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Review

The cognitive activation theory of stress

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Abstract

This paper presents a cognitive activation theory of stress (CATS), with a formal system of systematic definitions. The term ‘stress’ is used for four aspects of ‘stress’, stress stimuli, stress experience, the non-specific, general stress response, and experience of the stress response. These four meanings may be measured separately.

The stress response is a general alarm in a homeostatic system, producing general and unspecific neurophysiological activation from one level of arousal to more arousal. The stress response occurs whenever there is something missing, for instance a homeostatic imbalance, or a threat to homeostasis and life of the organism. Formally, the alarm occurs when there is a discrepancy between what should be and what is—between the value a variable should have (set value (*SV*)), and the real value (actual value (*AV*)) of the same variable. The stress response, therefore, is an essential and necessary physiological response. The unpleasantness of the alarm is no health threat. However, if sustained, the response may lead to illness and disease through established pathophysiological processes (‘allostatic load’).

The alarm elicits specific behaviors to cope with the situation. The level of alarm depends on expectancy of the outcome of stimuli and the specific responses available for coping. Psychological defense is defined as a distortion of stimulus expectancies. Response outcome expectancies are defined as positive, negative, or none, to the available responses. This offers formal definitions of coping, hopelessness, and helplessness that are easy to operationalize in man and in animals. It is an essential element of CATS that only when coping is defined as positive outcome expectancy does the concept predict relations to health and disease.

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Keywords: Arousal; Coping; Defense; Expectancy; Helplessness; Hopelessness

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1. Introduction

Stress is an old term, in English used for pressure or distress at least from the 13th century, and related to sources of strain. The purpose of this paper is to present a cognitive activation theory of stress (CATS). Over the last 30 to 40 years a considerable empirical basis has been established for the role of cognitive factors for 'stress' in man and animals. Ignoring this results in many claims of relationships between 'stress', strain, and health and are simply not true. We believe that a more precise and formal set of definitions may reduce the bewildering use of terms, which may cover the same phenomena. Therefore, CATS offers definitions formulated in symbolic logic presented separately at the end of this paper.

This is 'cognitive' stress theory because CATS assumes that the stress response depends on acquired expectancies of the outcomes of stimuli and available responses. We regard these as acquired (learned) relations between stimuli, and between responses and stimuli. We will deal with these phenomena as information-handling systems of the brain, and will accept that all advanced brains have such properties. It is an activation theory since it is based on neurophysiological activation and arousal concepts. It is a stress theory since it aims at explaining the psychobiology of conditions where people use the term 'stress', and are worried about possible health consequences.

2. Historical background

Hans Selye is frequently claimed to be the father of the stress concept. However, in his pioneer 1936 paper (Selye, 1936), a brief note in *Nature*, the term 'stress' was not used. According to tradition, this was because the medical establishment (and the referees in *Nature*?) found the term too unspecific, and too much used as a nonscientific attribution concept by the lay public. In his original 1936 paper, Selye simply described general, non-specific adaptation and maladaptation phenomena in rats exposed to 'various noxious agents' like cold, surgical injury, spinal shock, or sublethal intoxications. His rats progressed from a general, non-specific alarm through an adaptation phase to maladaptation and death. In his first paper, the syndrome was dramatic with a rapid (6–48 h) decrease of thymus, spleen, lymph glands, liver and fat tissue, erosions in the gastrointestinal tract, edema, loss of muscle tone, fall in body temperature, and changes in the adrenals. He compared the condition with histamine 'toxicosis' or surgical shock. After 48 h, there was some improvement which he attributed to a shift in pituitary secretion from growth hormone, gonadotropic hormones, and prolactin to thyrotropic and adrenotropic principles. If the treatment continued, the rats would shift from this 'adaptation' stage to 'maladaptation' and death.

Stress and stressors appear later in his work. From 1949 or 1950 'stress' is his main theme (Selye, 1950). Since he used the term stress on the response rather than the more proper word strain, he had to invent a word for the load or stimulus that triggered this response. This is the origin of the term 'stressor'. Later research

(Mason, 1968) pointed out that the most potent stimuli for pituitary–adrenocortical activity were psychological factors. Although Mason avoided the use of the term stress, the realization of the importance of psychological factors for neuroendocrine regulation ('the Mason principle') has been an important part of later stress theory (Ursin, 1998). It has also been realized that 'stress' is not necessarily a negative factor to be avoided, Selye expressed this by making a distinction between 'eustress' and 'distress' (Selye, 1974).

3. Four aspects of 'stress'

Stress is defined and operationalized by stimuli ('stressors'), subjective reports of an experience (humans only), a general non-specific increase in arousal (activation), and the feedback to the brain from this response (Levine and Ursin, 1991) (Fig. 1).

3.1. The stress stimuli

There seems to be consensus that if there is anything common to the stimuli that produced the state of stress and the stress responses, it was not their physical characteristics (Levine and Ursin, 1991). Whether a stimulus is pleasant or threatening depends on the individual appraisal of the situation, which is based on previous experience and expectations of the outcome. There are some stimuli that would be regarded as negative in most or all situations, and stimuli that will be perceived as positive by some individuals and negative by others. It also depends on the situational setting, and previous learning. What does the stimulus mean, what are the expectancies attached to this particular stimulus? This relates to the next aspect of stress.

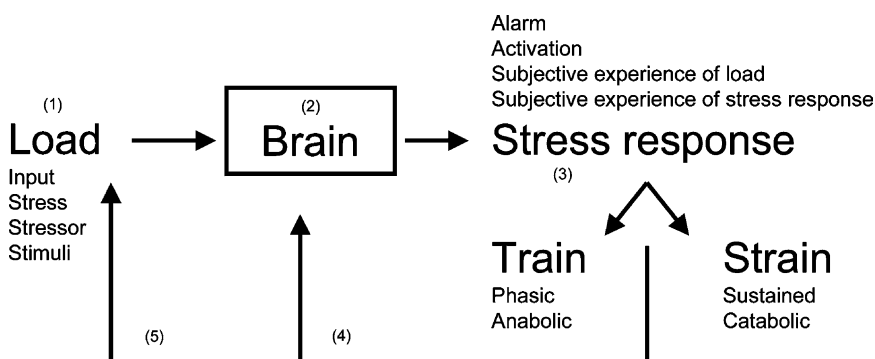


Fig. 1. The four main aspects of stress. The load (1, stressor, stress stimuli) is evaluated by the brain (2) and may result in a stress response (3, alarm) that is fed back (4) to the brain. The physiological stress response may lead to training or straining, dependent on the type of activation. Phasic arousal is seen in individuals with a positive expectancy. Sustained arousal may lead to pathology (strain). The brain may alter the stimulus (5) or the perception of the stimulus, by acts or expectancies.

