neuropeptide will inhibit eating without affecting spontaneous drinking when injected introcerebroventricularly.

Finally, interactions between different motivational drive systems, particularly in the hypothalamus are of paramount importance. For example, the effects of starvation are not limited just to increasing the drive to eat, they also reduce reproductive capacity. Similarly, dehydration leads to severe anorexia as well as increasing the drive to drink (Watts 2001). This cross-behavioral coordination is achieved by hormonal modulation acting together with the divergent neuroanatomic outputs from individual drive networks.

2.4.2 Premotor and motor networks. The brain has three sets of motor neurons with which to effect both motivated behavioral action and the internally-directed motor actions that accompany it: α-motor neurons in the ventral horn of the spinal cord that control the striate musculature and hence the expression of all behavior; postganglionic sympathetic and parasympathetic motor neurons that control autonomic motor function; and sets of parvicellular and magnocellular neuroendocrine motor neurons in the hypothalamus that control pituitary function. Motivated behaviors involve the coordinated activation, to a greater or lesser degree, of all three motor systems (see *Autonomic Classical and Operant Conditioning*; *Neuroendocrinology*).

Sets of premotor networks directly control oscillatory and more complex patterns of motor neuron firing. Simple rhythmic movement patterns develop from an interaction between oscillatory rhythm generators, which directly involve the motor neurons, and networks of premotor central pattern generators located somewhat more distally in the spinal cord and hindbrain. A critical feature of these pattern generators is that they are capable of producing rhythmic output without sensory input. In turn, pattern generator output is modulated further by afferents from those parts of the appropriate drive networks in the diencephalon and telencephalon. These often highly varied inputs provide the critical command and contextual information from object representational networks for selecting the most appropriate motor program at any particular time. Collectively, all these components begin to account for how motivated behavior is organized.

2.5 Feedback and Humoral Modulation

Feedback is a critical feature of behavioral control, and sensory signals encoding the magnitude and consequences of generated motor actions can control the length of a motivated behavioral episode. For example, postabsorptive humoral feedback (e.g., increasing CCK or decreasing plasma osmolality) and interosensory signals (e.g., gastric distension, oropharyngeal metering) lead to the termination of ingestive behaviors and subsequent behavioral refractoriness. Finally, rather than acting as feedback control a further set of regulatory signals are more modulatory and can influence a variety of neural structures at all brain levels. Steroid hormones, particularly gonadal steroids, are important components of this type, and many familiar motivated behaviors are critically regulated by this type of signal.

See also: Amygdala (Amygdaloid Complex); Arousal, Neural Basis of; Circadian Rhythms; Hunger and Eating, Neural Basis of; Learning and Memory, Neural Basis of; Reinforcement: Neurochemical Substrates; Reinforcement, Principle of; Sex Hormones and their Brain Receptors; Sexual Behavior: Sociological Perspective; Sleep: Neural Systems

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A. G. Watts

Motivational Development, Systems Theory of

Systems theory provides a powerful method for the description of systems in which feedback controlled regulation processes occur. Since human goal-directed behavior is regulated by such processes, systems theory is also very useful for psychological research. One of the most elaborated psychological models based on systems theory, the Zurich Model of Social Motivation by Bischof (1985, 1993), will be presented below, together with some empirical evidence for its validity.

1. Systems Theory

Systems or control theory originated from practical, engineering-related questions concerning regulation processes. Its aim is to analyze the structure of systems and to provide adequate, preferably quantitative, models for them. The basic unit of systems control is a negative feedback loop which consists of the following elements: a detector which provides the system with information about the environment (input), a reference value which indicates what the input ideally should be, and an output function that causes the system in case of a discrepancy between input and reference value to 'behave' in a way that affects the environment in order to reduce the discrepancy (for details see Bischof 1985, 1995).

The notion that processes such as these not only occur in machines, but also can be found in living systems such as animals or human beings was first introduced into the life sciences by Wiener (1948). Almost at the same time, it was also formulated in German by von Holst and Mittelstaedt (1971). Since then, this idea has appeared in different theories. The models based on systems theory, however, vary considerably in their degree of quantification, their complexity, and their generalizability.

