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An Evolutionary Perspective on Happiness and Mental Health

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The purpose of this article is to present a model of well-being based on current research in neurobiology and psychology, integrated in an evolutionary perspective of the human mind. Briefly, the primary purpose of nervous systems is to direct an animal toward behavior should be conducive to survival and procreation, and as a rule of thumb this implies either approach or avoidance. While behavior originally was based on reflexes, in humans the brain contains a system of negative and positive affect. Although an array of functions has evolved that employ emotions in order to handle various pursuits, recent studies suggest that they converge on shared neural circuits involved in mood, that is, they converge on circuits designed to generate reward and punishment. Happiness can be construed as the net output of these brain modules. Neural circuits tend to gain in strength and influence upon frequent activation, which suggests a strategy for improving happiness and mental health: to avoid excessive stimulation of negative modules, to use cognitive interference to enhance the "turn off" function of these modules, and to exercise modules involved in positive feelings.

Keywords: mental health, mood modules, Darwinian happiness

Happiness is presumably the key ingredient in quality of life. It has been a focal topic for philosophers, with important treatises dating back to the time of Aristotle and Plato. More recently, several lines of scientific inquiry have approached the question of happiness: in the social sciences the subject is typically referred to as positive psychology, and measured by questionnaires probing the level of subjective well-being (Diener, Oishi, and Lucas, 2003; Seligman, Steen, Park, and Peterson, 2005). In evolutionary biology the term Darwinian happiness has been used in an attempt to understand why evolution endowed the human species

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with the capacity to have either pleasant or unpleasant experiences (Grinde, 2002a, 2002b). Neuroscientists try to locate and understand the structure of the neural networks involved (Kringelbach and Berridge, 2009; Leknes and Tracey, 2008; Panksepp, 1998). The present paper draws on these lines of investigation in an attempt to generate a novel model for happiness that may have practical implications for mental health.

In certain traditions within philosophy and psychology, happiness has been viewed as either hedonic, which reflects the more sensual pleasures, or eudaimonic, which is more in the line of flourishing or inner contentment (Deci and Ryan, 2008). This dichotomy appears to differentiate between pleasure derived from the senses and the more "deeper" satisfactions. The latter has been associated with having a meaningful life, and appears to be somewhat equivalent to the mental condition referred to as "flow" (Csikszentmihalyi, 1990).

Both positive and negative sentiments can be derived from a long list of external and internal stimuli. In the present model it is argued that certain key neural networks are engaged regardless of the actual cause of pleasure or pain, and regardless of whether the positive emotions would be conceived as hedonic or eudaimonic; moreover, that these networks first evolved in the vertebrate lineage for the purpose of modulating behavior.

The Greek philosophers Democritus and Aristotle argued that happiness is about what is "good" for humankind, and that it should be the ultimate goal of humanity. This seems to be a rational stance, and if so the topic ought to be approached by the full force of modern science. Below I try to formulate a model that bridges the philosophical approaches with various lines of scientific examination. It seems possible to indicate the biological correlate of happiness, based on current knowledge of the brain, and to use this insight to suggest strategies for improving mental health and quality of life.

A Modular View of the Brain

Brain Modules as Units of Evolutionary Function

The mammalian brain has been shaped by evolution to care for various functions, thus a possible approach to understand the brain is to consider it as divided into numerous modules (Nesse, 2008; Philipson, 2002). Each module deals with a particular need that arose during our evolutionary history and can be engaged when required. The actual number of modules is primarily a question of to what extent one lumps related functions together or divides them into submodules. This model of the brain is based on an evolutionary perspective rather than on an anatomical approach, a particular brain module may engage dispersed neural circuitry, and the same nerve cells may be involved in several modules. The concept of modules simply provides an alternative, evolution based framework for organizing present knowledge in neurobiology and psychology. Neural networks are the substance of brain modules, but the actual anatomical location and neurochemistry of the networks involved in any given function is, at the best, vaguely understood.

Consciousness implies a capacity to influence affective neurobiology, and thus to some extent control how we feel. In theory we have the opportunity to manipulate the mind, and consequently our level of happiness; but in practice most people are swayed by environmental stimuli, as well as by processes initiated in the subconscious parts of the brain. In short, it is within the design of the brain to allow us to influence the modules involved with positive and negative feelings, but having the desired impact requires special knowledge and skills.

The Mood Modules

Brain modules involved in generating positive or negative affect may be referred to as mood modules. The early nervous systems were presumably akin to those still found in, for example, nematodes. Their primary purpose was to direct the organism either toward something, or to cause aversion; as exemplified by respectively obtaining food and avoiding a predator. These two functions (or modules) — attraction and aversion — are still a key ingredient in even the most advanced brains. As a gross approximation the brain is there to direct attention and actions either toward or away from particular situations and opportunities. While the response in nematodes is based on reflexes, in the mammalian brain the corresponding modules activate respectively positive and negative feelings: brain rewards imply any pleasurable sensations, while brain punishments are defined as processes meant to be unpleasant (Watson and Platt, 2008).

Pleasure and pain represent the subjective, hedonic value of rewards and punishments. Presumably evolution moved from reflexes to instincts and further on to emotional enticement and conscious assessment for the advantages of a more flexible response to environmental challenges. A reflex works well as long as the challenge is the same each time, such as moving toward nutritious substances; but in the case of chasing an intelligent prey, in competition with others, a more adaptive and advanced strategy is required.

In mammals, rewards elicit approach and consummatory behavior, while punishment elicits avoidance. In some situations they have an immediate effect on behavior, but they also help classify information relevant for dealing with future situations — the pleasure of success helps the organism remember that the strategy worked, while the pain of failure suggests a change in strategy. The flexibility of response requires the capacity to learn what is likely to yield either pleasure or pain.

