A Psychophysical Model: An Integrative Approach to Man

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This contribution proposes an approach to man which integrates psychological, linguistic and neurobiological perspectives. In addition, precise definitions of psychological terms and a psychophysical structure model are suggested as fundaments for a comprehensive understanding of human experience, thinking and action. A theoretically crucial distinction is made between cognition and intention. The cognitive components of the model include a representation subsystem, an emotion subsystem and a concept subsystem. The intentional part of the model consists of a motive subsystem and a behaviour subsystem. The activity of the entire system is controlled by an arousal subsystem.

Introduction

Human beings can be understood neither from an exclusively objectifying nor from a purely subjectifying perspective. A purely *objectifying* perspective neglects two crucial human features which distinguish humans from machines: human *subjective experience* and *free will*. A purely *subjectifying* perspective, however, neglects the dependence of human experience and abilities on the physical body. When our nervous system is damaged by disease or accident, the enormous extent to which our experience and our abilities depend on our physical integrity becomes clear. The neuropsychologist Sacks (1987) gives a moving account of this as he describes fates of his patients. A human being's very personality is based on an organic substrate. Alzheimer's disease is a cruel demonstration; it can virtually dissolve a personality with his or her entire remembered biography, without necessarily affecting organs other than the brain.

In forming our psychological approach, we want to regard man as a *system*. In a first step we limit our considerations to the human *organism*, which we view as an *open system*. The *physical environment* of this organism shall be the *environment of the system*. In order to represent the causal relations between this organism and its environment, in principle we can distinguish an *input variable* and an *output variable*. Physical *stimuli* make up the input variable of the system, and physical *behaviour* is the output variable of the system. Figure 1 shows these relations.

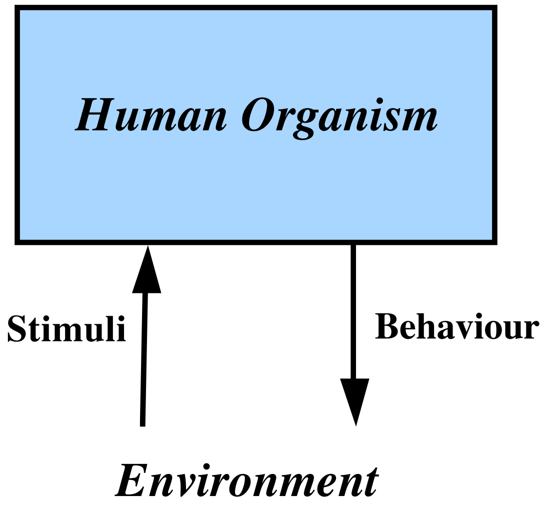


Figure 1: The human organism and its environment

Like every biological organism, the human organism – if it wants to survive – must act upon its environment in a manner conducive to its own existence. This requires first that it record *stimuli* containing *information relevant to its survival*. Then, the organism must be able to suitably modify its *behaviour* in accordance with the *meaning of these stimuli with regard to survival*. So far, this does not yet imply that the organism must experience this meaning subjectively.

For its own persistence, the organism performs many functions, such as substance and energy exchange with the environment in order to maintain stable conditions (homeostasis), defense against pathogenic agents, muscle activity and so on. Our main interest is in those functions of the organism connected to *processing stimulus information* and to *generating behaviour controlling information*. Therefore it makes sense to draw the boundary between the object of our consideration and its environment further inwards. If we are only interested in those parts of the organism immediately responsible for processing information gained from sensory stimuli and for controlling behaviour, we can restrict ourselves to consideration of the human *central nervous system*. The central nervous system consists of the *brain* and the *spinal cord*. By making the central nervous system the system considered, all the remaining parts of the organism belong to the system's environment, namely the *internal* environment. Let us call this system the *psychophysical system*, because we suppose that the central nervous system is the physical substrate of the structure of our psyche. As early as 1934, Bühler used the term psychophysical system with a comparable meaning (1982, p. 26, fig. 2, and p. 27-28).

From a physically objectifying perspective, one can observe the stimuli affecting a human organism and the behaviour this organism produces, while from a psychologically subjectifying perspective – through self-observation and communication – subjective experience becomes accessible. In agreement with Köhler (see Metzger, 1986, p. 257-263), we suppose that there is an *isomorphic relationship* between *subjective* reality and parts of *physical* reality taking place in the brain. Therefore, in principle, subjective experience is accessible by physically objectifying means – but, for the time being, to a very limited degree.

So far we have supposed that subjective reality in its entirety can be explained by means of the parallelism of subjective and physical events. But such a supposition would lead necessarily to the conclusion that man is unfree. No place would remain for *freedom* of the individual. If we accepted this view, there would be no human responsibility and no ethics.

As long as we regard the central nervous system of a human being as purely physically – i.e. also physiologically – it differs from a machine only by the fact that it is part of an organism which can reproduce itself, in a form slightly modified by recombination. With such an approach we do not take into account the most immediate aspect of human existence: all the time we *experience things subjectively*.

And we must recognize another fundamental difference between man and machine. A machine does exactly what it is determined to do according to physical laws, its construction plan and the environmental influences acting upon it. This is true both for the simplest mechanical device and the most powerful and complex computer. *A machine cannot want*. But as human beings we are convinced that we can want. We do not only experience ourselves as being determined. Over and over again, we experience ourselves as 'wanting' individuals.

In order to take into account not only physical reality but also subjective reality, we have to add something to the environment of the system. We have to add a *subjective world* to the *physical world*. And within the subjective world we have to introduce a *subject*.

The term subject, as used here, corresponds more or less to Eccles' idea of the *self* (Eccles, 1994). For parts of the psychophysical system there is *psychophysical parallelism* between events within the psychophysical system and events within the subject. For Hans Jonas (1984, p. 125) subjectivity is not only "accompaniment without any influence on the accompanied reality" [translated by P. F.-K.], but the subject itself has – as represented in Figure 2 – an effect on physical reality.