One simple, general, and well-known example of a negative feedback loop used to characterize human behavior is the TOTE unit described by Miller et al. (1960). A more complex attempt to explain the general principles of goal directed behavior in terms of systems theory stems from Carver and Scheier (1998). Examples of mathematically formulated control systems and their experimental verification can be found in Powers (1978).

Since systems theory not only is especially apt for the description of purposive behavior, but also allows for the description of short-term as well as long-term regulation processes, models or theories dealing with more specific topics can be found in the fields of motivational as well as developmental psychology. Examples in the area of motivational psychology are the control theory model of work motivation by Klein (1989) and the control system model of organizational motivation by Lord and Hanges (1987). The former describes individual work motivation as a function of feedback and several cognitive processes. The latter also deals with task performance, but can be applied to individual motivation as well as interpersonal activities in organizations. A more comprehensive model, which is at least partly based on a systemic approach, is presented by Dörner (1994, 1998), who intends nothing less than to discover the 'construction plan' of the human soul. In contrast to these authors, Hyland (1988) uses his motivational control theory as a meta-theoretical framework to integrate different, already existing, motivational theories which—according to him—reflect different aspects of a single underlying process which can again be described with a negative feedback loop.

In developmental psychology, a dynamic systems approach is used, for example, by Fogel and Thelen (1987) in their theory of motor development, even if they do not put it into terms of systems theory. The models of Burke (1991) and Bell (1971) are more explicitly based on systems theory. The former describes the process of identity formation as a negative feedback loop. The latter develops a control system to explain reciprocal socialization effects between children and their caregivers. A much broader model which is concerned with the general principles of human development is the developmental systems theory by Ford and Lerner (1992). The best known example for a systems approach in developmental psychology, however, is probably Bowlby's (1969) theory of infant attachment, a phenomenon which he viewed in feedback terms, although he never ventured to formulate it in a mathematical model. This was eventually performed by Bischof (1975, 1985, 1993), who provided a completely quantified model of social motivation. This is referred to as the Zurich Model of Social Motivation (or Zurich Model) and will be described in the following section.

2. The Zurich Model of Social Motivation

The Zurich Model of Social Motivation by Bischof (1985, 1993, Fig. 1) arose from the want of a quantitative model able to explain and predict processes of social distance regulations. Such regulations have been described by attachment theorists such as Bowlby (1969) and also occur during individuation processes in puberty and adolescence. In short, the model postulates three basic motivational systems: the security, the arousal, and the autonomy system. All of these are represented as negative feedback loops and are considered homeostatic. In addition, there is a fourth system, the coping system, which deals with cases in which one of the other systems gets blocked and cannot operate in its usual manner. These four systems will be described qualitatively, although there also exists a mathematical description (Bischof 1993, Gubler and Bischof 1991, Gubler et al. 1994).

2.1 The Security System

Security is defined as the feeling of intimacy, warmth, protection, and so forth that one obtains when one is close to a familiar person, typically one's primary caregiver. This feeling has its source in three input variables, all of which are sensed by a specific detector. The detector for familiarity provides the information

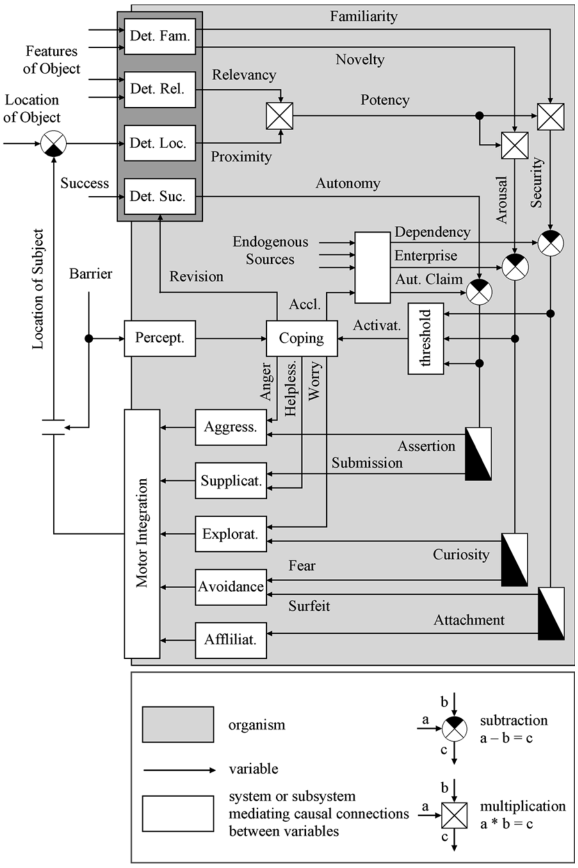

Figure 1
The Zurich Model of Social Motivation (after Bischof 1993, p. 13)

