and behaviour, first because this male type hormone by itself and by way of its metabolite, the female type hormone oestradiol, builds both male and female brains. Moreover, testosterone influences our motive drives in such a way that we want to understand the mechanical world and the hormone improves performance under highly challenging conditions. Finally, testosterone conveys no affiliative motives or motives to understand people as its affinity with sociality purely depends on sex, money or status. The largest hormonal difference between the sexes is observed for testosterone, thus the hormone's specific motivational properties may well explain sex differences in mathematical and social cognition. (*Netherlands Journal of Psychology*, 64, 177-183.)

Keywords: mathematical cognition; social cognition; sex differences; stereotypes; testosterone; motivation

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Worldwide, the academic faculties of universities in the fields of mathematics and science are overwhelmingly male. It has been suggested that fewer women are employed in mathematics and science faculties because women have less built-in aptitude for mathematical cognition. Males and females would be differentially predisposed, with male children more easily grasping mathematical information about objects and their mechanical relationships, whereas female infants more easily grasp social information about people, their emotions, and personal relationships. Males accordingly have cognitive systems that allow effective reasoning in mathematics (Baron-Cohen, 2003).

In a notable review, Spelke (2005) suggests that these claims are mistaken because infants show few cognitive sex differences, and male advantages in the processing of objects, space, or number are unproven. Spelke observes differences between the performance of males and females on certain cognitive tasks in adulthood, but there is no evidence for sex differences in overall aptitude for mathematical cognition at any point in development. Finally, research in highly talented students reveals some disparities in performance on speeded tests of quantitative reasoning, but abilities for mathematical cognition do not differ between the sexes (Spelke, 2005). Although these observations are compelling, the critical question remains unanswered: why do males outperform females on mathematical cognition at the upper end of the spectrum, in top-level sciences? Alas, Spelke escapes this question by explicitly not considering sex differences in 'human preferences, motives, attitudes, temperament, and decisions' (Spelke, 2005, page 950). In doing so, her account seems to be about ability to perform in the psychological laboratory rather than about true performance in real life or under challenging and threatening conditions. The ecological validity of her theory and arguments is therefore questionable, because motivation and other affect-related processes can underlie many performance domains.

Accordingly, Spelke may have misread Baron-Cohen (2003), who proposes that biological predispositions make males, on average, better in thinking analytically, or systemising (mathematical cognition) whereas females are better in empathising and processing information about social interaction, a process central to the study of social cognition. Baron-Cohen does not talk about cognitive capacities in Spelke's terms but argues that the motive or drive to identify another's mental states underlies superior empathising. In the same manner, excellence in mathematical reasoning is brought about by a biologically built-in motive drive to obtain knowledge about objects and their relationships. Much confusion exists about sex differences in mathematical and social intelligence. This may result from misunderstandings of the workings of endocrine mechanisms and evolutionary, neurobiologically and functionally mistaken notions of the interdependencies between motivation and cognitive capacities. These misunderstandings offer a breeding ground on which stereotypical thoughts and misguided scientific reasoning on mathematical and social cognition come to flourish.

In this perspective, we aim to elaborate on these relations by highlighting the role of the gonadal hormone testosterone. The largest hormonal difference between the sexes is observed for testosterone. Thus the hormone's specific motivational properties may help to explain sex differences in performance of mathematical and social cognition. Moreover, existing social stereotypes about sex differences in ability in mathematics and social cognition may persist, as testosterone motivates performance in these two fundamental domains differently under conditions of status-related challenge and threat that results from the stereotypes. Thus, by providing a better understanding of the role of testosterone in sex differences in mathematical and social cognition we hope to open new insights into how such differences emerge and to nail down the existence of the stereotypes we have about them.

Mathematical cognition

In 2005, Harvard University president Laurence Summers was heavily criticised for suggesting that innate differences in mathematic ability distinguish the sexes at the upper end of the performance spectrum in science. His arguments concerning the innate quality of females' biological disadvantage were unfounded, but reached the status of a media feeding frenzy which can potentially work as a self-fulfilling prophecy for this notorious sex stereotype. Whether or not Summers was politically incorrect, we are still waiting for an explanation for sex differences in performance in mathematical cognition at the upper end of the scientific spectrum. In this paper we argue that much of the variance associated with sex differences in mathematical cognition is mediated by the hormone testosterone, and therefore unlikely to be cognitive-intellectual in nature but rather motivational in origin. Misconceptions regarding the interrelations between motivation and cognitive abilities, together with a misunderstanding of the function of the reproductive axis, prevent scientific progress in the field. Throughout history, diverging testosterone levels have played an essential role in the formation and maintenance of female submission and male dominance (Niculescu & Akiskal, 2001). Although in modern societies the functionality of this sex-type social hierarchy is severely attenuated, the hormone keeps on sending the ancient message in us that produces sex-linked feelings and thoughts of competence and incompetence when dealing with challenges and threats (Josephs, Newman, Brown, & Beer, 2003).