3.2. *The stress experience*

There seems also to be consensus that all stimuli are evaluated or filtered by the brain, and that psychological, emotional ‘loads’ are the most frequently reported stress stimuli (Levine and Ursin, 1991). Given that a particular stimulus, or set of stimuli, is perceived (appraised) as threatening or negative, humans report this as ‘stress’. Animals are restricted to ‘report’ that this is something they want to avoid. For humans, this particular experience or feeling is easy to measure by interview or questionnaires. Particularly important for many people are concerns and beliefs about the possible health consequences of the state.

3.3. *The stress response*

The general response to stress stimuli is a non-specific alarm response, eliciting a general increase in wakefulness and brain arousal, and specific responses to deal with the reasons for the alarm. We will refer to this increase in arousal as activation. CATS, therefore, is an activation theory, or, more precisely, a theory built on general arousal and activation theory (Moruzzi and Magoun, 1949; Hobson and Brazier, 1980; Steriade, 1996). The increase in arousal manifests itself in many or most organ systems, with individual and situational variance in strength, reciprocal relations, and time parameters (Eriksen et al., 1999a).

3.4. *The feedback from the stress response*

The final link in the total stress concept is the feedback loop from the peripheral changes back to the brain, the experience of the stress response, which adds to the feeling of being stressed, the James–Lange principle in emotional theory. Similar positive feedback mechanisms exist in the rat, but require indirect measurements. The specific responses (coping attempts or strategies) may alter the stimulus situation (Section 3.1), and these effects will be stored as response outcome expectancies.

4. Measurement of ‘stress’

The four aspects of stress offer four ways of measuring ‘stress’. Current methods may cover one of the meanings, sometimes more than one meaning. The load (stimulus or ‘stressors’) (aspect 1) may be easy to measure, and often impress as the most objective way of measurement. However, even if it is easy to quantify external factors, it is the social and emotional factors that may determine survival in extreme environments (Ursin et al., 1991).

The experience or feeling of stress (aspect 2) is perhaps the most relevant in human stress research in working life. Questionnaires for job stress, for instance, are often constructed for this principle, asking whether a certain work condition or relationship is a ‘source of stress for you’ (e.g. Coopers stress questionnaires (Cooper, 1996)). By formulating the question this way, one is actually asking for

the final result of the evaluation the individual has made, based on the expectancies this individual has established for this and similar situations.

The stress response (or responses) (aspect 3) is the easiest to measure. Since arousal affects almost all organ systems, there is an abundance of methods from psychophysiology, psychoendocrinology, psychoimmunology, behavioral analyses, and brain biochemistry. A substantial number of current publications present new ways of measuring changes in physiology following some ‘stressor’. There is a traditional preoccupation with the pituitary–adrenal axis (Mason, 1968; Levine, 2000) and the catecholamine axis (Goldstein, 1995), or the interaction between these two systems (Kvetnansky et al., 1995). Most acute stress situations activate these axes, as well as most other physiological systems. The time axes differ, and reciprocal and homeostatic mechanisms must be taken into account (Eriksen et al., 1999a). Evaluation of behavior is also used, but should be used with caution. Stress related behaviors (‘coping attempts’, Weiss, 1972) or strategies (‘ways of coping’, Lazarus and Folkman, 1984) may be executed under varying degrees of arousal, depending on the expectancy attached to that specific behavior (Gunnar et al., 1996; Levine, 2000).

The feedback from the responses (aspect 4) is used in many questionnaires in human research. It is an essential element of many anxiety scales (Spielberger, 1976), and questionnaires on health complaints (Eriksen et al., 1999b). Most subjects will probably not distinguish between aspect 2 and 4, both blend in a positive feedback loop essential for the experience of any emotion. In animals it seems reasonable to assume that cue effects from peripheral arousal may play a role for state-dependent emotional and stress-related behaviors.

5. When does the alarm occur?

The stress response is a general, unspecific alarm response occurring whenever there is a discrepancy between what is expected or the ‘normal’ situation (set value) and what is happening in reality (actual value) (Table 1).

In general, the alarm occurs in all situations where expectancies are not met. It occurs to ‘novel’ stimuli, in situations where there is something missing, or where there is a homeostatic imbalance, or when there is a threat to the organism (Levine and Ursin, 1991). This follows very simple and basic principles from general control theory, and represents cognitive reformulations of homeostatic theory. The alarm occurs whenever there is a discrepancy between what should be and what is—between the value a variable should have (set value (SV)), and the real value (actual value (AV)) of the same variable (see statement 1, Table 1).

All brains have many such set values, with corresponding actual values, one for each of the systems the brain controls. These systems are often referred to as ‘motivational systems’. The alarm continues until the discrepancy is eliminated, by changing the AV, or the SV, when this is possible (statement 2, Table 1). The alarm is uncomfortable, the alarm is the ‘drive’ component that is required to make drive reduction theory work since it ‘drives’ the individual to the proper solutions.

Table 1
When does activation occur?

For all variables controlled by the brain, at any point in time:
 ‘Set value’ (SV): the value brain is ‘set’ on for that particular variable
 ‘Actual value’ (AV): the real value of that variable.
 Statement 1a: $(SV \neq AV) \Rightarrow \text{Activation}$
 and
 Statement 1b: $(SV = AV) \Rightarrow \text{No activation}$
 Statement 1a is to be read: When the set value differs from the actual value this implies (\Rightarrow) activation.
 Activation will sustain itself until activation affects mechanisms that serve to solve the underlying discrepancy, by changing the actual values, or the set value when possible, or shifting to other motivational systems (other SVs).
 Since (1):
 Statement 2: $(SV - AV \neq 0) \Rightarrow \text{Activation} \rightarrow ((SV - AV) \rightarrow 0)$
 Statement 2 is to be read: When the set value differs from the actual value this implies activation which, in turn, may lead to this difference being reduced or abolished.

Finally, the alarm is a safety system, which guarantees priority to serious and sudden discrepancies.

6. Expectancy: what does the stimulus mean, what can I do about it?

All brains store the relations between stimuli, and between responses and stimuli. This stored (learned) information is referred to as expectancy (Table 2).