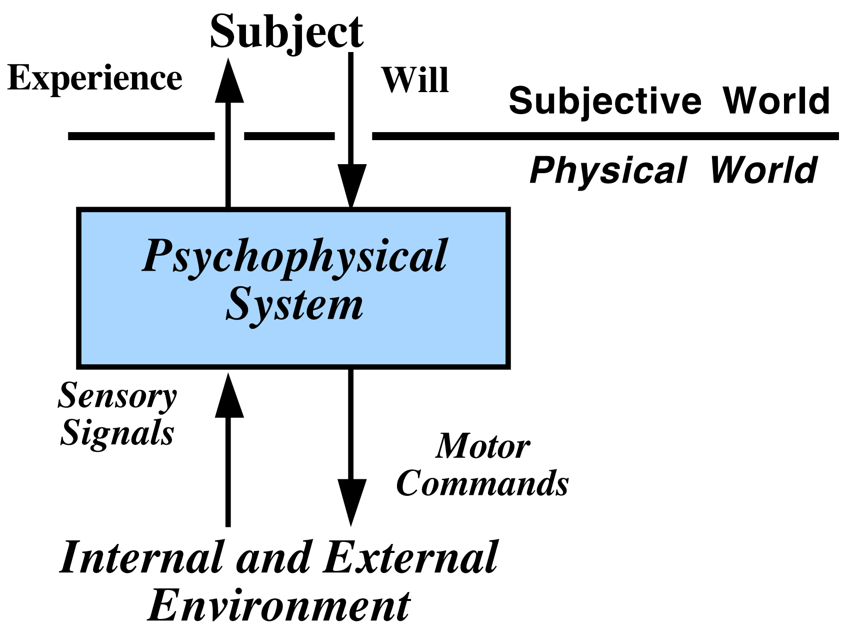


Figure 2: Subject, psychophysical system and physical environment

"Subjectivity is thus 'objectively' in the world as physical objects. Their reality means effectiveness, namely causality inwards *and* outwards, i.e. the power to self-determine thinking by thinking and body-determination by it in action. ... That nature in principle does not leave any room for the dynamics of subjective purposes, is an over-interpretation of its determinism no longer shared by modern physics. ... The contrary supposition of the powerlessness of subjectivity shows itself to be logically, ontologically and epistemologically absurd; and, in addition, to be *unnecessary* for the purpose intended, i.e. observance of the integrity of the laws of nature." (Jonas, 1984, p. 127) [translated by P. F.-K.]

After these preliminaries, let me make two remarks: The first remark concerns the use of the term individual. An *individual* is the *unity of subject and organism*.

A second remark concerns the figures in this paper: in the representations of the psychophysical model, arrows *within the physical world* stand for *nerve signals propagating along axons*. Every arrow represents the action potentials propagated by a huge number of different *nerve fibers*. *Theoretically*, every single axon could be represented by a separate arrow. In this case however, the model would look different for each individual, and it would no longer be a simplification of reality. The arrows *connecting physical world and subjective world* symbolize the *causal relations* between the two worlds.

Psychophysical Level

To take a dualist interactionist view of man leads back to the question raised by Descartes as to where in the physical world – i.e. where in the brain – this interaction is localized. The question is a double one:

Which parts of neural activity can be *experienced* subjectively?

Which parts of neural activity can be *influenced* subjectively?

In accordance with Köhler (see Metzger, 1986, p. 250-256), I call those parts of the brain whose activity can directly be experienced or influenced subjectively the *psychophysical level*.

The distinction between the psychophysical level and the remaining parts of the central nervous system is a *functional* one. Anatomically, the borders will depend on the *current functional state*. However, there are *anatomical maximum borders* distinguishing the areas whose brain activity can be *subjectively experienced* or *subjectively influenced* from the areas whose activity can neither be directly experienced nor influenced.

The question remains as to the extent to which the anatomical areas underlying subjective experience correspond with the areas whose activity can be influenced subjectively. In order to answer this question, one has to first localize the brain areas whose activity is directly experienced subjectively. Second, those brain areas must be localized whose activity can directly be influenced by the subject. The first task is much easier than the second.

Figure 3 depicts the relations between the psychophysical level, the remaining organism and the subject.

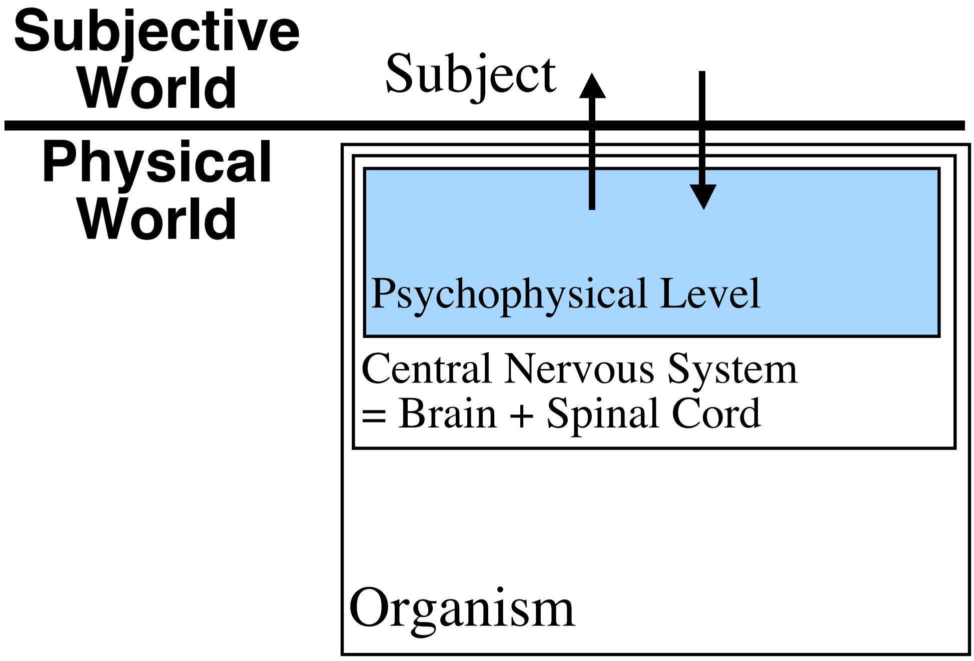


Figure 3: Subject, organism, central nervous system and psychophysical level

Essential Human Achievements

If we want to understand the processes underlying human experience, thinking and action from a psychological perspective, we have to distinguish two basic groups of processes: *cognitive* performance on the one hand, *intentional* performance on the other hand.