as to whether a certain object is familiar, in contrast to being new, unknown, or discrepant from one's expectancies. The detector for relevancy assesses the rank and the 'conspecificity' of the object in question. The detector's output is highest when the perceived object is an adult, high-ranking conspecific, and can be reduced, for example, by submissive behavior of the object or by substitution of a human adult by another object such as a child or an animal. The third detector gives information about the distance between oneself and the perceived object. The closer one is positioned to a familiar object the more security one obtains. Hence, the construct of security refers to a hypothetical emotional variable monotonically increasing with familiarity, relevancy, and proximity. Since proximity is the only one among those three variables which the subject can control, the obvious way to provide a homeostasis of security results in distance-regulating behavior.

The reference variable of the security system is the degree of dependency the subject feels. As long as dependency exceeds security, an appetence for security is maintained. This induces the subject to show attachment behavior, that is, to reduce the distance to a person who is able to provide security. The opposite situation, frequently encountered in puberty, results in an aversion against security and consequently in an avoidance of familiar persons (surfeit behavior).

2.2 *The Arousal System*

Arousal is defined as feelings such as interest, fascination, curiosity, as well as feelings of alarm or fear which can occur when one encounters a nonfamiliar person. Basically, the arousal system can be thought of as analogous to the security system, and moreover it can utilize the same three detectors. Like security, arousal is hypothesized to increase with the object's proximity and relevancy. Since the familiarity detector also provides information about how novel an object is, arousal can be connected to the output of this detector as well. Thus, the paradigmatic case for the arousal system is the encounter with a high-ranking, adult human stranger.

The reference value of the arousal system is labeled enterprise. Again, a distinction between an aversive and an appetent behavioral response can be made. Aversion against arousal and subsequent fear behavior result from arousal exceeding enterprise. If arousal falls short of enterprise, an appetence for arousal develops which leads to exploratory behavior.

The security and the arousal systems do not work independently of each other. Both systems respond to the same stimulus situations. Thus, the quantitative processing of the inputs involved leads automatically to effects such as fear-evoking stimuli intensifying attachment behavior towards an available caregiver, or the caregiver serving as a security base for exploratory ventures. Furthermore, the two systems do not develop independently during ontogeny. The reference variables—dependency and enterprise—are assumed to be negatively correlated, and to covary with the individual's age and maturity. Young infants are strongly dependent and only modestly enterprising. They need the presence of a security-providing caregiver in order to start exploring the environment and to acquire competence. Later in development, usually culminating around early adolescence, this pattern changes: growing independence and enterprise now demand and allow for the separation from the familiar partners and the establishment of new relationships. Finally, after adolescence, the two reference values normally level out.

2.3 *The Autonomy System*

The autonomy system can be regarded as analogous to the security and the arousal systems. The input here,