The second consensus statement formulated by Levine and Ursin (1991) was that the input is evaluated or filtered before it gains access to any response system. In CATS, two filters (or gates) are defined, one related to stimulus expectancies, and

Table 2
The expectancy concept

Stimulus expectancy: Statement 3
 When the subject has learned that one stimulus (S1) predicts the occurrence of another event (S2) this is referred to as stimulus expectancy:
 Statement 3: $_{S1}E_{S2} = (S1 \Rightarrow S2)$
 Statement 3 is to be read: The stimulus expectancy S1–S2 means that S1 implies S2.
 In classical conditioning, S1 is the conditioned stimulus (CS), S2 is the unconditioned stimulus (UCS), and the conditioned response is the response to expecting the UCS.
 Response outcome expectancy: Statement 4
 When the subject has learned that performance of a response (R1) brings a certain outcome (S2): $(R1 \Rightarrow S2)$, this is referred to as response outcome expectancy:
 Statement 4: $_{R1}E_{S2} = (R1 \Rightarrow S2)$
 Statement 4 is to be read: The R1 expectancy of S2 means that R1 implies S2.

one to response outcome expectancies (see Fig. 2). The first filter is related to defense mechanisms, the second to coping, helplessness and hopelessness.

Expectancy is a particular brain function of registering, storing and using the particular information that one stimulus (event) precedes a second stimulus, or one response leads to a particular outcome. Brains learn (store) that certain stimuli or responses precede other stimuli. To perform complex acts like catching an insect a frog must direct its movements to where the prey is expected to be in the next time interval. When the brain has established that one event precedes another, the brain 'expects' the second event after the first event has been presented or the response has been performed.

Expectancy is an essential element in many reformulations of learning theory from the last decades (Dickinson, 1989). Edward Tolman (1886–1959) used the concept, systematized to a Hull-like set of postulates by MacCorquodale and Meehl (1953). The formulations in the present paper rest heavily on Bolles' cognitive formulations (Bolles, 1972), which follow closely those of Tolman. When a rat learns an instrumental response for food, it typically first learns that certain cues predict food, and then learns that certain responses produce food, for instance pressing a bar in the Skinner operant box. In an avoidance situation, it first learns the stimulus contingencies predicting shock, and then learns that it is possible to avoid the shock.

These formulations represent a 'two process' theory of learning. Several formulations exist (Mowrer, 1960; Rescorla and Solomon, 1967; Gray, 1975). Briefly, there are two stages in any learning situation. The first stage, stimulus–stimulus learning, is to be regarded as classical conditioning. The second stage, response learning, represents instrumental conditioning. This position is developed further to regard phase one (classical conditioning) as acquisition of stimulus expectancies, phase two (instrumental conditioning) as acquisition of response expectancies. These cognitive reformulations of learning theory are essential for the CATS positions on the relationship between learning, activation, and the relations between 'stress' and health. It is

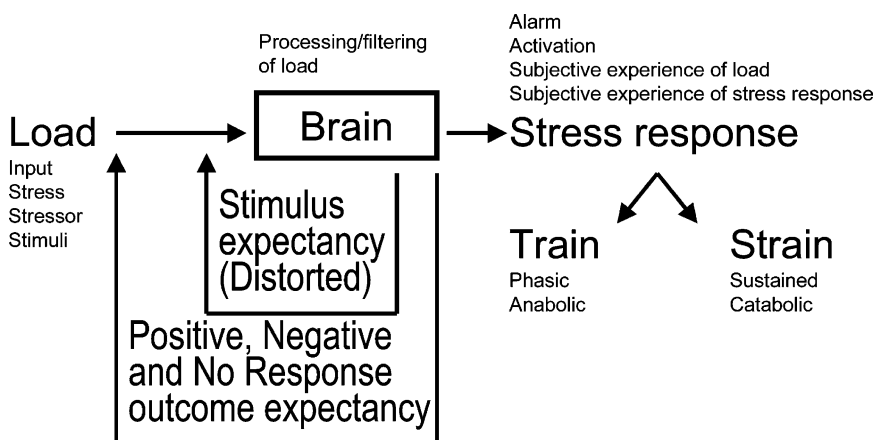


Fig. 2. The two main 'filters', the stimulus expectancy (defense), and the response outcome expectancies (coping, hopelessness or helplessness; i.e. positive, negative, and no expectancy).

also essential for CATS that it is the perceived relationship that counts for stress responses and stress consequences, not the objectively true contingencies.

7. Dimensions of expectancy

Expectancies are quantified by three dimensions: acquisition strength, perceived probability, and affective value (Table 3).

The acquisition strength (H ‘habit value’) (Bolles, 1972: ‘the strength’) of an expectancy expresses that expectancies are acquired, according to the general principles of learning theory. The terminology is chosen in reverence of the Hullian habit value concept for this dimension. Whether learning will occur or not, and how strong the learning will be, depends on properties of the events, the contiguity in the presentation, the number of presentations, and how often the events are occurring together (the predictive value).

The perceived probability (PP) (Bolles, 1972) of an expectancy expresses the probability of the expected event, as it is perceived by the individual. This is a subjective evaluation of the probability based on learning (the H value). It may differ consider-

Table 3
Dimensions of the expectancy concept

Acquisition strength

Acquisition strength is referred to as H (‘habit value’), which is assumed to have values between 0 (minimum) and 1 (maximum). Formally, the strength of $S1 \Rightarrow S2$ is expressed by $H_{(S1E_{S2})}$ and has values between 0 and 1:

Statement 5a: $H_{(S1E_{S2})} \in (0,1)$.

Or, in more detail:

Statement 5b: $\forall_{S1E_{S2}} \exists H_{(S1E_{S2})} \in (0,1) \{0\}$.

Statement 5b is to be read: For all $S1E_{S2}$ there is an H -value between 0 and 1. When the H value is close to zero, there is no expectancy ($\{0\}$).

The same is true for $R1E_{R2}$:

Statement 6: $H_{(R1E_{R2})} \in (0,1)$.

Perceived probability:

The subjective predictability and control which is referred to as ‘perceived probability’ (PP) will also be attributed values between 0 (very low perceived probability) and 1 (very high perceived probability). Formally, for stimulus expectancies:

Statement 7: $PP_{(S1E_{S2})} \in (0,1)$.

For response expectancies:

Statement 8: $PP_{(R1E_{S2})} \in (0,1)$.

Affective value:

The reinforcing or attractive/aversive value of the expected outcome or stimulus event will be referred to as the affective value (A) and will be allocated values from -1 (highly unattractive) to $+1$ (highly attractive). Formally:

Statement 9: $A_{(S1E_{S2})} \in (-1, +1)$, and $A_{(R1E_{S2})} \in (-1, +1)$

The affective value of an expectancy depends on (is a function) (f) of the expected event $S2$.

Therefore:

Statement 10: $A_{(S1E_{S2})} = f(A(S2))$ and $A_{(R1E_{S2})} = f(A(S2))$.

ably from the true or objective probability. For the stimulus expectancies a high level of perceived probability is often referred to as predictability, high levels of perceived probability for response outcomes may be referred to as control.