It seems pertinent to define happiness as the sum of activity, or net output, of the mood modules. For this definition to make sense, the word "mood" should include not only the long-term aspects of temperament or emotions, but also short-term pains and pleasures. Mood is here considered to be an aspect of the mind that moves up or down a scale that ranges from pleasant to unpleasant. Positive and negative affect may be used somewhat synonymously with rewards and punishment, or with mood value; but affect, like emotion, typically focuses on the particular functional role (for example, love, grief, or anger), while mood points to the actual positive or negative quality of affects, emotions, and sensations. According to the present model, there are independent neuronal networks caring for the particulars of each type of emotion or sensation, while they converge on partly shared structures responsible for their mood value (data supporting this conjecture are supplied below).

Positive mood is best understood as depending on two distinct overarching modules, referred to as seeking (wanting or incentive salience) and liking (the reinforcing feelings associated with the actual consumption) [Berridge, 2003; Panksepp, 1998]. In the early nervous systems, seeking and liking presumably reflected two independent functions: animals were instigated first to search for relevant items in the environment, such as food, and subsequently for devouring the items. As these two functions were separated at an early stage in the evolution of nervous systems, they are expected to have distinct neurobiology, which appears to be the case (Kringelbach and Berridge, 2009).

The various mood modules collaborate in directing behavior, thus they appear to have a "common currency" which enables comparison as to the relative importance of various options (Cabanac, 1979). A minor pain should, for example, not ruin the chance for a major reward; thus the pain should be subdued in order to direct the mind toward the reward. Similarly, a small reward is not worth a life-threatening situation, and should consequently be ignored in order to secure avoidance behavior. As reviewed by Leknes and Tracey (2008), various lines of research have demonstrated the above principles. Pleasure related analgesia implies suppression of pain, while various forms of pain (either physical or related to anxiety and depression) reduce or obliterate the capacity to experience gratification. The more chronic form of the latter condition is referred to as anhedonia (Gorwood, 2008).

Punishment and rewards may also be viewed as a question of encouraging the restoration of, or maintaining, homeostatic balance in the body; for example, to consume food when blood sugar is low. The principle referred to as alliesthesia points to the expected correlate between the intensity of the activation of mood modules and the magnitude of homeostatic restoration (Cabanac, 1979). Food rewards, for example, are more pleasurable when hungry, and a trivial fear can change to panic if the situation becomes life-threatening.

The Neurobiology of Mood Modules

The neurobiology of pleasure and pain has been covered in recent reviews (Kringelbach and Berridge, 2009; Leknes and Tracey, 2008). Below is a brief outline adapted to the purpose of the present text.

All mammals have brain structures homologues to those understood to be involved in reward and punishment (Panksepp, 1998). Moreover, the conserved nature of the corresponding mental states can be deduced from the observation that different mammals display related affective (facial) expressions (Steiner, Glaser, Hawilo, and Berridge, 2001).

The main neurotransmitters involved in the mood modules — dopamine, serotonin, and opioids — are used in even the most primitive neural systems, such as that of nematodes, where they apparently serve the evolutionary homologues functions of attraction and avoidance (Chase and Koelle, 2007; Nieto–Fernandez, Andrieux, Idrees, Bagnall, Pryor, and Sood, 2009). This observation further strengthens the idea that the human mood modules represent an evolutionary expansion of processes involved in directing animals either toward opportunities or away from dangers.

In the vertebrate lineage there has been a shift from behavior based on simple reflexes, to non-emotional instincts, and eventually to behavior directed by positive and negative feelings. The affective aspect of behavior became gradually more important when moving from fish to mammals, primates, and humans. It is debated whether a fish has a conscious experience of, for example, pain (Braithwaite and Boulcott, 2007), while reptiles appear to appreciate pleasures (Cabanac, 1999), and it is generally assumed that mammals do.

As to the mammalian brain, there are extensive data pertaining to the neuroanatomical correlates of mood modules, based on various types of brain scans, as well as on neurochemical modulators and electrical stimulation (reviewed in Kringelbach and Berridge, 2009; Leknes and Tracey, 2008). The more ancient, presumably subconscious, neural circuitries involved are located in the basal parts of the brain, and include parts of thalamus, hypothalamus, amygdala, and hippocampus. The cognitive extension appears to involve circuitry in the orbitofrontal, lateral prefrontal, insular and anterior cingulate parts of the cortex. The basal parts are probably essential for generating positive and negative feelings, while the cortex enables both a more precise awareness, and a capacity to modulate the impact of feelings.

The various sub-modules involved in mood have apparently retained a partly shared neurobiology both as to anatomical features and neurochemistry. This observation testifies to their common evolutionary origin, as well as to the need for a close collaboration between rewards and punishment in order to derive at optimal behavioral instigations. Although there has been extensive elaboration of these systems in the lineage leading toward humans, the comparative approach has yielded relevant insight into their neurobiology.

Although the mood modules have features in common, it is possible to describe distinct neurobiology for the two pleasure modules (seeking and liking) and the pain module. For example, the opioid system serves a key role in liking, while dopaminergic nerve cells are important in the seeking (or wanting) module (Leknes and Tracey, 2008).

There is growing evidence supporting the notion that the various types of pleasures and pains — including sensual stimuli as well as social gratification and agony — converge on certain key neurobiological features. For example, experiencing envy of another person's success activates pain-related circuitry, whereas experiencing delight at someone else's misfortune (what is referred to as Schadenfreude), activates reward-related neural circuits (Lieberman and Eisenberger, 2009; Takahashi, Kato, Matsuura, Mobbs, Suhara, and Okubo, 2009). Similarly, feeling excluded or being treated unfairly activates pain-related neural regions (Eisenberger, Lieberman, and Williams, 2003; O'Connor, Wellisch, Stanton, Eisenberger, Irwin, and Lieberman, 2008). On the other hand, positive social feelings, such as obtaining a good reputation, being treated fairly, and cooperating with others, offer rewards similar to those obtained from desirable food (Izuma, Saito, and Sadato, 2008, 2010; Tabibnia and Lieberman, 2007; Tabibnia, Satpute, and Lieberman, 2008). Moreover, the same reward related brain regions are activated when having sex or enjoying music (Blood and Zatorre, 2001).