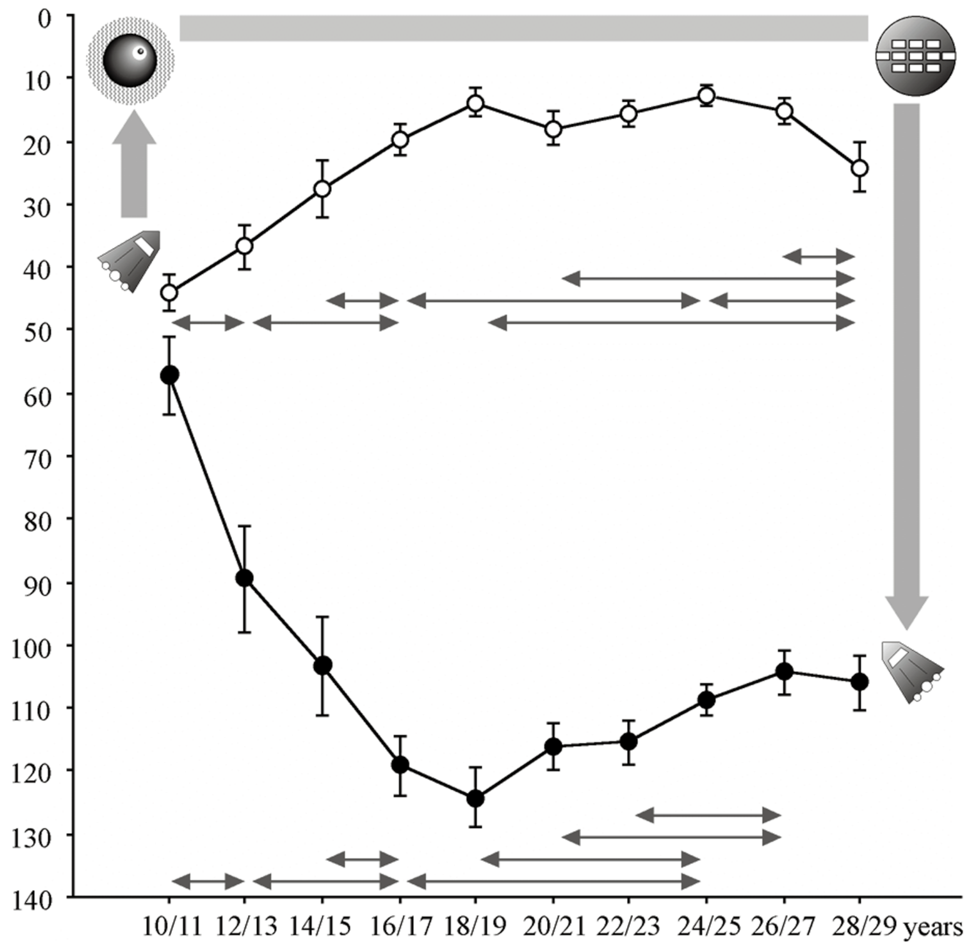

Figure 2
Mean proximity to the security base (black points) and maximal proximity to the source of arousal (white points) in virtual distance units. Error bars indicate standard errors. Horizontal arrows show the nearest age groups which differ with $p \leqslant 0.05$

however, stems from a different source. The detector which provides the amount of felt autonomy senses experiences of success such as obtaining obedience, acknowledgement, or admiration from other people, solving difficult problems, or being competent in certain subjects. Therefore, autonomy can be described as feeling competent, strong, and powerful, and having influence, prestige, and authority.

The reference variable of the autonomy system is called 'autonomy claim' and is closely related to the power and the achievement motives, as well as the need for prestige and an aspiration for self-confidence. In the case of a discrepancy between the feeling of autonomy and the autonomy claim, however, the model postulates the occurence of behaviors stemming clearly from the domain of power and dominance. If individuals feel an appetence for autonomy, they are assumed to behave assertively by becoming threatening, demanding, or even aggressive. In the opposite case, if individuals have too much autonomy and feel aversive, they will show submissive behaviors such as behaving humbly or servilely.

The autonomy claim is not independent of the other two reference variables, dependency and enterprise. On the contrary, the autonomy claim is postulated to underlie the connection of the security and the arousal system by affecting dependency negatively and enterprise positively.

2.4 The Coping System

The coping system operates in cases where one of the other systems gets blocked by an (internal or external) obstacle or barrier. The coping system provides three external and two internal coping strategies, external strategies being active attempts to change the situation and internal ones being efforts to adapt oneself to the situation. The three external coping strategies are labeled invention (searching for a detour), aggression (attempting to destroy the barrier), and supplication (begging someone else to remove the barrier). The two internal strategies are referred to as acclimatization (adaptation of the reference value to the input) and revision (adaptation of the perception of the situation).

The model does not predict which one of these coping responses is performed in a given context since this is primarily a result of the individual's learning history. However, it is assumed that the internal strategies will succeed if the external strategies do not lead to a success.

3. Empirical Evidence

The assumptions made by the Zurich Model of Social Motivation were tested by means of several behavior observations and estimation studies. Both types of studies were conducted with either very young children of about one year of age or with older participants ranging from late childhood to adulthood. Since the Zurich Model contains several ideas of attachment theory, settings similar to the Strange Situation Test by Ainsworth et al. (1978) were used for the younger children. For the older participants, a spaceship simulator was developed in which they experienced a space flight which was also designed according to the Strange Situation.