The affective value (A) of an expectancy covers the ‘hedonic’ value of the expected outcome, i.e. whether the expected outcome is attractive, aversive, or neutral (Irwin, 1971). This decides the reinforcing properties of the expected event.

8. The CATS coping concept: positive response outcome expectancy

Coping is the acquired expectancy that most or all responses lead to a positive result. This leads to a reduced arousal level (Table 4).

In English, and in the stress literature, coping is used in many meanings. Most commonly the term covers either the act or the result. What do you do (coping attempts, ‘ways of coping’), and what is the result? In CATS it is the result that counts.

The most adequate way of reducing arousal to a threat is to reduce or eliminate the threat itself by action. This is the simplest definition of coping, the coping act. There is also a second meaning, the individual establishes an expectancy of being able to cope. This is the CATS definition, coping is a positive response outcome expectancy. The double meaning in common language has, in our opinion, unfortunate effects on the scientific and the clinical literature. It is only when defined as positive outcome expectancy that the term coping has any predictive value for stress,

Table 4
Coping defined as positive response outcome expectancy

Coping is a positive response outcome expectancy

(Approach learning: $A(S_2) \rightarrow 1$):

Statement 11: $H_{(R_1)E_{S_2}} \rightarrow 1$, $PP_{(R_1)E_{S_2}} \rightarrow 1$, $A(S_2) \rightarrow 1$

Statement 11 is to be read: The habit value of R1 leading to S2 is high, the perceived probability of R1 leading to S2 is high, and the affective value of S2 is high.

(Avoidance learning: $A(S_2) \rightarrow -1$):

Statement 12: $H_{(R_1)E_{S_2}} \rightarrow 1$, $PP_{(R_1)E_{S_2}} \rightarrow 1$, $A(S_2) \rightarrow -1$ Since $A(S_2) \rightarrow -1$, R1 is abolishing a negative event, therefore $A_{(R_1)E_{S_2}} \rightarrow +1$.

Statement 12 is to be read: The habit value of R1 leading to the abolishment of S2 is high, the perceived probability of R1 leading to the abolishment of S2 is high, and the affective value of S2 is low. Since the affective value of S2 is negative, R1 is abolishing a negative event, therefore, the affective value of R1 abolishing S2 is positive.

Comments: It follows from Statement 12 that discussions on whether avoidance behavior is maintained by ‘safety’ or ‘residual fear’ are a sham problem. Since $-(-1) = +1$, there is no logical reason to prefer one of the two expressions, it is really the same whether one deals with the negative affect of S2, or the positive affect of S2.

Given that SV is to obtain a highly attractive stimulus (S2 with a high A value), it follows from Statement 1b that the arousal level is expected to be low when coping exists.

arousal, and health. Our formal definition of coping, therefore, is crucial for the CATS position.

Weiss (1968) was the first to use coping in the animal literature, but not in our meaning. He claimed that numerous coping attempts, in the absence of feedback, would result in stomach ulcers and a depletion of noradrenaline in the brain. Coover et al. (1973) used coping specifically for rats in avoidance learning. When given shocks for the first time, rats showed a high level of arousal, behaviorally and measured by a rise in plasma corticosterone. However, when the avoidance response had been well established, there was a clear-cut reduction in the corticosterone level, and in overt expressions of behavior. The authors concluded that the animals had learned not only a correct response, but also that this response eliminated the shocks, and used the term ‘coping’ for this type of learning. They described the animal as ‘a minimally aroused, behaviorally relaxed, coping rat’.

Many previous authors had commented upon the relaxed nature of the animals in late stages of avoidance. When the performance is approaching a level of perfection, the performance becomes stereotyped (‘asymptotic’, ‘mastery’) with a decrease in overt emotional reactions (Solomon and Wynne, 1953). Within traditional learning theory, the reduction in overt fear is due to the avoidance responses, removing the animal from the fear stimulus. However, this reduction is so fast and efficient that it terminates the anxiety reaction before ‘it is more than minimally elicited’ (Solomon and Wynne, 1954). In CATS we suggest that this low level of arousal is due to an expectancy of future events, tied to the expectancy of a positive outcome of the avoidance act.

Ursin et al. (1978) tested this position in an experiment with parachutists. They assumed that when the trainees had acquired the proper response, arousal would be reduced. It turned out that the ‘coping’, the trust in one’s own abilities to perform jumps, came very early in a learning phase. Actually, in a training tower situation, the subjectively reported fear, and the vegetative and endocrine responses to the jump, were reduced after the first training sessions, long before their performance had reached any acceptable level (Ursin et al., 1978). It was not the performance, or the feedback from evaluation of the performance, that mattered, it was the subjective feeling of being able to perform that reduced the ‘stress’ responses.

9. Helplessness

Helplessness is the acquired expectancy that there are no relationships between responses and reinforcement (Table 5).

What happens when coping is impossible? This may occur in experimental situations with uncontrollable and unpredictable negative events, or in humans subjected to unpleasant life events beyond their control. Formally, in this case, the expectancy is that there is no relationship between anything the individual can do and the outcome. The classical experimental situation is the experimental neurosis occurring after unpredictable negative events (Pavlov, 1927). Mowrer and Viek (1948) intro-

Table 5

Helplessness and hopelessness defined as response outcome expectancies

Helplessness exists when:

Statement 13: $H_{(R_1E_{S2})} \rightarrow 1$, $PP_{(R_1E_{S2})} \rightarrow 0$, $A_{(S2)} \rightarrow -1$,

$$PP_{(R_1E_{S2})} \sim PP_{(R_1E_{S2})}$$

Statement 13 is to be read: Helplessness exists when the perceived probability of avoiding an unpleasant stimulus approaches zero. (Detailed readout: see Statement 11)

Comment:

From Statement 1a the arousal level is expected to be high. For prolonged states, at least with positive affective value for S2, Statement 15 may predict low arousal.

Hopelessness exists when:

Statement 14: $H_{(R_1E_{S2})} \rightarrow 1$, $PP_{(R_1E_{S2})} \rightarrow 1$, $A_{(S2)} \rightarrow -1$.

Statement 14 is to be read: Hopelessness exists when there is a very high probability that available responses bring results of high negative affective value.

Comment:

Statement 1a predicts high arousal levels.

duced the term ‘sense of helplessness’ for the condition arising from non-escape situations. When escape is possible, there are no or at least less disruptive effects (Mowrer and Vieck, 1948).

Two of Solomon’s students, Overmier and Seligman (1967), found that dogs with previous experience with inescapable shocks did not learn avoidance tasks. They found that this state of ‘helplessness’ generalized to situations where control is possible. Translated to CATS, the perceived probability of avoiding the aversive stimulus with a response is the same as for no response. In other words, the response is without any perceived consequence for the occurrence of the aversive event. The organism has no control.