Although several parts of the brain are involved when sensing pleasure, only a few "hotspots" are known that will cause activation, in the form of enhanced pleasure, upon relevant stimulation (Smith and Berridge, 2007). The stimulation may be either in the form of electrodes inserted in the region, or local injection of neurotransmitter modulators. These hotspots are found only in subcortical structures such as the nucleus accumbens shell and the ventral pallidum. They are neurobiologically connected, and presumably form a functional unit with strong links to the relevant cortical regions. The same regions appear to be involved in both liking and seeking, but while opioids and cannabinoids stimulate liking, dopamine amplifies seeking. Their subcortical location supports the notion that the mood "motor" is subcortical, while the cortical regions act more like a "dashboard."

Mood Modules and Happiness

Evolutionary Perspective

Concomitant with the development of more advanced brains, evolution devised emotional and cognitive assessments of options. The evolutionary advantage rests with the power of a more flexible response to environmental challenges, which helps the species survive under varying and unexpected conditions. A parsimonious evolutionary scenario suggests that the elaboration of early reflexive or instinctive behavior associated with attraction and aversion started by first adding mood value, and subsequently gradually increasing conscious involvement. In short, installing rewards and punishment was a strategy that promoted adaptive behavior by improving the plasticity of response. The individual would, in effect, select an option based on the expected hedonic value of various alternatives, the expectations being based on innate guidance and on previous experiences. Over time the individual would learn to adjust behavior according to the potential harvest of pleasure, which — in a natural environment — should reflect what is best for the genes. A peculiar side-effect of this evolutionary strategy is that it allows for happiness.

It may be hypothesized that with the advent of more advanced cognitive functions, such as those reflected in self-awareness and free will, a concurrent enhancement of the mood value would be called for, as the individual might otherwise use the elevated level of free will to choose options that diverge from the interest of the genes. That is, higher cognitive functions imply a further gain in flexibility, but at the risk of ending up with behavior that is less conductive to procreation — particularly if the environment changes. The conjecture implies that humans may have the capacity to be the most happy — and most unhappy — of any animal. The conjecture is supported by the observation that endorphins, are expressed at higher levels in human brains as compared to apes (Cruz–Gordillo, Fedrigo, Wray, and Babbitt, 2010). It is conceivable that the capacity for happiness has been further boosted by sexual selection in the human lineage, that is, people may have preferred partners displaying good mood.

According to the present model, evolution expanded the role of the mood modules in the mammalian lineage. Not only did the element of mood become stronger, but the modules became engaged in an increasing variety of situations and behavioral encouragements. The cognitive component of the system presumably expanded to accommodate novel applications, while subcortical elements of the modules were retained. The subcortical elements may deliver a tonus of positive and negative feelings, while the cortex adds the "flavor" associated with the various experiences. A good meal, for example, produces a rather different impression compared to the joy of an aesthetic object, yet the pleasure itself may in both cases be cared for by the same reward circuitry. In other words, brain mechanisms involved in the instigation of fundamental behavior, such as eating or sex, also cater to behavior considered specific for humans, such as enjoying music or gossiping. Evolution has apparently erected all pleasures and pains on the same neurobiological framework.

Punishment, or negative affect, implies subjective distress and dissatisfaction that may be associated with a broad range of emotions — including fear, sadness, anger, guilt, and jealousy. Similarly, rewards, or positive affect, may include not only explicit happiness, but also feelings associated with being interested, energetic, confident, and optimistic. The notion that various positive and negative affects reflect evolutionary developments based on a common platform is supported not only by the shared neurobiology, but also by the observation that they tend to co-occur both within and across individuals (Watson and Naragon–Gainey, 2010). Moreover, the notion is in line with current understanding of how the process of evolution typically operates.

Setpoint of Happiness

Much of daily conscious activity has only limited relevance for the level of happiness. People do not experience life as a stream of either good or bad events, but rather as a relatively steady state. Mood may move slightly up or down, as when respectively working on an interesting task or feeling bored. More rarely, episodes may cause a particular surge of pleasure or pain. In other words, the mood modules do not normally dominate the mind, but that does not imply they are inactive. It seems more appropriate to envision a tonus of mood caused by a balance of positive and negative activity. The steady state tonus presumably reflects what some scientists refer to as a setpoint of happiness (Lykken, 2000). While it is easy to find a stimulus that sends happiness temporarily beyond the setpoint, it is more difficult, but not impossible, to boost the setpoint itself.

The human mind receives a vast variety of input. Some are initiated by the sense organs and reach consciousness via various processing centers in the brain; other input is internally initiated, for example, hunger and thirst as part of the homeostatic system. Most inputs — as well as the experiences, thoughts, and sensations they generate — may connect with the mood modules, but only some have sufficient impact to be consciously regarded as pleasure or pain. In some cases the effect on mood can be significant, but is still not recognized as such, for example when a situation causes a person to worry without an awareness of the apprehension. The activity of the positive and negative mood modules may change even without alerting the conscious brain, that is, both external and internal signals can have an impact on emotions in the absence of attention (Tamietto and de Gelder, 2010).

Cognitive Assessment

The function of the mood modules can be described as telling the individual whether it is on the right or wrong track toward survival and procreation. In humans, however, there is a considerable element of cognitive assessment that influences what is construed as beneficial or detrimental. Collecting butterflies may not improve the chance of survival, but it is possible to prime the brain to accept that finding a rare species is the most important thing to do, and consequently harvest a solid reward for doing so. The human mind is susceptible to this sort of learning and molding. In an environment that differs from what evolution has prepared us for, such as an industrialized society, the system easily causes behavior totally at odds with the interest of the genes — but not necessarily at odds with maximizing happiness.