Cognition

Since the so-called cognitive shift, the term *cognition* and the attribute *cognitive* derived from it have been used excessively for entirely different objects, with the consequence that cognition is not a precise scientific expression. I wish to use the term precisely defined. My use of the terms *cognition* and *intention*, while inspired by Bischof (1987), is nevertheless different.

Cognition will refer to all processes by which for an individual *stimuli* from the objective world are transformed into *perceived phenomena* connected to *subjective meaning* and by which *fictitious* objects, states and processes of the external and internal environment can be experienced as *imagined phenomena* connected to *subjective meaning*.

In general, subjective meaning refers to the meaning of a phenomenon for the *life* of the individual experiencing the phenomenon. However as we shall see, by *empathy* a human being can also experience the meaning of phenomena for the lives of *others*.

Intention

Intention will refer to all the processes by which an individual – depending on cognitive contents present and his or her free will – can *produce behaviour* and transform cognitive contents by *attention processes*, *imagination processes* and *thinking*.

Linguistic presentations are linear. Unfortunately, the linear presentation of a netlike system has its inevitable problems. Therefore in presenting the model of the psychophysical system, I cannot help using several terms before they have been properly introduced.

In the following, the internal structure of the psychophysical system defined above will be developed. Let us begin with the cognitive components.

Cognitive Structures

Physical Input to the Cognitive Components of the Model

Before we can look at the single cognitive components, shown as blocks in the model, we have to realize where the sensory information comes from, which in the physical world is the input variable to the cognitive components.

Human knowledge depends essentially on the senses. Sensory perception begins with the recording of environmental reality by specialized *sensory cells*. These *receptors* respond to adequate stimuli: photoreceptors in the retina of the human eye translate electromagnetical waves from about 400 to 700 nm wave length into nerve signals with the subjective meanings of *brightness* and *colour*. Mechanoreceptors of the inner ear translate air pressure waves into nervous signals with the subjective meanings of *volume* and *pitch*. Analogous translations are made by all the other senses, the senses for the perception of body surface and the interior of the body. In general, receptors transform *stimuli* into *nerve signals*. They pass these nerve signals on to the psychophysical system, where they are additionally processed by the representation subsystem.

Representation Subsystem

The representation subsystem is the physical substrate upon which *physical reality can be phenomenally experienced*. Our subjective experience can be divided into two main types of experience. One type of subjective experience is based on our senses and will be called here *sensory-modal experience*. Phenomenally – i.e. in its immediate content of experience – it claims to be either *real world* or *imagined world*. This type of subjective experience always refers to *objective physical reality*, whether we experience it as our *perception* of the real world or as *imagination* of a possible world. However, physical does not necessarily mean material. Light, for instance, is a physical reality, but phenomenally it is immaterial. Although in physics the particle model sees light as something material, as a phenomenon of human experience it is immaterial. We do not experience light as a particle bombardment. Below we shall look at sensory-modal experience in detail. But first let us discuss a second kind of subjective experience.

This second kind of subjective experience does not represent world, either perceived or imagined. But it is the *meaning* of the contents of subjective experience *for living, experiencing individuals*, whose existence is threatened at any moment and cannot be taken for granted. We experience these meanings as *emotions*. Therefore, here this kind of subjective experience is called *emotional experience*. Emotions are, among other things, *interpretations* of sensory-modal experience. Emotions allow us to realize whether the reality for which the sensory-modal content of a perception or imagination stands is favourable or harmful to our lives. In addition to this interpretative component, emotions have a *motivational* component. They appeal to us internally to *do* something specific. An example: The *fear*-emotion – in its specific form – is the interpretation of a specific content of sensory-modal experience as source of danger. The fear-emotion motivates us to avoid this source of danger by flight or to destroy it by fight. We shall discuss emotional experience in detail when presenting the emotion subsystem.

Let us return to sensory-modal experience. Sensory-modal experience is structured phenomenally by *sensory qualities* within a *spatial reference system*. For the perception of specific aspects of physical reality, our organism possesses suitable sensory cells or sensory organs. The contents perceived with these sensory organs can be subjectively experienced as specific *sensory qualities* (see e.g. Schmidt & Thews, 1993). Table 1 presents an overall view of the human sensory modalities and sensory qualities.

Sensory Modalities	Sensory Qualities
visual	brightness, colours, colour saturation
auditory	volume, pitch
mechanical	pressure, touch, vibration, tension, stretch
thermal	warmth, cold
nociceptive	surface pain (first and second pain), depth pain, visceral pain
gustatory	sweet, sour, salty, bitter
olfactory	a large number of distinct smells

Table 1: Sensory modalities and sensory qualities in man

Sensory modalities (see. e.g. Schmidt & Thews, 1993) – i.e. the single senses – refer to certain aspects of physical reality. Seeing refers to electromagnetical waves within a certain frequency range or to photons within a certain energy range. Hearing refers to periodical air pressure changes within a limited frequency range. Tasting refers to the presence of certain substances on the tongue. Smelling refers to the presence of a large number of substances in the air which we can specifically distinguish and which are relevant for us. The selection of these substances is the result of human phylogeny (see e.g. Lorenz, 1977). As a consequence, we lack a sense for many substances although they are relevant – namely dangerous – for us nowadays, since they have been part of our environment for only a very short time phylogenetically, e.g. carbon monoxide.

Not only our perception is structured by the sensory qualities mentioned above, but also our imagination. Yet not all these modalities are equally important for our imagination. Imagination is dominated by the visual and auditory modalities. Evidence of this can be found in examinations of sleep experience, i.e. dreams. With regard to its generation, sleep experience can be regarded as *imagination*, since at the moment of dreaming, dream contents do not originate from the sensory organs. Phenomenally however, dream contents are *perception*, because dream phenomena claim to be present external reality. As Strauch & Meier (1992, p. 81) report from the field of experimental dream research, 56 % of remembered dream experience is *visual*, 24.4 % is *auditory* and 19.1 % is *somaesthetic*, i.e. body sensations. Only 0.5 % of reports refer to smell or taste sensations. In principle, the *physical processes* underlying our experience of imaginations, take place in the same brain areas as the physical processes underlying our perception experience. This is supported by studies of regional glucose metabolism with positron emission tomography (e.g. a sleep study by Buchsbaum et al., 1989, p. 1354, but also many studies of waking subjects).