An essential feature of helplessness is that it tends to become a generalized response expectancy, for all possible responses, in man as well as in animals. This is the background for Seligman’s offering helplessness as a cognitive model for depression (Seligman, 1975). The changes in hormones, immune variables, and brain biochemistry during prolonged states of helplessness (Murison and Overmier, 1993) support the validity of this model. However, when the ‘helplessness’ expectancy is truly approaching zero, and the individual ‘accepts’ that there is no solution, the arousal may be reduced. Arousal may also be reduced if the helplessness leads to secondary gain and support from society. In such cases, helplessness may function as a coping strategy, and the secondary gain may reinforce and sustain the helplessness condition.

10. Hopelessness: negative response outcome expectancy

Hopelessness is the acquired expectancy that most or all responses lead to a negative result (Table 5).

Hopelessness is more directly opposite of coping than helplessness, since it is a negative response outcome expectancy. There is control, responses have effects, but they are all negative. The negative outcome is his or her fault since the individual has control. This introduces the element of guilt, which may make hopelessness a better model for depression than helplessness (Prociuk et al., 1976; Johnson et al., 2001). Depression defined as a generalized negative expectancy is now an important part of the cognitive tradition in depression research and treatment (the ‘hopelessness theory of depression’, Alloy et al., 1999).

The logical and psychological differences between helplessness and hopelessness, as defined here, may imply neurobiological differences between the two states. Given that depression is best expressed as hopelessness, post-traumatic stress disorder (PTSD) may be more related to helplessness, as defined here. The intensity of PTSD depends not only on the traumatic event, factors like ‘lack of control’ and ‘predictability’ also matters (Yehuda, 2002). This offers an interesting possible psychobiological explanation for the described differences in the hypothalamic–pituitary–corticotropin axis (HPA) for PTSD and depression (Yehuda, 2002). In PTSD the axis is more sensitive than normal, while depressed patients, in general, are less sensitive in this axis.

11. Coping with coping concepts

Many concepts cover coping strategies and the expectancy attached to such responses.

11.1. *Ways of coping, coping strategies, coping style*

The ‘ways of coping’ questionnaire has been a very important instrument (Lazarus and Folkman, 1984). It has also had an important impact on stress theory. However, the strategy chosen does not predict the internal state, and, therefore, it does not predict health effects. On the other hand, it is obvious that the strategy chosen must be based on experience and rewards. Successful responses generalize to similar strategies in similar situations, which then develops into the ‘coping style’ of that individual. Since this preference for particular coping or defense styles seems relatively stable, it is often regarded as a characteristic of the personality (‘trait’) (Folkman and Lazarus, 1990).

11.2. *Formal (or ‘objective’) work conditions*

‘Control’ is frequently used to cover the ability to handle stress and work, in many ways for the phenomena we refer to as ‘coping’. In humans, the control term is used in the most influential model in the analyses of potential psychosocial work factors for health, the demand–control model (Karasek and Theorell, 1990). According to this model, it is the combination of psychological demands, task control and skill use at work that predicts work-related ill health. Individuals working in a job where they have high demands, low control, and low social support carry the highest risk

of illness and disease (Karasek and Theorell, 1990). Low psychological demands and high levels of control carry the lowest risk. High psychological demands and high control, and low psychological demands and low control have an average risk. However, for the internal state it is the results that count. When the control is combined with positive outcome expectancy the predictive power increases, at least for subjective health factors as muscle pain and fatigue (Eriksen and Ursin, 1999).

Hopelessness also involves control; the difference is that the result is unacceptable and unpleasant. CATS defines ‘control’ as an acquired perceived high probability of a given response outcome, regardless of the value of the outcome. The term ‘control’, therefore, albeit related to coping, is not an identical phenomenon. The essential aspect is the subjective or perceived feeling of being able to control the situation (Skinner, 1996), which may develop into positive response outcome expectancy. The generalization of the expectancy from one situation to all situations is an important aspect (Skinner, 1996). Individuals feeling that they have control over their situation are said to have an internal ‘locus of control’ (Rotter, 1975).

Self efficacy (Bandura, 1982) is another related concept, defined as the belief that an individual can act in a way that leads to a particular goal. When this expectancy is generalized it becomes identical with the CATS coping concept. However, most often the term is related to one particular strategy or treatment. The generalized self-efficacy concept also relates to self-esteem, neuroticism, and locus of control, as measured with standardized questionnaires (Judge et al., 2002). This indicates a common core construct, which may be what the CATS coping concept is all about.

There are also other related, or perhaps identical, terms. Toughness, an increased ability to deal with the stressor (Dienstbier, 1989), develops through repeated exposures to a variety of stressors. Other related concepts are hardiness (Kobasa et al., 1982), high self-esteem, affective stability (Zorrilla et al., 1995), mastery (Pearlin et al., 1981), sense of coherence (Antonovsky, 1987), and older concepts like the ‘instinct of mastery’ of Hendrick (1943), and the effectance concept of White (1959). We do not claim that this list is complete. In our opinion, it emphasizes the need for formal, rather than verbal definitions of core concepts.

12. Predictability, fear and anxiety

Predictability is used both for the true relations between events, and the subjective or learned (perceived) relation. Only the acquired (learned) relation is related to internal state of the organism. Perceived predictability offers formal definitions of fear and anxiety.

A highly probable, as well as a highly improbable, event are both predictable, and are concurrent with low arousal. Uncertainty produces high arousal. However, predictability in itself is not enough to predict the internal state, or the behavioral consequences. In situations where the affective value of the expected event is highly unattractive, high perceived probability leads to high arousal rather than low. Occurrence of an unattractive event is very much against the set values of an organism

(follows from statement 2). This is a reasonable definition of fear. When the perceived probability of the unattractive event is low, the arousal is low, this is safety. If the perceived probability of an unattractive event is at chance level, that is, the perceived probability is close to 0.5, the arousal is high, this is uncertainty. This is a reasonable definition of anxiety. Fear and anxiety are also often different in time perspective, fear is to a specified event in time and space, anxiety uncertain also for the time dimension.

A very extensive literature from humans and non-humans show that predictability, a sense of control, and feedback all permit the organism to reduce its levels of arousal. This requires information about the relationship between responses and their results. This is referred to as ‘feedback’. Without feedback, rats develop stomach ulcerations (Weiss, 1972). Low feedback affects the level of corticosterone. This is a remarkable efficient and sensitive principle. In rats it was sufficient to shift from fixed ratio of reinforcement to the same, but variable ratio (Goldman et al., 1973) to produce significant increases in plasma corticosterone.