The mood modules may be activated directly from a sensory experience, such as tasting sweet food or burning a finger; or cognitive modulation may intervene to the effect of either subduing or enhancing the rewarding or punishing feelings. Minor alterations in a situation or a line of thought — whether due to conscious input, subconscious brain activity, or external factors — can change the net effect abruptly from a positive to a negative experience.

Fear is an illustrative example. Normally fear is an unpleasant feeling because it is meant to keep the individual away from dangerous situations. If the eyes catch a stick resembling a snake, the startle is unpleasant; when upon closer examination the person realizes it is only a twig, the decline in tension is pleasant. In other situations the fear itself may be pleasurable: a climber appreciates the adrenalin kick of challenging a dangerous mountain. If he loose control, however, the feeling suddenly becomes disagreeable. The link between danger and the reward module is explained in evolutionary terms by the advantage of occasionally facing treacherous situations, for example, in connection with hunting.

Another example concerns grief. Normally this is a negative experience, as it is evoked by events that are unfortunate for the genes, such as the loss of a partner or failure to complete a task. The brain reacts by marking the occurrence as something to be avoided. On the other hand, the reaction of grief serves a purpose in that it may help the individual overcome the situation. Furthermore, the sorrow is visible in the face, which suggests that it helps to communicate this feeling, presumably in order to elicit support. The notion that grief may actually improve fitness implies that, in the appropriate context, the individual is best served by engaging the emotion; and in order to instigate this setting of the mind, a reward is called for. Consequently, sorrow may feel either good or bad. This conjecture helps explain why people attend sad movies, when your own situation is not jeopardized, the reward part of grief may overwhelm the negative aspects. In fact, O'Connor et al. (2008) have shown that while grief normally activates pain-related areas of the brain, in some people it activates reward centers.

It is not obvious whether a particular situation will add or subtract to the level of happiness, that is, whether the situation will activate positive or negative mood modules. The context, the particulars, and cognitive assessment, may move the experience toward being either pleasant or unpleasant.

Default Contentment

According to the present model, it is assumed that both hedonic and eudaimonic happiness operate via the same mood modules of the brain. The idea is supported by the presumed prudence of the process of evolution. It seems unlikely that evolution devised two independent systems aimed at putting the mind in a positive state. Moreover, the "reward circuitry" described above appears to be involved in all types of pleasure, including those often cited to be of eudaimonic character such as love and compassion. The observation that people suffering from anhedonia have reduced ability to experience happiness in general (Gorwood, 2008; Kringelbach and Berridge, 2009), further supports the contention.

The above reasoning does not necessarily imply that the dichotomy is unwarranted, as the sources and nature of eudaimonia may differ appreciably from typical hedonic sensations. While the early nervous systems responded primarily to the basal requirements of life (for example, dangers, food, and mating), the complexity and repertoire of behavioral instigations have expanded considerably. One of the foremost items related to eudaimonia is having a "meaningful life." It seems rational for evolution to attach positive feelings to utility, which implies that we are rewarded for doing something considered constructive. Similar reasoning may apply to other values typically incorporated in eudaimonia, such as being virtuous and obeying social rules. Evolutionary speaking, the ultimate objective should be survival and procreation, but more proximate purposes may also activate reward modules. In other words, the positive affect labeled as eudaimonia may simply reflect a subset of the vast array of stimuli that connect to a common reward motor.

Hedonism, or sensual pleasure, tends to be frowned upon in Western society. This sentiment may be explained by certain features of the pleasures typically associated with eudaimonia: they are either more lasting, less likely to cause harm by misuse, or considered virtuous and beneficial to society. Thus, the preference for eudaimonic values may reflect an attempt to coach people toward choosing particular types of rewards. The preferred list would include those more likely to ensure optimal long-term happiness, and those favored due to social or political priorities.

There is, however, another aspect to the design of the brain that may help explain why people tend to consider eudaimonia as a different form of happiness. In the absence of adverse factors, humans (and other mammals) are apparently designed to be in a good mood — what may be referred to as a *default state of contentment* (Grinde, 2004). It is presumably in the interest of the genes to reside in a body/mind with a positive attitude to life, as this state of affairs is conducive to the pursuits required for survival and procreation. The individual is more likely to take the trouble of looking for food or a spouse if in a good mood. In support of the default contentment hypothesis, there is considerable data suggesting that people tend to be happy and optimistic (Diener and Diener, 1996; Lykken, 2000). The point is reflected in the tendency to gamble, as well as in personal assessment of happiness: when asked about subjective well-being, people claim, on the average, to be on the happy side of neutral.

The default contentment is likely to be associated with eudaimonia rather than hedonia, as it does not require any external (sensual) stimuli, and as it is not in any way detrimental. Furthermore, retaining this state of mind is probably more important for the level of happiness compared to pursuing typical hedonic pleasures. Hedonic stimuli are generally fleeting, and sometimes at odds with long-term happiness, while a positive default state implies a continuous and wholesome source of happiness. Yet, it seems likely that the default contentment simply reflects that the mood modules are designed to operate with a net positive value as long as the negative modules are not specifically activated. That is, in a person with proper mental health, whose basal needs are cared for, the setpoint of happiness is positive.

Mental Health

The Role of Mood Modules

Mental disorders have become a major burden of health in industrialized societies, both in terms of the quality of life of citizens, and by disrupting the economy as a common cause of sick leaves and disability. According to estimates, 31–50% of the population suffers from a mental disorder at some point in life, whereas 17–33% had a diagnosable condition during the last 12 months (Moffitt, Caspi, Taylor, Kokaua, Milne, Polanczyk, and Poulton, 2010; Murray and Lopez, 1996).