Take, for example, the following study from our laboratory (Aleman, Bronk, Kessels, Koppeschaar, & van Honk, 2004) on mental rotation, one of the most difficult forms of spatial cognition. Testosterone levels of healthy young women were temporarily elevated to the levels of males by way of a single 0.5 mg administration of testosterone in a placebo-controlled study, which resulted in improved learning performance on mental rotation. Typically, such behavioural effects are attributed to testosterone-induced changes in cognitive or intellectual ability. However, although superior performance in complex forms of cognition unmistakably relates to testosterone (Postma, Meyer, Tuiten, van Honk, & Koppeschaar, 2000), one should distinguish carefully between *ability* and *performance* in light of the neurobiological evidence which suggests that the hormone targets cognition primarily by way of motivation (van Honk et al., 2004).

When faced with the challenge of having to perform an intellectual task, a person's performance has been shown to depend critically on two factors: (1) baseline levels of testosterone, and (2) whether one was in a low or high status role in the domain of the task. Specifically, challenges to one's status have been shown to evoke thoughts and feelings of inferiority or superiority, depending on one's testosterone level. Importantly, as a result of these testosterone- and status-related thoughts and feelings, subsequent intellectual performance either suffered or benefited (Josephs et al., 2003; Josephs, Sellers, Newman, & Mehta, 2006). These data suggest that lower testosterone levels may be viewed as a biological proxy for submissiveness, whereas higher levels may be viewed as a proxy for dominance (Wingfield, Hegner, Dufty, & Ball, 1990).

A recent article by Newman, Sellers and Josephs (2005), published in Hormones and Behavior, opened Pandora's box by letting *the mind deceive the brain*. Individuals with high levels of testosterone were psychologically manipulated into an inferior submissive position, and - strikingly - their performance on a test of spatial ability dropped to a level well below that of the low testosterone subjects.

From the same group, a study revealed the devastating power of the sex stereotype itself on intellectual performance (Josephs et al., 2003). In a mixed-sex university population, all of whom were selected for being highly motivated to excel at mathematics, math performance was assessed. Theorising from the notion that testosterone levels influence behaviour only under condition of status challenge or threat (Wingfield et al., 1990), the authors demonstrated that social stereotypes about sex differences in math abilities affected performance on a math task differently for men and women. Specifically, the positive stereotype about male mathematic abilities (i.e., an expectation of success) *improved* performance among high testosterone males as a result of experiencing a challenge to further enhance the higher status position, whereas negative stereotypes about female mathematical abilities (i.e., an expectation of failure) turned challenge into threat of status for high testosterone females resulting in decreased performance (see Schmader, Johns, & Forbes, 2008, for possible mechanisms by which threat may impair such performances). Under conditions of low baseline levels of testosterone, nothing happened in terms of threat and performance. This indicates that stereotype-hormone interactions can increase sex differences in *scientific performance* associated with biologically based motive drives without the involvement or alteration of cognitive or *intellectual ability*.

A compelling thought that generalises from these data is to argue that high testosterone women, especially those few who find themselves at the highest levels of the academic spectrum, constantly face a battle not only with the Laurence Summers' of the world but also with their own inner voice of doubt and inferiority created by the threat that their own strong desire for high status does not match with a world that sees them as unsuitable for such positions. Comparably, high testosterone males not only feel superior in these high status positions, but also confirm the scientific community's beliefs in the notion of exceptional innate intellectual cognitive qualities associated with the male of the species.

When holding in mind that testosterone has clear reward-sensitivity enhancing and punishment-sensitivity reducing properties (e.g., van Honk et al., 2004), one can see how sex stereotypes are preserved. Superior performance of high testosterone (always male) rodents in spatial environments is typically explained in terms of superior cognitive ability (Jonasson, 2005). However, to get the animal to act in the environment, rewards need to be applied, and high testosterone rodents arguably yearn for rewards. Their superior spatial performance can be explained in terms of motivation (Newman et al., 2005).