In this simulator, the participants were seated in a cockpit where the virtual space was visible on a computer screen. There were several instruments to manipulate in order to move, orient oneself in space, and protect the spaceship from dangers. The effects of the participant's actions were visible on the screen and the participants could hear sounds, such as their gun firing or the noise of the accelerating engine. In addition, the simulator was moved according to the steering maneuvers of each participant, which ensured a high emotional involvement.

During their virtual flights the participants were confronted with two different objects. One object was considered familiar (either the earth or a home base) and served as an orienting point in space as well as protection. The proximity of the participants to this security base served as a measure for their dependency. A novel object—a strange planet—also appeared during the flight. This planet was fascinating as well as potentially dangerous to the participants. The proximity to this source of arousal was used to assess the enterprise of the participants.

In the late 1980s and throughout the 1990s 14 studies were conducted with this spaceship simulator. Participants were for the most part schoolboys and girls as well as students between 9 and 33 years (N = 704, mean age = 21.2 years). The data obtained in these studies (Fig. 2) strongly support one of the main theoretical assumptions made by the Zurich Model: dependency and enterprise correlate and take an inverse developmental course. The time of the biggest difference is attained at about 18 years, when dependency reaches its minimum while enterprise is at its maximum.

In the spaceship simulator, as well as the laboratory settings used for the younger children, the behavior of the participants was registered continuously. This allowed for investigation methods exceeding simple comparisons of groups by analyzing the distance regulation processes of single participants. In the estimation studies mentioned above, it was possible to simulate the actual behavior of the participants by means of a parameter estimation based on the mathematical formulation of the Zurich Model (Fig. 3).

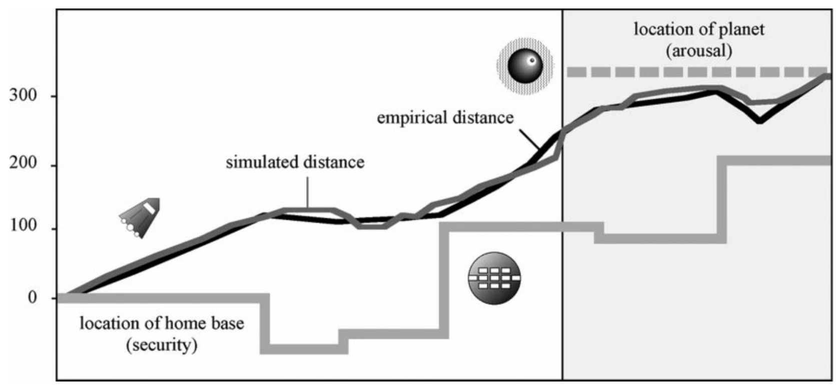

Figure 3
Example of simulated and real distance regulation behavior of one participant (after Gubler et al. 1994, p. 115). The vertical scale indicates virtual distance units, the horizontal scale represents the time of the flight

These studies gave further evidence for the validity of the model (for details see Gubler and Bischof 1991, Gubler et al. 1994).

4. Future Directions

While the functioning of the security and the arousal systems is sufficiently supported by empirical evidence, there are still several open questions for future research. Although the existing data also support the assumptions made about the autonomy system, the causal link of the autonomy claim to dependency and enterprise still has to be established. Since the Zurich Model was originally conceived from the point of view of a child, more adult motives such as altruism have to be included as well. Furthermore, the study of the developmental course taken by the different reference variables or motives also has to be extended to older age groups in order to get a model explaining the motivational development of the whole life span.

See also: Academic Achievement Motivation, Development of; Intrinsic Motivation, Psychology of; Motivation and Actions, Psychology of; Motivation: History of the Concept; Motivation, Learning, and Instruction

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M. E. Schneider

Motor Control

The rich varieties of human and non-human animal movement are the final product of motor mechanisms within the nervous system and the muscles they innervate. The selective contraction and relaxation of these muscle groups support the organism (posture), mediate internal functions such as heartbeat, breathing, and peristalsis of the digestive system, and propel the creature through its external world. The *motor neurons* typically work in concert with interneurons and sensory mechanisms that are orchestrated together through intricate patterns of activity. The motor control pathways in whole organism actions read-out these patterns from many parts of the brain

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