There are two main quandaries associated with mental problems: one, patients are unhappy; and two, they do not function optimally in society, which may or may not cause further suffering. These two aspects do not necessarily go together. People with Down's syndrome, for example, tend to be happy as long as they are cared for (Robinson, 2000); while a depressed person can be deeply unhappy, but still function satisfactorily.

Adverse events — such as hunger, fear, or breaking a leg — cause negative feelings, but the brain normally returns to a positive frame once the particular experience is ended (Lykken, 2000). The unhappiness aspect of mental illness reflects either a negative reaction in excess of what is (biologically) appropriate, or the preservation of discontent in the absence of adverse events. In both cases the problem is presumably due to distorted functioning of neural networks associated with the punishment module.

The more common mental problems are related to anxiety and depression (Wittchen et al., 2011). These conditions apparently reflect the sub-modules more likely to become distorted in industrialized societies. Their presumed related neurobiology (the punishment module), may contribute to the co-morbidity observed (Berna, Leknes, Holmes, Edwards, Goodwin, and Tracey, 2010; Kessler, Chiu, Demler, Merikangas, and Walters, 2005). Even a sub-clinical level of unwarranted activity in these modules would be expected to reduce happiness, thus, the diagnosable psychiatric disorders may be the tip of the iceberg as to reduced quality of life caused by the punishment module. As expected, psychological indicators suggest that a tendency toward anxiety or depression correlates negatively with subjective well-being (Nes, Roysamb, Tambs, Harris, and Reichborn–Kjennerud, 2008; Watson and Naragon–Gainey, 2010).

Anxiety may be regarded as perverted activity of the fear module. This module is of considerable importance in evolutionary terms, and has a reasonably well characterized neurobiology that partly overlaps with regions involved with the more classical forms of pain, that is, in the amygdala and periaqueductal grey (Bandler and Shipley, 1994; Panksepp, 1998). The main function of fear is, like pain, to avoid endangering oneself, which explains a connection with the punishment module.

Depression is presumably associated with hyperactivity in a "low mood" module, but while fear has an obvious biological function, it is less clear why humans need a module for low mood (Nesse, 2000). One likely purpose is to secure social relations. In the Paleolithic hunter–gatherer, a lack of a strong social network would be a serious threat to survival. The low mood induces a negative feeling (loneliness) in order to teach the individual to seek companionship with others. A connection between the neurobiology of pain and that of social rejection has been documented (Eisenberger, Lieberman, and Williams, 2003). The low-mood module is probably also activated when unsuccessful in a task.

Unwarranted activity in these two sub-modules tends to diminish rewarding sensations and demolish the default state of contentment. Preventing or treating these ailments is arguably the most compelling way of improving well-being — and mental health — in society. As pointed out, the prevalence of diagnosable cases is considerable, but excessive, non-functional activity probably bothers a much larger percentage of the population. It may manifest itself as undue rumination on worries, or a vague gloom.

Preventive Measures

It is possible to treat anxiety and depression by either cognitive or pharmacological intervention, but a preferred strategy is to implement preventive measures. The notion that the cause is excessive activity in punishment sub-modules suggests a possible option.

It is common knowledge that the size and strength of muscles will improve upon exercise, but also neuronal tissue may expand upon use (Pascual–Leone, Amedi, Fregni, and Merabet, 2005). The point is easily demonstrated in animals where it is possible to apply experimentally controlled stimuli and subsequently remove the brain for detailed anatomical analyses (Hensch, 1999); but the principle has been confirmed in humans, hippocampal grey matter is, for example, increased as a consequence of exercising navigational skills (Maguire, Gadian, Johnsrude, Good, Ashburner, Frackowiak, and Frith, 2000). It seems reasonable to assume that by exercising a brain module — that is, activating it regularly — the module will not only tend to improve or strengthen, but also have a greater impact on consciousness. For example, by regularly stimulating the fear function, one is more likely to suffer from excessive activity of this module, that is, more likely to develop anxiety related problems, as has been documented in connection with research on early life stress (Bremne and Vermetten, 2001).

It should be pointed out that strengthening of brain modules due to "exercise" (or, if one prefers, learning), is not necessarily a question of anatomical expansion of tissue. It may, for example, be a question of engaging various mechanisms involved in pruning or intensifying connections between neurons, or even atrophy of certain regions. Depression is associated with decreased activity (and reduced size) in certain parts of the brain (Panksepp, 1998; Savitz and Drevetsa, 2009), yet in the present terminology the low mood module is still activated and strengthened.

It is not surprising that mental complaints are associated with undesirable activity in feelings perceived as negative. There is not the same cause for complaint if the reward circuits of the brain become overactive, unfortunately this is a less likely scenario. The punishing sub-modules are there to avoid adverse situations, consequently they typically have a low threshold for activation. It is, for example, better to react at the sight of a stick resembling a snake, than not to respond when approaching a real snake. The ease of activation implies that the functions are more likely to be "exercised" to the extent that they end up dominating the mind.

I have previously described a possible scenario for why anxiety has become such a common problem in Western societies (Grinde, 2005). Briefly, infants rely on parental help to avoid danger, whether in the form of burglars or wild beasts, thus they do not understand that a locked door implies safety. Parental proximity is the key to avoid activating the fear module, and the preferred distance is skin-to-skin. The present way of handling infants typically involves reduced parental proximity; for example, strollers instead of carrying, less skin contact, and less co-sleeping. It is well known that the stress of infant separation or abuse can cause susceptibility to later anxiety disorders (Bremne and Vermetten, 2001). In fact, this form of stress has recently been related to changes in the orbitofrontal cortex, a part of the brain associated with the mood modules (Hanson, Chung, Avants, Shirtcliff, Gee, Davidson, and Pollak, 2010). Milder forms of stress, such as insisting that the infant shall sleep alone at night, may not lead to distinct changes in the brain, but still imply an increased vulnerability to anxiety.