Whatever phenomenon we perceive or imagine in sensory modalities, it is experienced within a spatial reference system. However, this is not true for olfactory contents, i.e. smells. The spatial reference system of *perception* is *egocentric* (see also Bischof, 1974, p. 312-314). This means that we experience its origin within our body. The direction of the coordinates is determined by the gravitation vector and the plane of symmetry of our body. The gravitation vector determines which direction we subjectively experience as *below*. The plane of symmetry of our body separates phenomenally *left* from *right*. The vestibular organ in the inner ear registers the direction of gravity. Nonetheless, it would be wrong to speak of a gravity sense, because what we experience subjectively is not the direction of gravity. However, the direction of gravity recorded by receptors determines how perceived phenomena are oriented within phenomenal space.

The phenomenal reference system of *imagination* can be *ego- or exocentric*. In our imagination, we can move to any place we want, and we can orientate ourselves to any direction. This ability is one of the cognitive presuppositions of *perspective taking*, i.e. the ability *to put oneself in the situation of another human being* (see Bischof-Köhler, 1989).

Since Kant, the idea has persisted that not only space, but also time, is a reference system of our sensory-modal experience. Instead of speaking of a spatial reference system, Kant called *space* a “necessary phenomenal feature (*Vorstellung*) a priori ... underlying all external phenomena (*Anschauungen*)” (1956, p. 38 of the original edition B) [translated by P. F.-K.]. In his *transcendental aesthetics* (p. 33-73 of the original edition B), Kant also regards *time* as a phenomenal feature (*Anschauungsform*), while in my opinion – for phenomenal reasons – time is a system of *abstractions* from a reality which can be immediately experienced. Later in the paper, such abstractions will be called *concepts*. Time cannot be experienced as an immediate phenomenal feature, whereas space has this phenomenal immediateness!

We distinguished above between perception and imagination. *Perceptions* are subjective representations of real objects, states and processes of the present *external* environment or of one’s own body (*internal* environment). Perceptions are *images* of real objects, and therefore they cannot be voluntarily transformed. Transformable however are the *real* objects, especially our own body, which allows us to *indirectly* transform subjective *representations* of objects, states and processes in the external environment and in our body. That which is *unperceivably present* (*das unwahrnehmbar Vorhandene*) described by Metzger also belongs to perception (Metzger, 1975, p. 31-33), for it consists of perceptions made in the situation just a moment before. These perceptions still claim to represent the present situation correctly. The subjectively experienced *now* is always based on a succession in the perception process. This is especially true of visual and tactile perception.

Imaginations are voluntarily transformable subjective representations of real or fictitious concrete or abstract objects, states or processes. This second level of experience independent of immediate perception is phylogenetically relatively young. It appears for the first time in the chimpanzee. Köhler (1973) describes this in an impressive manner. Bischof (1987) writes: “There is no doubt that the chimpanzee possesses the ability to try out action plans in his imagination: he actually lives in a doubled world, for besides perceptions he possesses imaginations, and the level of perception is superimposed by a level of *imagination*." (Bischof, 1987, p. 82) [translated by P. F.-K.]

Within the representation subsystem, human beings can focus their *attention* on specific sensory modalities and, within these modalities, on specific locations of phenomenal space. This determines which part of perceivable reality will become *conscious*. In part, certain stimuli or stimulus features draw attention upon themselves, but *attention processes* are one of the areas influenced by free will.

So far the description of the representation subsystem may have created the impression that everything we experience in sensory modalities is *concrete*. One might think that representations are always representations of real or imagined concrete physical objects, states or processes. This is not the case. We also experience *abstract* contents, namely linguistic *expressions*. Language *signs* consist – as de Saussure (1967) made clear – of an *expression* side, the so-called signifiant, and a *content* side, the signifié. Linguistic *expressions* can take two different forms; they can either be *sound* or *character sequences*, which can be understood by members of a language community on the basis of conventions. In linguistics one speaks of *phonems* and *graphems*. We hear phonems as temporal sound patterns, and we see graphems as two-dimensional geometrical patterns. Whether we *perceive* words by listening or reading or whether we *imagine* them, we always experience them as auditory or visual phenomena. Our entire linguistic thinking – which takes place in the concept subsystem, as we shall see – produces representations that can be experienced auditorily or visually, even if we remain mute. It is not the representation subsystem that produces language, but the representation subsystem is the substrate of our sensory-modally determined experience of language, whereas the emotion subsystem is the substrate of our experience of subjective language aspects.

Now to the *content* side of linguistic signs. The content of a linguistic sign is its *meaning*. The sensory-modal part of the meaning of a linguistic sign is realized as a sensory-modally specific *prototype*, actually as a phenomenal *archetype* of the meaning of a sign. This may be a visual prototype (see e.g. Aitchison, 1994, p. 51 ff.), an auditory prototype or even a somatosensory prototype. Some expressions are connected to several prototypes of different sensory modalities. The *sensory abstract* part of the meaning of a sign can be understood as part of a *semantic concept network*, as will become clear when we discuss the concept subsystem in the model. A purely *abstract* term is stored as a *concept network* exclusively. In addition, a concrete term is also stored as a *prototype*. On the content side of linguistic signs, only the prototypic representation can be immediately experienced. When we think of the word *tree*, in our imagination we see a prototype of a tree. Yet when we think of the word *freedom*, at best *associations* connected to the content side of this word can become experienced as representations. Apart from these associations, with abstract terms we only experience the expression side, i.e. the sound or character sequences belonging to this word. But the content side of the word has its effects below the surface of consciousness, within the concept subsystem namely, by coordination of connections between contents that can be experienced themselves (representations and emotions).

The representation subsystem is, as we said, the substrate on which physical reality is transformed into phenomena that can be subjectively experienced. For physical reality to be experienced as a phenomenon, three different processes are necessary. First, sensory-modally specific nerve signals have to be *depicted phenomenally*. Then two additional achievements – which are possible only in coordination with the concept subsystem – are required, namely *identification* of representations and *representation* of phenomena.