13. Set values, expectancies, and access to the activation of the arousal system

Stress (alarm) occurs when something is missing, i.e. when there is a discrepancy between goals (*SV*) and reality (*AV*). The probability of eliminating such discrepancies influences access to the arousal system (Table 6).

The Sokolov (1963) model for orienting responses and habituation was important for the development of cognitive theory and control theory in neuroscience. Sokolov ascribed orienting responses—and neurophysiological activation—as responses to mismatches between what was expected (set value) and what really happened (actual value). Orienting responses, in man and animals, occurred to events that did not correspond to any templates in the brain. When such templates had been acquired, there was no longer a response to the stimulus, the ‘orienting reflex’ was extinguished (habituation).

Sokolov based his theory on sudden, short-lasting events, CATS expands this to include all events with mismatch between set values and actual values. Sokolov demonstrated that orienting also occurs when an expected stimulus does not appear, or when response expectancy is not met. Corticosterone levels increase during early extinction trials (Coover et al., 1973). Levine and Ursin (1991) have pointed out that ‘stress’ occurs when something is missing, and that the arousal level is reduced when expectancies are met. Rats trained to barpress for water on continuous reinforcement (CRF) have higher values if shifted to a variable interval (VI) schedule, while VI trained rats have lower values if shifted to a CRF schedule (Goldman et al., 1973). Predictability, therefore, is important for arousal.

The affective value of the expected event also counts. Cues signaling positive events (e.g. food to hungry rats) produce a decline in the corticosterone response (Coover et al., 1977). Thirsty or hungry rats have high levels of plasma corticosterone

Table 6

Access to the activation system

Access to the activation and arousal system depends on the perceived probability of success

Low probability:

Statement 15: $\text{Activation} \rightarrow 0$ if $SV_1 \neq AV_1$, and if $PP((SV_1 - AV_1) \rightarrow 0) \rightarrow 0$

Statement 15 is to be read: For any particular motivational system with a difference between the set value SV_1 and actual value AV_1 , the arousal is reduced by low or eliminated activation if there is a low (perceived) probability that the difference between the set value and the actual value will be eliminated.

High probability:

Statement 16: $\text{Activation} \rightarrow 0$ if $SV_1 \neq AV_1$, and if $PP((SV_1 - AV_1) \rightarrow 0) \rightarrow 1$

Statement 16 is to be read: For any particular motivational system with a difference between the set value SV_1 and actual value AV_1 , the arousal is reduced by low or eliminated activation if there is a high (perceived) probability that the difference between the set value and the actual value will be eliminated.

These processes contribute to the hierarchy of motivational systems:

Statement 17:

If $SV_1 - AV_1 \neq 0$ and $SV_2 - AV_2 \neq 0$,

and if $PP(R_1 \Rightarrow (SV_1 - AV_1) \rightarrow 0) > PP(R_2 \Rightarrow (SV_2 - AV_2) \rightarrow 0)$

and if $A(SV_1) \sim A(SV_2)$,

then

$P(R_1) > P(R_2)$

Statement 17 is to be read: When an organism is faced with two problems, and the perceived probability of solving problem 1 is greater than for the second problem, the probability (P) of the behavior (R_1) involved in the solution to the first problem will be greater than the behavior involved in the second problem (R_2).

when there is uncertainty about whether food (or water) is coming or not, and low levels when there is a very high or very low probability that food (or water) is coming (Coover et al., 1984). The perceived probability of success, therefore, has a decisive influence on the arousal level. Increased arousal, or 'stress', is not a direct function of deprivation unless there is some probability that the missing item may be available. From a biological point of view it would be inadequate if, for instance, the food or water-deprived animal kept running around in its cage when food or water is not available. Instead, they are quiet until some cue signals that the deprivation period may be over.

We propose that the probability of success have consequences also for the hierarchy of set values. This is an important psychological function. At any point in time, the brain monitors many set values, and some selection mechanism must be operating. Detailed and complex models for such shifts have been introduced in ethology motivation theory (see Toates, 1995).

14. Activation and arousal theory

Stress is an adaptive response

The ability to respond to changes and challenges in the environment with a general alarm response should be regarded as an essential element in the total adaptive and self-regulating system of the organism (Levine and Ursin, 1991). Since arousal and 'stress' are essential elements in all complex brains—in fish, birds, and mammals—the activation response must be assumed to be 'adaptive'. The response is uncomfortable and drives the organism to provide specific solutions to abolish the source of the alarm, as well as the alarm itself. The arousal will be sustained until the reason for the arousal is eliminated. In other words, arousal turns off arousal by initiating and driving the system to produce the proper actions. The stress response, therefore, is an optimal, positive and desirable alarm response, where physiological resources are mobilized to initiate and improve performance. It provides the necessary tool for an immediate resetting of priorities, and for sustained alarm if the correcting devices are insufficient. In its simplest form, the orienting response to novel stimuli, the first part of the response is an arrest of all ongoing activity (Kimmel et al., 1979). The more complex forms secure the possibility of resetting priorities when required.

15. Psychological defense

Stress may be reduced by distortion of stimulus expectancies.

Within traditional ego psychology or psychodynamic theory coping was one of many ways to defend (Haan, 1977). This is still influential in literature on stress, and in many animal studies. Toates (1995) defined stress as a 'chronic state that arises only when defense mechanisms are either being chronically stretched or are actually failing'. To Folkman and Lazarus (1990) defense is a coping strategy.

Within ego psychology, the first systematic use of a coping concept as distinct from defense seems to occur in 1963 (Kroeber, 1963; Haan, 1977). Coping has been suggested to be the highest and most mature ego process (Vaillant, 1971). Haan (1977) saw all strategies used to handle threats as having two poles, one related to defense, one to coping. Defense involved distortions of reality, coping was used for strategies associated with accepting the true nature of the situation. In other words, she used the term coping only for strategies that did not involve defensive distortions of reality: 'Cope if you can, defend if you must'. Recent distinctions between 'adaptive' and 'non-adaptive' coping are, in our opinion, better explained within this theoretical framework. From a theoretical point of view, 'emotion focused coping' (Folkman and Lazarus, 1990) should relate to defense defined as stimulus distortions. However, in our own operationalizations of the original Lazarus questionnaires this factor did not carry much of the variance. It lost out to instrumental coping, defensive hostility (acting out coping style), and cognitive defensive strategies (denial and disengagement) (Eriksen et al., 1997).

In CATS, defense and coping are defined as clearly distinct phenomena. Defense is related to stimulus expectancies, coping to response expectancies. Defense, therefore, is a filtering mechanism different from coping. It covers cognitive mechanisms that distort, denies or explains away threatening stimuli. This means defense is related to the stimulus expectancies (Bolles, 1972), while coping is related to response outcome expectancies. Psychological defense reduces the endocrine response to a threatening stimulus, without the individual being aware of this strategy. Defense is operationalized with questionnaires, tachistoscopic methods, or clinical interviews (Olf et al., 1991). Individuals with high defense mechanisms (tachistoscopic evaluation) differ from others in their electroencephalographic and evoked responses to new and threatening information (Eriksen et al., 2000).