Similarly, the high prevalence of depression may reflect that modern societies are troubled by a suboptimal social environment, as well as by too much pressure on achievements that are difficult to attain. Altering these conditions may reduce excessive exercise of the low mood module.

As argued elsewhere, it seems unlikely that the present prevalence of anxiety, depression, and chronic pain is the natural state for the human species (Grinde, 2009). A common denominator of the causes suggested above is that they reflect ways of living in industrialized societies that differ from the way of life in the evolutionary formative Paleolithic period. Consequently, the problems may be viewed as stemming from environmental conditions that are at discord with how the human species is genetically adapted to live. However, to pinpoint the actual culprits among the list of possible discords requires further research.

It is also possible to exercise the modules of the brain associated with rewards. In this case, the mood tonus, or setpoint of happiness, would be expected to improve. Meditation appears to be relevant "brain exercise" in this respect. Certain forms of meditation, such as that based on the Tibetan Buddhist tradition, have been investigated in some detail. It has been claimed that this practice is capable of installing in the brain a sufficiently strong reward module to allow for a positive sentiment regardless of the external situation (Ricard, 2007). The positive effect of meditation is partly substantiated by measuring activity in brain centers associated with rewards in Buddhist monks (Lutz, Greischar, Rawlings, Ricard, and Davidson, 2004; Wallace, 2007), as well as by positive effects on psychiatric patients (McGee, 2008).

Activation and Deactivation of Mood Modules

The subconscious transfers only select information to the conscious brain, and conscious control over mental and bodily functions is limited to what was useful during the evolution of the species. If, for example, the sight of an elevator activates claustrophobic fear, the sufferer is typically unable to turn that fear off. Yet it is possible to impact on the mood modules.

The brain presumably contains structures designed to turn off positive and negative feelings, that is, to disengage pains and pleasures when these are no longer appropriate. The hedonic pleasure associated with food, for example, will eventually vanish when the bodily needs are satisfied, as the instigating delight signal is no longer relevant for the genes. Similarly, pain and fear should be turned off when no longer useful as a statement meant to prevent further inflictions.

The brain structures, or modules, designed to turn off feelings may also be exercised and strengthened. Cognitive therapy is one way of boosting the deactivation structures, and has proven particularly successful in treating certain forms of anxiety (Otte, 2011). Exposure is often a key element of therapy, as it allows for the exercise of the deactivating element. Presumably the same principle applies to a mountain climber who learns to control the fear of heights.

The fact that anxiety and depression are so prevalent suggests that the system of activation and deactivation not always function according to the intention. Apparently it is more likely that the various sub-modules turning on punishment have elevated activity, compared to those meant to turn it off. The cause of this situation may be related to the discord nature of fear stimuli. In the Paleolithic period, dangerous situations were more likely to be an event with a clear "end" signal. Today anxiety often stems from situations that linger and have no distinct conclusion, thus the deactivation circuitry is not sufficiently engaged. That is to say, the reason for the high prevalence of anxiety may be brought down to a misbalance between the modules activating fear and those deactivating it.

Concluding Remarks

What allows humans to enjoy life is the dichotomy of what is good and bad for the genes, together with the evolutionary construct of respectively positive and negative feelings to deal with the two types of situations. Once evolution established emotions as an upgraded version of behavioral control, the mood modules became an integral part of the brain. Presumably they deliver a constant basal activity, not necessarily recognized as either pleasure or pain, but the modules are ready to turn the mood up or down on the scale of happiness depending on internal homeostasis and external opportunities or hazards.

The present model of happiness is based on the notion that all forms of pleasure and pain are elaborations of ancient functions of the nervous system designed to deal with respectively attraction and avoidance. Some people may object to the idea of considering all mood related brain activity as activation of either brain rewards or punishments. Even those who agree may dislike the use of the term happiness for the positive output from these modules. Both objections are, in my mind, primarily semantic issues, where the appropriateness of the semantic choices made depends partly on how the brain is organized, partly on the perspective taken. If one wishes to stress dissimilarity, it seems rational to choose separate descriptive terms; while if one wishes to point out shared aspects — the prospect that all positive feelings converge on brain circuitry designed to generate a reward — a common term seems appropriate.

In the present text, happiness is taken to encompass all positive affect. The choice of word, however, is neither obvious nor important. The important issue is whether the present model can help improve quality of life. The key element in this respect is the notion that appropriate "brain exercise" can lead to enhancement of nerve circuitry. As to the pursuit of happiness, and improvement of mental disorders, the logical consequence is to avoid stimulation of the activating arms of negative sub-modules, while it seems rational to stimulate the deactivating arms, as well as the activating arms of positive sub-modules.

Other mammals apparently have more or less the same repertoire of feeling that we find in humans, including the capacity for a wide range of pleasures and pain (Panksepp, 1998). The positive and negative mood values may be stronger in humans, but the important difference is that humans have the competence to understand, and to use that insight to make the most of the situation. According to the theory of happiness presented here, strategies for improvement should focus primarily on how to reduce the activity of the punishing sub-modules (particularly anxiety and depression), and secondarily on how to stimulate activity of rewarding modules. The former seems to be the main problem because in the absence of punishing activity, the default state of contentment ought to secure a happy life. As the brain is most malleable during infancy, it is particularly relevant to focus on how children are brought up.

I have suggested that the excessive stimulation of negative sub-modules is due to the discord nature of living in an industrialized society. People with a vulnerable disposition, or a less suitable way of life, consequently end up with happiness threatening mental problems. I believe preventive measures, based on the notion of discords, should improve the net balance of activity in the mood modules of the average citizen; but they cannot, and should not, obliterate negative feelings as these are important for survival. For example, the inability to feel pain, such as in people with congenital insensitivity, is a severe condition associated with increased injury (Young, 2007).