A motivational hypothesis will enjoy confirmation when a shift in the motivational properties of the task from reward to punishment results in more punishment-sensitive animals (namely, lower testosterone—almost always female rodents) becoming the better performers (cf. van Honk et al., 2004). If animals with relatively lower testosterone levels learn faster in punishing spatial environments, their superior performance could be explained in terms of motivation (i.e., coping with anxiety and potential threat) with no reference to cognitive or intellectual ability. Importantly, recent data on attention orienting show that in humans punishment and reward-related motivations improve spatial cognition (Engelmann & Pessoa 2007).

In sum, testosterone may mediate sex differences in mathematical cognition at the upper end of the spectrum in part because the hormone motivates one to understand the nonsocial world (Baron-Cohen, 2003), but primarily because under conditions of threat or challenge the hormone motivates the individual to learn under specific reward contingencies. In line with the challenge hypothesis, coping with challenge is rewarding for individuals with high levels of testosterone, but is of little help to performance in social cognition because social cognitive processes generally occur automatically and effortlessly (Dijksterhuis, Chartrand, & Aarts, 2007).

Social cognition

Outstanding performance in parsing the social world has been argued to importantly underlie the evolutionary success of humans (Kringelbach & Rolls, 2003). However, in modern societies social intelligent abilities are much less appreciated than mathematical abilities. The intelligent quotient (IQ) and not emotional quotient (EQ) is the golden standard and parents even tend to be proud of socially retarded autistic children with some excellent mathematic abilities. The term standardly used for this social deficit is 'high-functioning' autism, which is a pretty odd concept for an evolutionary relapse.

This seemingly positive stereotype regarding autism again works out negatively for females because autism is observed primarily in the male population. Crucially, in Baron-Cohen (2003), high levels of foetal testosterone masculinise the brain and predispose the individual for autism. Excellence in parsing one's social world—in essence, high performance in social cognition—enabled humans to communicate and cooperate and live together in peace in very large groups. Herein, females take the lead because they are better in automatically and effortlessly reading other people's minds and responding appropriately (Baron-Cohen, 2003). Indeed, sex differences have been observed in emotion recognition, social communication and mind reading. There is increasing interest for these sex differences in social cognition research. Evolutionary arguments have been proposed for this female superiority. One idea is that historically, females migrated to the social group of their mate, whereas males remained in their birth group. Females therefore were forced to form social alliances with non-kin (Geary, 2002).

Baron-Cohen (2003), as mentioned above, proposes that on average, females are better at social cognition *because of their inherent motive* to identify another's mental states and respond to these with an appropriate emotion. Sociability may be more rewarding for the female brain and hence females may be more motivated to seek and secure social ties (van Honk, in press). This notion is by no means speculative in that the neurobiological mechanism can be tied to oxytocin-opioid interactions in reward centres of the brain. Oxytocin-opioid interactions are superior in females (Curly & Keverne, 2005) and might well be antagonised by testosterone (van Honk, in press). Relative to the male brain, the female brain is arguably motivated for superior social cognition because its hormonal circuitry has an evolved reward-seeking basis in social behaviour.

In short, female-specific motives involve understanding the social world and thus correctly identifying another person's beliefs and desires and then responding appropriately. Male-specific motives involve understanding the mathematical world, i.e., understanding objects and their mechanical relationships. Thus, in general, males may be more challenged by mathematical issues and women by social/interpersonal issues. Moreover, threatening people's current status role by offering them social stereotypes may cause those people with high levels of testosterone to become worse in solving the issues. Indeed, as we discussed before, when one's status is threatened as a result of priming the negative stereotype, women perform worse on a mathematical task, especially when they have high baseline testosterone; men with high baseline testosterone tend to become better when they can confirm the positive stereotype and enhance their status (Josephs et al., 2003).

However, there is some recent evidence showing that men may suffer from negative stereotypes in social skill domains as well (Hall & Mast, 2008; Koenig & Eagly, 2005). In one study (Koenig & Eagly, 2005), men and women had to perform a social sensitivity task assessing the ability to accurately interpret the expressive behaviour of others and to decode others' nonverbal cues – an aspect of social intelligence or social competence (Archer, Costanzo, & Akert, 2001). Unlike the mathematical cognitive skills, social sensitivity may involve relatively automatic processes (Aarts, Dijksterhuis, & Dik, 2008). Important for the present purpose, male and female participants were primed or not with the stereotype that men do worse than women on this ability. Results showed that the stereotype prime impaired males' performance, whereas females' performance was slightly increased by the stereotype prime. When the stereotype prime was absent, men and women performed equally well.