For each representation and for each phenomenal feature, the *identification* of representations is based on a specific structure of analysis. I would like to call such an analysis structure the *identification schema*. If several elements of a phenomenon activate the same identification schema, they are experienced as belonging to the same object or feature. An identification schema is a directed connection from the representation subsystem to the concept subsystem. The formation of an identification schema is based upon concept-subsystem-internal connections. Identification schemata are a specific class of concepts.

However, pattern recognition made possible by an identification schema can hardly be based on a template-like structure consisting of connections from every phenomenal element to a concept. Such a hypothesis could not explain why pattern recognition functions so well, even with strongly varying patterns at different places and in different positions. It seems more plausible that an identification schema performs feature analysis (for a discussion of this topic see Anderson, 1996, p. 45-52).

The formation of *representations* is based on structures projecting from the concept subsystem to the representation subsystem, here called *representation schemata*. A representation schema is a directed connection from the concept subsystem to the representation subsystem. Representation schemata are a special class of concepts. The formation of a representation schema is based on concept-subsystem-internal connections.

While the identification process is a bottom-up-process, i.e. a process towards higher abstraction from sensory stimuli, the representation process is a top-down-process. The two processes take place at the same time and complement each other in a functional circuit. Representation schemata do not only fulfil a task of perception, but also aid the *generation of imaginations*. Thanks to representation schemata we can imagine objects independently of perception. And representation schemata fulfil yet another function: if a representation schema is activated only a little, the perception threshold for the discovery of a certain environmental content can be lowered, without the subject having actually experienced the content phenomenally. As soon as a suitable stimulus pattern is found, the corresponding content becomes a phenomenon. The human ability of *selective perception* is based on the activation of representation schemata with certain contents, depending on the motivational state present. The stronger that preactivation by a representation schema is, the weaker a stimulus can be in order for us to experience the corresponding content as a phenomenon. A *perception expectation* can lead us to the edge of hallucination, so that we believe to perceive things before they are there. [See e.g. Posner and Raichle's (1997, p. 84) thoughts about bottom-up and top-down processes.]

Figure 4 gives an overall view of the processes that take part in the transformation of physical reality into phenomenal experience. The figure does not take into account the processes of *directing the senses*. Through motor behaviour – e.g. eye movements – these processes determine which part of the environment will affect the receptors as stimuli – e.g. the part of the environment from which light will fall on the retina.

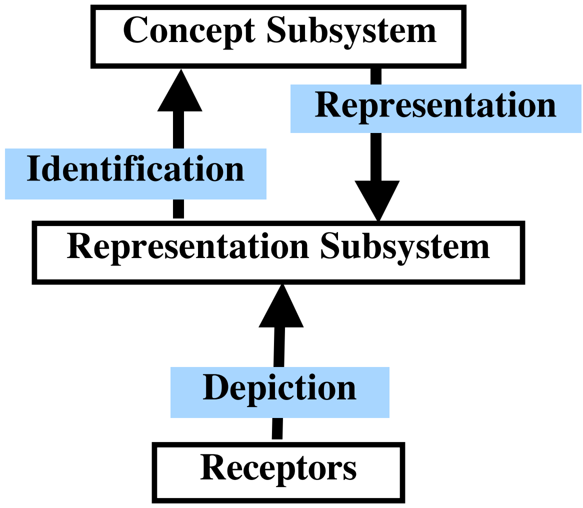


Figure 4: Processes related to the transformation of physical reality into phenomenal experience

Emotion Subsystem

Experiencing representations is a phenomenally crucial aspect of human *cognition*. If human beings want to survive thanks to the *knowledge* cognition provides, they need another form of phenomenal experience whose relation to reality is entirely different from that of sensory-modal experience.

While sensory-modal experience refers to physical facts perceivable with sensory organs, to light, sound, touch, warmth and the presence of certain substances, *emotional experience* refers to *subjective meanings*.

Emotions fulfil five important functions: First, they allow aids or dangers to one's own survival to be experienced as *pleasant* or *unpleasant* subjective qualities. Second, they serve as a motor. They move us to adequate *reactions* to aids or dangers, and they motivate us to *actively* search for survival aids and to avoid dangers. Third, emotions trigger *arousal,* without which the organism could not produce behaviour efficiently enough *in situations of existential relevance*. Fourth, emotions allow a permanent change of future world interpretation and future coping with the world by *learning*. And fifth, emotions trigger *expressive behaviour* which allows others some access to one's own experience.

Emotions do not always refer to the meaning of an aspect of reality for one's *own* life. Thanks to our imaginative ability to experience reality from another's perspective (empathy), we can also experience emotionally *aids or dangers to the lives of others*. This ability is strongest with regard to other humans, but we can extend our empathy to animals and plants and, with the aid of animistic projections, even to inanimate objects.

Before defining the term emotion, I would like to remark that the term refers to two different types of contents, both in everyday language and in psychology. On the one hand, the term describes certain *qualities of subjective experience*, e.g. fear, anger or joy. On the other hand, the term emotion also refers to something more complex, e.g. when one talks about pride, jealousy or guilt. In these cases the subjective experience is not only a specific *non-sensory-modal* quality, but *in addition* it comprises conceptual aspects which are *indirectly* accessible via (sensory-modal) *linguistic expressions*. So on a non-sensory-modal level, jealousy cannot be distinguished from anger. But in contrast to anger, jealousy does not simply have one or more sensory-modally experienced reference objects. Rather, two reference objects and the subject are conceptually connected to a specific social meaning structure. One object is the person loved and desired by me. The other object is a person who disputes my right to that first person.

The *core* of many terms understood as emotions in everyday language refers to something I would like to call *simple emotion*. Yet in addition these emotions refer to meaning aspects we can only experience linguistically. As a simple emotion, I would accept a phenomenon with an original quality independent of the (sensory-modal) experience of linguistic expressions. However, phenomenon complexes such as pride, jealousy, guilt or shame, which are only phenomenally distinguishable through their (sensory-modally experienced) linguistic expressions are to be called *complex emotions*. Complex emotions are emotionally-sensory-modally mixed phenomena.