The estimated prevalence of anxiety and depression is prone to a more or less arbitrary cut-off as to what is considered pathological. However, regardless of where the line is drawn, it seems likely that there is considerable non-functional activity due to discord aspects of the present environment. One would not expect the fear and low mood functions to be designed by evolution in such a way that a substantial fraction of the population suffers from obviously irrational, maladaptive, and more or less debilitating anxiety or depression. And even if this assumption should be wrong, the present advice as to avoiding undesirable activity in the negative sub-modules would be expected to improve quality of life. However, more research is needed in order to formulate more specific advice, as we do not yet know which discords are the more important culprits.

References

Bandler, R., and Shipley, M.T. (1994). Columnar organization in the midbrain periaqueductal grey: Modules for emotional expression. *Trends in Neuroscience, 17,* 379–389.

Berna, C., Leknes, S., Holmes, E.A., Edwards, R.R., Goodwin, G.M., and Tracey, I. (2010). Induction of depressed mood disrupts emotion regulation neurocircuitry and enhances pain unpleasantness. *Biological Psychiatry, 67,* 1083–1090.

Berridge, K.C. (2003). Pleasures of the brain. *Brain Cognition, 52,* 106–128.
Blood, A.J., and Zatorre, R.J. (2001) Intensely pleasurable responses to music correlate with activity in brain regions implicated in reward and emotion. *Proceedings of the National Academy of Science USA, 98,* 11818–11823.
Braithwaite, V.A., and Boulcott, P. (2007). Pain perception, aversion and fear in fish. *Diseases of Aquatic Organisms, 75,* 131–138.
Bremne, J.D., and Vermetten, E. (2001). Stress and development: Behavioral and biological consequences. *Developmental Psychopathology, 13,* 473–489.
Cabanac, M. (1979). Sensory pleasure. *The Quarterly Review of Biology, 54,* 1–29.
Cabanac, M. (1999). Emotion and phylogeny. *Japanese Journal of Physiology, 49,* 1–10.
Chase, D.L., and Koelle, M.R. (2007). Biogenic amine neurotransmitters in *C. elegans. WormBook, February 20,* 1–15.
Cruz–Gordillo, P., Fedrigo, O., Wray, G.A., and Babbitt, C.C. (2010). Extensive changes in the expression of the opioid genes between humans and chimpanzees. *Brain, Behavior and Evolution, 76,* 154–162.
Csikszentmihalyi, M. (1990). *Flow: The psychology of optimal experience*. New York: Harper and Row.
Deci, E.L., and Ryan, F.M. (2008). Hedonia, eudaimonia, and well-being: An introduction. *Journal of Happiness Studies, 9,* 1–11.
Diener, E., and Diener, C. (1996). Most people are happy. *Psychological Science, 7,* 181–185.
Diener, E., Oishi, S., and Lucas, R.E. (2003). Personality, culture, and subjective well-being: Emotional and cognitive evaluations of life. *Annual Review of Psychology, 54,* 403–425.
Eisenberger, N.I., Lieberman, M.D., and Williams, K.D. (2003). Does rejection hurt? An fMRI study of social exclusion. *Science, 302,* 290–292.
Gorwood, P. (2008). Neurobiological mechanisms of anhedonia. *Dialogues in Clinical Neuroscience, 10,* 291–299.
Grinde, B. (2002a). Happiness in the perspective of evolutionary psychology. *Journal of Happiness Studies, 3,* 331–354.
Grinde, B. (2002b). *Darwinian happiness — Evolution as a guide for living and understanding human behavior.* Princeton, New Jersey: The Darwin Press.
Grinde, B. (2004). Darwinian happiness: Can the evolutionary perspective on well-being help us improve society? *World Futures — Journal of General Evolution, 60,* 317–329.
Grinde, B. (2005). An approach to the prevention of anxiety-related disorders based on evolutionary medicine. *Preventive Medicine, 40,* 904–909.
Grinde, B. (2009). Can the concept of discords help us find the causes of mental diseases? *Medical Hypothesis, 73,* 106–109.
Hanson, J.L, Chung, M.K., Avants, B.B., Shirtcliff, E.A., Gee, J.C., Davidson, R.J., and Pollak, S.D. (2010). Early stress is associated with alterations in the orbitofrontal cortex: A tensor-based morphometry investigation of brain structure and behavioral risk. *Journal of Neuroscience, 30,* 7466–7472.
Hensch, T.K. (1999). Whisking away space in the brain. *Neuron, 24,* 623–637.
Izuma, K., Saito, D.N., and Sadato, N. (2008). Processing of social and monetary rewards in the human striatum. *Neuron, 58,* 284–294.
Izuma, K., Saito, D.N., and Sadato, N. (2010). Processing of the incentive for social approval in the ventral striatum during charitable donation. *Journal of Cognitive Neuroscience, 22,* 621–631.
Kessler, R.C., Chiu, W.T., Demler, O., Merikangas, K.R., and Walters, E.E. (2005). Prevalence, severity, and comorbidity of 12-month DSM-IV disorders in the National Comorbidity Survey Replication. *Archives of General Psychiatry 62,* 617–627.
Kringelbach, M.L., and Berridge, K.C. (2009). Towards a functional neuroanatomy of pleasure and happiness. *Trends in Cognitive Science, 13,* 479–487.
Leknes, S., and Tracey, I. (2008). A common neurobiology for pain and pleasure. *Nature Reviews Neuroscience, 9,* 314–320.
Lieberman, M.D., and Eisenberger, N.I. (2009). Neuroscience. Pains and pleasures of social life. *Science, 323,* 890–891.
Lutz, A., Greischar, L.L., Rawlings, N.B., Ricard, M., and Davidson, R.J. (2004). Long-term meditators self-induce high-amplitude gamma synchrony during mental practice. *Proceedings of the National Academy of Science USA, 101,* 16369–16373.

Lykken, D. (2000). *Happiness: The nature and nurture of joy and contentment*. New York: St. Martin's Griffin.