These results suggest that men and women were differently motivated as a result of threat and challenge of their status in the social skill domain, thereby pointing to a potential role of testosterone and oxytocin in social cognition. Although this line of reasoning is tempting, we should be careful here. There is ample evidence showing that stereotype primes can affect performance directly by means of a perception-behaviour link (Aarts et al., 2005; Dijksterhuis et al., 2007). Thinking about being slow or fast, helpful or unhelpful, or good or bad in a social sensitivity task can cause one to act in accordance with the prime without intention. Accordingly, it may be the case that men and women simply acted on the stereotype without status threat or challenge being involved in the first place.

Keeping focus on testosterone, the hormone of challenge (Archer, 2006) seems to have little affinity with sociability, at least when it does not bring about testosterone's 'true' rewards such as sex, money or status. Research targeting human social cognition is, however, in its infancy and individual differences in social cognition and the unmistakably involved neuroendocrine mechanisms have received little attention.

Nonetheless, human research indicates that the neuroendocrine system establishes individual variation in social cognition (Montagne, van Honk, Frigerio, Burt, Perrett, & de Haan, 2005; Kosfeld et al., 2005; Schultheiss, Wirth, & Stanton, 2005; van Honk et al., 1999, 2004), and is accountable for enhanced empathic, mind-reading and emotion recognition abilities in females (Domes, Heinrichs, & Michel, 2007; Hampson, Anders, & Mullin, 2006; Hermans, Putman, & van Honk, 2006; van Honk & Schutter, 2007). However, supporting the high functioning autism stereotype above, female scientists put forth efforts in attempting to defend the notion that females and males have similar cognitive talents in mathematical cognition (Spelke, 2005). But many talented people come up short because in the end motives are especially critical at the highest levels of performance spectrums where obstacles and challenges require additional effort and resources.

Moreover, the superiority in social cognition suggests that the female brain is evolutionarily further evolved than the male brain. Evidence for this assumption comes from the famous Social Brain Hypothesis from behavioural biology (Dunbar, 1998) which has received very little attention in the psychological and biological sciences. Dunbar's Social Brain Hypothesis holds that increases in social group size underlie increases in the size of the primate neocortex. However, Lindenfors (2005) recently showed that the Social Brain Hypothesis applies to females exclusively, and that the male brain may even show a slight decrease when the social group size increases.

Recent behavioural data indicate that the motives underlying male and female social behaviour differ considerably. Female social behaviour stems from pro-social motivations whereas male social behaviour seems mostly instrumentally driven (e.g., Aarts, Gollwitzer, & Hassin, 2004; van Vugt, de Cremer, & Janssen, 2007). Testosterone's role in sex differences in sociality can be seen in recent data using testosterone administrations in placebo-controlled designs which show that the hormone increases fairness and social cooperation when this sociality pays off moneywise. If not, sociality fades away (Eisenegger, Heinrichs, & Fehr, 2008; Tromp, van de Vugt, Bos, Terburg, & van Honk, 2008).

Conclusion

From early development until death testosterone together with its female-type metabolite oestradiol construct the sexually dimorphic brain (Carter, 2007; van Honk, in press). Testosterone is omnipotent in sex differences in brain and behaviour, as the hormone by itself and by way of its metabolite, the female type hormone oestradiol, builds male and female brains. Moreover, testosterone influences our motive drives in such a way that we want to understand the mechanical world, and the hormone especially improves performance under highly challenging conditions. Importantly, testosterone conveys no affiliative motives or motives to understand people as its affinity with sociality is purely instrumental and depends on sex, money or status. Critically, the largest hormonal difference between the sexes is observed for testosterone and adds up to the hormone's specific motivational properties to explain sex differences in mathematical and social cognition. Finally, social stereotypes about sex differences in mathematics and social cognition may also interact differently and in complex ways, and although testosterone may motivate performance primarily in mathematical cognition, in certain social situations involving status-related challenge and threat the hormone might also strive for excellence in social cognition.

In sum, sex differences in mathematical and social cognition depend on differential (social) motive drives that are generated by sexually dimorphic neuroendocrine circuitry wherein the gonadal hormones testosterone and oestradiol play important roles.

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