Now we will give two definitions of the emotion term. The first is a phenomenal definition: *Emotions* are experience qualities with the phenomenal dimensions of *pleasant* (unspecific quality of *pleasure*), *unpleasant* (unspecific quality of *suffering*) and *urging* (unspecific quality of *tension*) plus a specific *interpretative* and *motivational* content. *Simple emotions* can be identified *without referring to sensory-modal experience*. *Complex emotions* can be identified only *with reference to sensory-modally experienced linguistic expressions*. Complex emotions are composed of a *single emotion* and the sensory-modal experience of *linguistic expressions*. The second definition is a functional definition: Emotions are – from a *functional* perspective – 1. *subjective interpretations* of the reality standing behind representations (perceptions and imaginations), concepts and motives, 2. *motivational appeals*, 3. triggers of arousal (activity of the sympathetic nervous system), 4. triggers of learning processes and 5. triggers of expressive behaviour.

The number of emotional qualities, i.e. *simple emotions*, that can be distinguished phenomenally has been a matter of controversy (see e.g. Meyer et al., 1993, Bower, 1992, p. 8-11, Fischer et al., 1990). Possible candidates are *joy*, *fascination*, *fear*, *anger*, *sadness* and *embarrassment,* as well as the organism-related emotions of *hunger*, *thirst*, *satiety*, *nausea*, *fatigue* and *pain*.

While the number of single emotions is relatively limited and interindividually universal (see e.g. Izard, 1991) and most probably to a large extent genetically determined, the number of *complex emotions* is much larger. Their range is more variable and seems also to be influenced by socially mediated learning. Among the complex emotions there are presumably *guilt*, *shame* and *jealousy*. But there are also aesthetical emotions, such as experienced *beauty* and *ugliness*. As mentioned in the definition above, complex emotions can be distinguished phenomenally by the subject only in the light of linguistic experience – in contrast to single emotions. So that experiencing the complex emotion of *jealousy,* for example, is composed of experiencing the single emotion of *anger* plus linguistically experienced thoughts, for my jealousy means that my anger refers to a person who disputes my right to a person I desire.

Cognition and Emotion

In psychology, the relation between emotion and cognition has been discussed controversially. However, part of this dispute is a consequence of different ways of using the term cognition (see e.g. Zajonc, 1980, Lazarus, 1982, Zajonc, 1984, Lazarus, 1984, Bischof, 1989). I regard emotional experience also to be *cognitive* – i.e. providing knowledge. In the debate on whether thinking processes have to precede emotional experience or not, it has too often been assumed that thinking processes need to be conscious to the subject. Yet this is not necessarily the case. The question of whether thinking processes have to precede emotional experience or not has to be answered in two different ways, depending on the case.

In a first case, emotional experience is based upon an analysis which is concept-driven. In other words, before I can experience *fear* in a certain situation, I must have categorized it conceptually as dangerous. But this does *not* mean that I have to experience this analysis *consciously*. And it does also not mean that the analysis must take *a lot of time*.

Apart from this case, there is a second. Emotions can be based on states of the organism about which the emotion subsystem is informed by the arousal subsystem – without any need for complex analysis by the concept subsystem. In this case, simple emotions such as thirst or fatigue are directly activated.

Emotionally-interpreted aspects of reality

Emotional interpretations of representations, concepts and motives are based on the experience of *usefulness and harmfulness* of the reality standing behind these representations, concepts and motives to one's own life or the lives of others. This experience of usefulness and harmfulness can be phylogenetic experience stored in one's genes (see Lorenz, 1977), or it can be experience learned during one's own life. Perceptions and imaginations are connected to concepts and emotions. On the basis of content *similarities with earlier perceptions, imaginations and concepts*, new perceptions, imaginations and concepts become connected to the emotions associated with those earlier perceptions, imaginations and concepts.

Let us have a look at different kinds of reality contents (objects) that can be connected with emotions:

Emotions can refer to *living individuals*, to human beings, and animals, especially pets. An emotion I am experiencing can be an interpretation of *myself* or of *another individual*. Corresponding emotions are *sympathy*, *love*, *antipathy* and *hatred*. If unpleasant emotions refer to myself, they can become threatening. Unpleasant emotions referred to one's self – e.g. self-hatred – can lead to depression, from which some people only escape by suicide. But in general, emotions fulfil the essential function of allowing us to experience existentially relevant aspects of reality.

Emotions can also be referred to an *object*, but we have to remark that also the *body* or *body parts* of living organisms can be experienced as objects, e.g. a *face*. As *visual* or *auditory* phenomena, living or inanimate objects can make us experience the emotions of *beauty* and *ugliness*. At first sight, it may seem absurd to call beauty and ugliness emotions. But if we define emotions as subjectively experienced evaluations of reality contents, it is consistent to regard beauty as en emotion. The beauty emotion is the pleasantly experienced interpretation that the object referred to is favourable to our existence. The opposite is true of the ugliness emotion. Of course, often the beauty emotion and the ugliness emotion are *false interpretations* of reality, and it is well known in psychology that emotional interpretations can lead one astray.

There is another aspect of reality that we can experience emotionally. We experience emotionally the *success* or *failure* we achieve when striving to realize our motives. By comparing presently intended states and processes with the present real ones, we come to know our own success, competence and our failures. This emotional interpretation can be called the experience of *autonomy* (term following Bischof, 1985, p. 353 ff.). The experience of autonomy is the integrating of experience of the success of one's behaviour. Success means the degree of correspondence between a produced behaviour and its effects on the one hand, and the intended behaviour and effects on the other. If we cannot realize our motives, we experience *annoyance*. If we fail in realizing our motives in the long run, this leads to the experience of *frustration*.