Reducing fear by distortion of true relations between stimuli may be dangerous, particularly in situations where the stimulus really is signaling physical danger. Accordingly, there are controversial claims that perceptual defense measured with a tachistoscopic technique predicts inadequate behavior in many different types of dangerous tasks requiring split second decisions (Torjussen and Værnes, 1991).

16. Sustained high levels of arousal and health

Only sustained high arousal levels constitute a potential health risk.

Weiss (1968, 1972) claimed that numerous coping attempts, in the absence of feedback, would result in stomach ulcers and a depletion of noradrenaline in the brain. We have regarded this as sufficiently analog to the situation in humans, as described by Karasek and Theorell (1990), to produce a composite figure comprising both sets of data (see Fig. 3). The model predicts disease, especially related to cardiovascular disease.

The stress response is dynamic and develops over time (Eriksen et al., 1999a). In a healthy organism, a short-lasting activation has no proven ill effects. When coping has been established, there is still a short-lasting phasic arousal when individuals handle a difficult task (Ursin et al., 1978). In humans this arousal seems to be limited to epinephrine (not norepinephrine), heart rate increase, and a modest testosterone rise (Ursin et al., 1978; Arnetz, 1984, 1996). This arousal pattern, therefore, may have training effects, but, to the best of our knowledge, no straining effects, and may be referred to as an anabolic stress response (Arnetz, 1984, 1996).

Repeated, but brief exposures leading to alarm and arousal ('allostasis', Sterling and Eyer, 1988) have been of some concern, particularly in cardiovascular pathology. Homeostatic mechanisms may be taxed too much, producing lasting changes ('allostatic load', McEwen, 1998). Recent data point to the importance of resetting the 'normal' values, an increased need for recovery (Sluiter et al., 1999). In exposed groups, basal values may be increased, while stress values are lower than in coping control subjects (Kristenson et al., 1998). Within CATS, such changes are expected in individuals faced with challenges they do not expect to be able to handle.

Sustained ('tonic') arousal, in particular sustained high levels of norepinephrine,

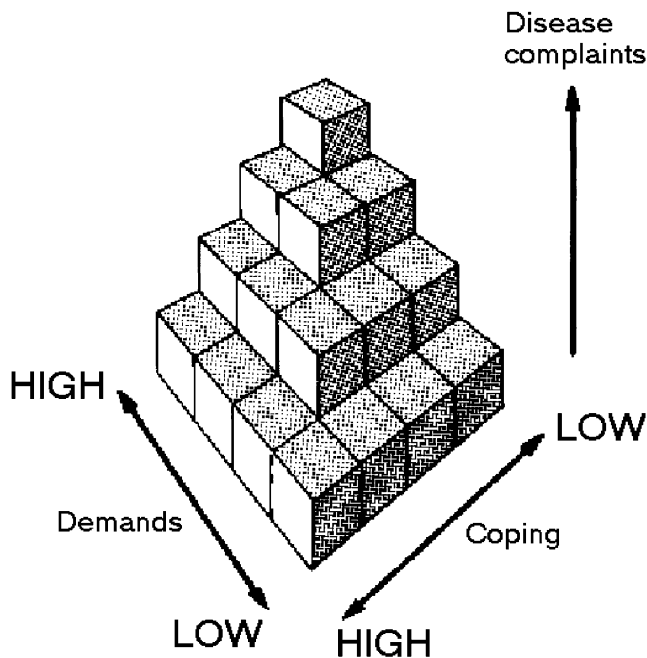


Fig. 3. Modified from [Ursin and Murison \(1983\)](#). Composite figure, based on relations described in animals and in humans. Disease, illness, and subjective health complaints are highest in individuals with high demands and low control in humans ([Karasek and Theorell, 1990](#)). In animals high levels of coping attempts (demands) combined with low levels of feedback (control) produced ulcers ([Weiss, 1972](#)). In our own studies we get the best predictions for subjective health complaints when the axes are labeled 'demand' and 'coping' ([Eriksen and Ursin, 1999](#)).

cortisol, vagal discharges, and thyroxin may produce somatic pathology ([Ursin and Murison, 1983](#)). Animals that are left in situations beyond their control ([Murison and Overmier, 1993](#)) may develop gastric ulcerations, hypertension, cardiac failure, immunological deficits, or changes in the brain biochemistry similar to those occurring during depression and psychoses ([Ursin and Murison, 1983](#)). In humans, it is generally assumed that similar situations may produce disease and or illness ([Murison and Overmier, 1993](#)). The striking similarity between the models offered for the relationship between psychological stimuli and health consequences in animals and in humans is illustrated in [Fig. 3](#). The final pathology ('organ selection') depends on genetics and environmental factors interacting with the sustained arousal.

It is widely believed that stress or sustained arousal, produce changes in immune functions. In acute experiments, there is no doubt that arousal has a very significant impact on immune functions ([Olff et al., 1995](#)). However, these changes occur under acute, short-lasting arousal and are part and parcel of the general alarm system, without obvious pathophysiological consequences. The disappearance of natural killer cells and T cells from circulation may simply be a consequence of a physiological adaptation to potential dangers. The cells are where they may be needed, close

to the vessel wall or in the tissues. When sustained, the changes are less impressive, but long-term changes have been reported for immunoglobulins (Endresen et al., 1991) and immune competence, for instance in wound healing (Glaser et al., 1998).

However, the most important route to somatic disease and illness is not the traditional psychosomatic pathways. Life style (smoking, diet, inactivity) is by far the most important killer, and the most important source of illness. Subjective and unexplained health complaints (muscle pain, fatigue, gastrointestinal problems) are the most important sources of sickness absence and encounters with medical care (Eriksen and Ursin, 1999). The unequal social distribution of illness and disease may be related to motivation for choice of life style, which may represent unequal reinforcement schedules for the development of coping (Eriksen and Ursin, 2002).

17. Coping and social status

Social order is related to expectancies, coping and health.

In animals and human societies social order reduces hostility and conflict. Ptarmigans (willow grouse), an arctic bird, establish order during winter. The dominating male has low cortisol, high testosterone, high secondary sexual features, and lower body temperature than subordinate males. Once order has been established, fighting decreases. The catabolic stress responses decreases in the whole flock, most in the dominating male, but also in the subordinate birds. Energy is conserved, which is a condition for survival (Myhre et al., 1981). Similar findings have been reported from other species, including primates (Virgin and Sapolsky, 1997). These psychoendocrine findings are readily explained within the CATS framework. The dominating male has a higher level of positive response outcome expectancy, hence lower arousal. Social order is also established in children, with consequences for the psychoendocrine status (Dettling et al., 1999).