Maguire, E.A., Gadian, D.G., Johnsrude, I.S., Good, C.D., Ashburner, J., Frackowiak, R.S., and Frith, C.D. (2000). Navigation-related structural change in the hippocampi of taxi drivers. *Proceedings of the National Academy of Science USA, 97,* 4398–4403.

McGee, M. (2008). Meditation and psychiatry. *Psychiatry, 5,* 28–41.

Moffitt, T., Caspi, A., Taylor, A., Kokaua, J., Milne, B.J., Polanczyk, G., and Poulton, R. (2010). How common are common mental disorders? Evidence that lifetime rates are doubled by prospective versus retrospective ascertainment. *Psychological Medicine, 39,* 899–909.

Murray, C., and Lopez, A. (1996). *The global burden of disease: A comprehensive assessment of mortality and disability from diseases, injuries and risk factors in 1990 and projected to 2020*. Cambridge, Massachusetts: Harvard University Press.

Nes, R.B., Roysamb, E., Tambs, K., Harris, J.R., and Reichborn–Kjennerud, T. (2008). Well-being and ill-being: Shared environments, shared genes? *Journal of Positive Psychology, 3,* 253–265.

Nesse, R.M. (2000). Is depression an adaptation? *Archives of General Psychiatry, 57,* 14–20.

Nesse, R.M. (2008). Natural selection, mental modules and intelligence. In G.R. Bock, J.A. Goode, and K. Webb (Eds.) *The nature of intelligence: Novartis Foundation Symposium 233* (pp. 96–115), Chichester, United Kingdom: John Wiley & Sons.

Nieto–Fernandez, F., Andrieux, S., Idrees, S., Bagnall, C., Pryor, S.C., and Sood, R. (2009). The effect of opioids and their antagonists on the nocifensive response of *Caenorhabditis elegans* to noxious thermal stimuli. *Invertebrate Neuroscience, 9,* 195–200.

O'Connor, M.F., Wellisch, D.K., Stanton, A.L., Eisenberger, N.I., Irwin, M.R., and Lieberman, M.D. (2008). Craving love? Enduring grief activates brain's reward center. *Neuroimage, 42,* 969–972.

Otte, C. (2011). Cognitive behavioral therapy in anxiety disorders: Current state of the evidence. *Dialogues in Clinical Neuroscience, 13,* 413–421.

Panksepp, J. (1998). *Affective neuroscience*. Oxford: Oxford University Press.

Pascual–Leone, A., Amedi, A., Fregni, F., and Merabet, L.B. (2005) The plastic human brain cortex. *Annual Review of Neuroscience, 28,* 377–401.

Philipson, L. (2002). Functional modules of the brain. *Journal of Theoretical Biology, 215,* 109–119.

Ricard, M. (2007). *Happiness — A guide to developing life's most important skill*. Boston: Atlantic Books.

Robinson, R.J. (2000). Learning about happiness from persons with Down syndrome: Feeling the sense of joy and contentment. *American Journal of Mental Retardation, 105*, 372–376.

Savitz J.B., and Drevetsa, W.C. (2009). Psychiatry–developmental disorder imaging phenotypes of major depressive disorder: Genetic correlates. *Neuroscience, 164*, 300–330.

Seligman, M.E., Steen, T.A., Park, N., and Peterson, C. (2005). Positive psychology progress: Empirical validation of interventions. *The American Psychologist, 60*, 410–421.

Smith, K.S., and Berridge, K.C. (2007). Opioid limbic circuit for reward: Interaction between hedonic hotspots of nucleus accumbens and ventral pallidum. *Journal of Neuroscience, 27,* 1594–1605.

Steiner, J.E., Glaser, D., Hawilo, M.E., and Berridge, K.C. (2001). Comparative expression of hedonic impact: Affective reactions to taste by human infants and other primates. *Neuroscience and Biobehavioral Reviews, 25*, 53–74.

Tabibnia, G., and Lieberman, M.D. (2007). Fairness and cooperation are rewarding: Evidence from social cognitive neuroscience. *Annals of the New York Academy of Science, 1118*, 90–101.

Tabibnia, G., Satpute, A.B., and Lieberman, M.D. (2008). The sunny side of fairness — preference for fairness activates reward circuitry (and disregarding unfairness activates self-control circuitry). *Psychological Science, 19,* 339–347.

Takahashi, H., Kato, M., Matsuura, M., Mobbs, D., Suhara, T., and Okubo, Y. (2009). When your gain is my pain and your pain is my gain: Neural correlates of envy and Schadenfreude. *Science, 323,* 937–939.

Tamietto, M., and de Gelder, B. (2010). Neural bases of the non-conscious perception of emotional signals. *Nature Reviews Neuroscience, 11,* 697–709.

Wallace, A.B. (2007). *Contemplative science: Where Buddhism and neuroscience converge*. New York: Columbia University Press.

Watson, D., and Naragon–Gainey, K. (2010). On the specificity of positive emotional dysfunction in psychopathology: Evidence from the mood and anxiety disorders and schizophrenia/schizotypy. *Clinical Psychology Review, 30,* 839–848.

Watson, K.K., and Platt, M.L. (2008). Neuroethology of reward and decision making. *Philosophical Transactions of the Royal Society of London B, 363,* 3825–3835.

Wittchen, H.U., Jacobi, F., Rehm, J., Gustavsson, A., Svensson, M., Jonsson, B., Olesen, J., Allgulander, C., Alonso, J., Faravelli, C., Fratiglioni, L., Jennum, P., Lieb, R., Maercker, A., Preisig, M., Salvador–Carulla, L., Simon, R., Steinhausen, H.C. (2011). The size and burden of mental disorders and other disorders of the brain in Europe 2010. *European Neuropsychopharmacology, 21,* 655–679.

Young, F.B.J. (2007). A life without pain? Hedonists take note. *Clinical Genetics, 73*, 31–33.