As a last class of reality aspects which can be experienced emotionally, there are also *existentially relevant physical parameters of the subject organism* that cause emotions, such as *hunger*, *thirst* or *satiety*. In contrast to the emotions presented above (apart from the experience of success, which is a special situation), these emotions are *not* elicited by real or fictitious *representations* of objective physical reality, *but* by *physical reality itself* taking place within the subject organism. This physical reality is the so-called milieu intérieur (term from Claude Bernard, *Leçons sur les phénomènes de la vie communs aux animaux et aux végétaux*, 1878-1879, quoted in Kupfermann, 1991a), i.e. the plasma concentration of several nutritive substances and hormones as well as body temperature. It is essential to the organism to keep the concentrations of several substances and body temperature within a small range of values. The state of the milieu intérieur cannot be experienced as physical reality itself. But interpretation of the state of the milieu intérieur elicited in the emotion subsystem, and the motivational appeal connected with it, are contents of subjective experience. It is not low glucose level that can be experienced, but hunger.

Motivational Aspects of Emotions

Emotions are, as stated, among other things *motivational appeals*. This means that they elicit certain motives – i.e. goals currently followed by an individual – and hereby they elicit behaviour indirectly. *Representations and concepts* can, for instance, lead to *fascination*, *fear* or *anger*. These emotions activate motives such as *exploration*, *avoidance* – by flight or non-proximity seeking, or *elimination* – by fight or destruction. *Hunger*, *thirst* or *satiety* motivate the organism to eat, drink or to stop either of these activities.

The motivating aspect of emotions raises the fundamental question of the existence of free will, for emotions are an appeal to behave in a certain way. Hunger appeals to us to eat, fear makes us flee or avoid something. In general, we can resist these behavioural appeals, if we want to, but they can become so strong that we follow them nearly blindly. Attacks of panic come to mind here. Not to obey extremely strongly motivating emotions is hardly bearable. In such cases we obviously reach the limits of our free will.

Emotions Trigger Learning Processes

Emotions are of crucial importance with regard to *learning processes*. *Pleasure*-mediated learning leads to functional strengthening of a connection from a *motive* to a *behaviour programme,* from a motive to a *thinking programme* or from a motive to an *imagination programme*. This reinforcing allows an individual to repeat pleasure-bringing behaviour, thinking or imagination in the future. The situation with *suffering*-mediated learning is different. Suffering-mediated learning cannot simply consolidate a certain presently active connection for future use. Rather a *coping* process has to be started – with the goal to activate motive-behaviour-programme-, motive-thinking-programme- or motive-imagination-programme-connections *other* than those whose activation leads to suffering.

The question as to the mechanisms which cause pleasant emotions to have different learning effects than unpleasant emotions is not trivial at all. A possible answer may be that pleasant emotions might be connected to the release of different transmitters at probably different effect sites with different synaptic effects. However, the present state of research does not allow a final answer (see e.g. Christianson, 1992, McGaugh, 1992, Nilsson & Archer, 1992). The fact that pleasure indeed leads to different learning effects than suffering can be seen in the reinforcing effect that the consumption of pleasure-eliciting substances has upon future action. This is the basis of addiction. The asymmetrical effects of pleasant and unpleasant emotions on learning known from the field of education are most likely not only based on different cellular mechanisms, but also on different attention processes.

Concept Subsystem

As stated above, the representation subsystem transforms physical reality into phenomenal experience. The emotion subsystem allows us to experience subjective meanings of the reality behind representations, concepts and motives. Human cognition, however, is not based entirely on *phenomena*, i.e. on representations and emotions. Human beings are said to be rational. They are able to abstract from single phenomena and to build up complex relations between them – logical, mathematical and syntactic. The functional unit capable of building up relations between different cognitive and – as we shall see – intentional contents is called the concept subsystem in the model. The concept subsystem is the location of intellect. Actually, it is a linguistically, i.e. logically, mathematically and syntactically organized world interpretation structure. The concept subsystem forms synchronous and sequential connections between representations, emotions and motives.

At this point, for the understanding of the suggested model it cannot be stressed enough that the contents of the *representation* subsystem and the *emotion* subsystem only are accessible to conscious experience. The contents of all the other components of the model are deducible only insofar as they influence our experience of representations – i.e. perceptions and imaginations – and of emotions.

The human ability to *abstract* from single contents of experience is based on the ability of the psychophysical system to relate representations, emotions and motives to each other by means of *concepts*. A *concept* is a cognitive content of the psychophysical system which cannot be directly consciously experienced. Concepts are *directionally* connected with contents of the other subsystems (representations, emotions or motives) or with other concepts. Directionally connected refers to the fact that all neural connections via chemical synapses have a well-defined direction of transmission. So while there may be a connection *from* content A of the psychophysical system *to* content B, this does not necessarily mean that there is also a connection from B to A.

Concepts can be connected either directly with contents of the other subsystems or indirectly via other concepts, which themselves are connected with contents of the other subsystems, either directly or indirectly. Concepts connected *directly* with representations, emotions or motives are called *concrete concepts*. Concepts connected only *indirectly* with representations, emotions or motives via other concepts are called *abstract concepts*.

In order to understand what concepts are, we need a few basic terms of propositional logic. In logic, a proposition is – in the simplest case – a connection of an object about which something is said with a property attributed to it. The object about which something is said is called the logical *individual*. The property attributed to the object is called the logical *predicate*. For example, the proposition "the house is large" consists of the logical individual "the house" and the logical predicate "be large". The predicate "be large" is a *single* predicate, for it has *one* empty place, i.e. place for exactly *one* logical individual which can be connected with this predicate. Yet a proposition can also be more complicated. As an example, in "Ann and Jane are sisters.", the predicate "be sisters" cannot be attributed to *one* single individual. The proposition "Ann is a sister" does not make sense. To the contrary, the predicate "be sisters" is a *multiple* predicate, since it only can be attributed to several individuals, at least to two individuals. In propositional logic, a multiple predicate is called a *relation*.