These findings may be relevant for the socioeconomic gradients in health, within most or all societies (Adler et al., 1994; Marmot et al., 1997). Three main sources for these differences have been suggested. General fitness (biological and psychological) determines your status (survival of the fittest), illness may reduce your status (the ‘drift’ hypothesis), and the lower you are on the social gradient, the more ‘stress’ you encounter (Adler et al., 1994). Within CATS, the gradient in health is related to a gradient in general positive response outcome expectancy. There are social differences in the reinforcement contingencies for the development of coping. Success breeds success, higher social classes have a higher chance of developing coping (Eriksen and Ursin, 2002), and, therefore, may have more motivation, information, and trust in life style changes.

18. Brain mechanisms

A prerequisite for the CATS position on stress is a general, non-specific brain stem activation concept.

The concept of arousal entered psychology from neurophysiology, with the documentation of a mesencephalic brain stem system for evoking and maintenance of wakefulness (Moruzzi and Magoun, 1949). The concept has been controversial, but seems to us to be necessary in physiological, psychological, and clinical science, in man and animals. In a Science commentary Steriade (1996) stated that it was ‘encouraging that the concept of brainstem activation of the cortical processes has been rescued from oblivion and substantiated’. Corticocortical and corticothalamic neuronal loops are controlled by activating systems in the brainstem and in forebrain structures (Steriade, 2001). Our position is that this modulation and control depends on the cognitive activity analyzing available information, in this particular situation with the acquired expectancies for this situation.

This activity depends not only on the traditional brain stem systems, but on ‘supra-reticular activating systems’ (Ursin et al., 1967), in particular limbic structures and the frontal lobes. There is no general acceptance of specific circuits (Heilman, 2000), but consensus that amygdala and its connections with hypothalamus are involved, in particular for the arousal effects of helplessness and hopelessness, pain, and fear (Ursin et al., 1981; LeDoux, 1993).

Finally, sustained arousal leads to changes in the brain itself. Helplessness and hopelessness in animals produce the same biochemical changes in the brain as those counteracted with antidepressive and antipsychotic drugs (Shanks et al., 1991). Exposure to inescapable but not escapable shock increases extracellular levels of 5-HT in the dorsal raphe nucleus of the rat (Maswood et al., 1998). Uncontrolled pain, or ‘stress’, bias the brain towards helplessness and depression (Overmier and LoLordo, 1998), whether you look at it from a biochemical or cognitive point of view.

There are also several demonstrations of long-lasting or sustained ‘stress’ affecting even more specific brain mechanisms, depending on cognitive factors. The biochemistry and pharmacology of hippocampus neurons are affected by the controllability of stress stimuli (Wellman et al., 1998). Social stress in primates (Virgin and Sapolsky, 1997) produces receptor changes and morphological changes in the hippocampal pyramidal cells (Sapolsky, 1994). These effects have been related to cortisol (‘cortisol intoxication’, Sapolsky, 1994).

CATS postulates that only sustained arousal constitutes a potential health risk. High levels of transmitters and hormones generally lead to down-regulation of receptors. This may be an important mechanism for loss of dynamic capacity to respond to new challenges, and increased levels of illness and disease. The picture emerging from recent research on brain regulation of endocrine systems is still incomplete, partly because of the lack of consistent nomenclature for ‘stress’. For the HPA axis there are reasonably consistent findings of increased baseline levels of cortisol and attenuated responses to ‘stress’ stimuli, to negative or inconsistent expectancies, and to depression (Kristenson et al., 2003). Cortisol reactivity and regulation have also been related to the long-lasting effects of trauma (‘post-traumatic stress disorder’, Yehuda, 2002). Sustained arousal may lead to a hyporesponsive HPA axis. However, hypocortisolism may be a common phenomenon even in childhood (Gunnar and Vazquez, 2001).

19. Conclusions

CATS differs from many other approaches to 'stress' in the emphasis on the positive health consequences of the normal alarm response, occurring whenever the organism is lacking an essential factor. The theory is an expansion of general arousal and activation theory from neurophysiology. The stress responses are normal activation responses leading to an increase in arousal, and corresponding changes in behaviour as well as in most or all parts of the body. These somatic changes are mediated through well-described and well-understood mechanisms in psychophysiology, psychoendocrinology and psychoimmunology. CATS does not intend to offer new insights in these physiological mechanisms. CATS does intend to offer a systematic insight in the psychological mechanisms explaining when the alarm occurs, and when it may become maladaptive.

The alarm produces non-specific changes as part of a general preparation to face any form of challenge or danger. The alarm produces coping behavior. When that is expected to bring positive results the alarm is reduced or eliminated. CATS differs from common stress concepts in emphasizing the difference between the responses, and the expectancies attached to the responses. When these expectancies are positive, there is no health risk in a healthy organism. Ill-effects occur only when there is a lack of coping. CATS offers strict definitions of two different expectancies occurring when there is no coping: helplessness and hopelessness. Both states may lead to somatic disease through sustained arousal. Both states may also lead to somatic disease and illness through a lack of motivation to engage in positive life styles. CATS, therefore, offers a new and alternative explanation for social differences in health, based on social differences in the reinforcement contingencies for the development of coping.

CATS differs from other stress theories by offering formal definitions expressed in symbolic terms, which makes it possible to arrive at clear definitions and consistent use of language. The stress field offers an abundance of terms, which may or may not cover the same or similar phenomena. Through the use of formal symbolic logic the amount of terms may be reduced, or at least translated into a common language. This formal and systematic theoretical system makes it possible to predict health consequences of the various types of expectancies. The theory also permits comparisons across species, without referring to non-verifiable assumptions of 'mental' activities beyond the assumption that brains handle information according to basic logic principles.

Finally, CATS suggests that new systematic approaches are required for understanding the normal and adaptive functions of the alarm system in the brain. The adaptive functions of the stress responses are not an unfortunate phylogenetic residue. The adaptive functions explain why 'stress' is reported from all complex brains, from fish, birds to mammals. The systematic approach to the expectancies attached to 'stress' stimuli and related responses explains when arousal is sustained and may become a health risk. A better understanding of the relationships between loads, experience of loads, alarm responses, and the subjective experience of these somatic and psychological changes may in itself lead to better understanding, better preven-

tion, better therapy, and healthier lifestyle. Erroneous attributions to normal and adaptive responses are not only wrong. They may actually become true, not because they are true, but because they are held to be true, and give rise to unnecessary concern and worry.

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