Predicates are *abstract* concepts, i.e. they are *not directly* connected to representations, emotions and motives, but only indirectly via concrete concepts. In spite of this, a predicate has a syntactic and semantic content even *without a connection to concrete concepts*. So a predicate demands *syntactically* that other abstract concepts are to be connected in a certain *order*. Additionally, every abstract concept has to fulfil certain *syntactic criteria* so as to be allowed to stand at a *certain position* in the connection structure. It has to stand in a certain case. However, in contrast to most languages, this is not clearly visible in the English language, since all grammatical cases have the same form. Concept-connections are also not isolated in a semantic respect, but they are integrated into a semantic network. Concept-*connections* are not stored just anywhere in the concept subsystem, but they are brought into relationship with other concepts because every concept and every concept-connection *means* something. Let us consider the relation "x and y be parents of z". Its meaning results on the one hand from *connections to concrete concepts* which on their part receive their meaning by connections with representations, emotions and motives, on the other hand from *connections to other abstract concepts*. There are several possibilities of explaining the meaning of the relation “x and y be parents of z”. One possibility is to refer to the two relations “x be mother of z” and “y be father of z”. Another possible way is to refer to the relation “x and y have sired z”, which makes clear that temporal relations are also part of the meaning of the relation “x and y be parents of z”. In this way, an endless semantic network can be formed.

The concept subsystem is organized *linguistically*, not simply in the categories of a certain single language, however, but rather in the categories of a so-called universal grammar. Since Noam Chomsky (1957), generations of modern linguistics researchers have searched for grammatical universals. But it would be more correct to speak of *syntactic and semantic universals*. Contrary to Chomsky’s conviction, most of these universals can hardly be regarded as inherited. Rather they are individually learned patterns of culturally-acquired adaptations to similar environmental conditions. The most important aspect is *the situation of human existence itself*. For all human beings, even living under most diverse geographic and cultural conditions, it is essential to structure the world cognitively by the same basic abstract categories. Certain *temporal* distinctions related to states and processes, for example, make sense in all human environments. One example is the distinction between *static and dynamic,* discussed by Lyons (1980, p. 309-322). Some aspects of reality remain as they are; others change. For instance, person’s gender is a static aspect of reality. However, the weather is a dynamic aspect of reality.

All the abstract aspects of linguistic meaning structures belong to the concept subsystem. But in addition, the concept subsystem allows the human achievement of syntactically connecting words to sentences. This ability is essential both for language production and language reception. Language production and language reception are based on a crucial human ability, namely *thinking*. But what is thinking? Within the model suggested, thinking is defined as the activation of concept-connections. The concept subsystem is the physical substrate upon which thinking takes place. This thinking is controlled by the motive subsystem to be discussed below. Let us now turn to several important concepts.

With the relation of *causality* we interpret two phenomena as belonging together so that one of them can explain the other. It thunders *because* there was lightning beforehand. The relation of *synchronous identity* allows us to consider two phenomena as representations of the same reality. We can recognize the representation of an object and the representation of its mirror-image as the same object. *Logical* relations – e.g. *and*, *or*, *not* and so on – are also examples of concepts.

Our experience of time is based upon the interaction of the representation subsystem and the concept subsystem. It builds on the time relations of *precedence*, *simultaneity* and *consequence* and a *now-reference*. In addition, it depends on the fundamental distinction between *past*, *present* and *future*. If a phenomenon is categorized as past, it is regarded as something that can no longer be influenced. A phenomenon categorized as future is interpreted as voluntarily transformable.

Our perception registers only the present. Therefore, our perception provides the now-reference. Apart from perception, we can also experience as phenomenally present that which forms in our imagination on the basis of linguistic utterances of others. When we talk to someone on the telephone, and the other person describes his or her current environment, our imagining of this environment also becomes part of our experience of the real present. In our imagination, moreover, we can also move the now-reference to past or future.

A past phenomenon is unchangeable. We can imagine what would have happened if this or that had been different or if somebody else or we ourselves had acted differently. But as phenomena, such imaginations remain imaginations, and as such they do not claim to reflect how things really were.

The future, however, is *open* in principle, not predictable with certainty. Temporally, it is the only part of reality which we can influence. Past and present – in a strict sense – cannot be changed. But future can be formed by our present will underlying our – in a strict sense – future actions. The appendix “in a strict sense” means that a moment separated from the present even only by the reaction time of the brain, i.e. several hundred milliseconds, is future. What I want to do can be done by my muscles only in a few hundred milliseconds. This separation of present and immediate future can also be justified from a phenomenological perspective. As long as I want to do something, I am not yet doing it. As soon as I am doing it, I no longer want to begin with it. Rather I want to continue, but this wanting to continue is always referred to the immediate future.

We still have to discuss a group of concept subsystem contents which are psychologically highly relevant: concepts of human *actions*. In everyday life it is not sufficient to perceive how somebody *behaves*. We want to know *why* somebody does what he is doing. If somebody pushes us in a crowd, it makes a fundamental difference to us whether it was done deliberately or because the person was clumsy. The person’s *goal* might be to distract us in order to steal our purse! Predictability and interpretability of reality is essential for us. This is especially true with respect to human behaviour. We can interpret and predict human behaviour better if we can relate it to the goals (motives) another follows.

The terminological distinction of action and behaviour is fundamental. I suggest that we use the term *behaviour* to refer to the muscular activity of living organisms. Behaviour can be described from a non-empathetic perspective, according to which we disregard the subjective experience of a human being showing certain muscle activity. In particular, we are not interested in people’s conscious experience of pursuing their motives, and anyway, of course, motives are phenomenally accessible to the subject only as representations and emotions. The non-empathetic perspective from which we observe and describe behaviour is not only a physically objectifying perspective, which would allow us to speak only of *mass*, *energy*, *speed* and so on. But although we disregard the experience of the behaving individual when describing his or her behaviour, we refer to our knowledge about sense relations within the environment of the behaving individual. Otherwise we would not be allowed to say that a man seizes a *bank note* with his *hand* and gives it to a *shop-assistant*. As physicists we would never be allowed to do so. Two important subtypes of behaviour can be distinguished: *voluntarily* controllable behaviour and *not* voluntarily controllable behaviour.

Action refers to that muscular activity of living organisms which we regard as subjectively intended. Action can be described from an empathetic perspective. A single action is the pursuit of a goal (motive) by certain behaviour.

The definitions are open both to human activity and the activity of other animals. If we describe human activity as *behaviour*, we describe it from a *non-empathetic* perspective. If we describe human activity as an *action*, we take an empathetic perspective by claiming a causal relation to a *conscious* motive. A motive, as will be defined below, is a *goal* to which present thinking, imagination and behaviour are directed. To an action one attributes *intentionality* (see Stegmüller, 1987, Vol. II, p. 109). An action is intended. – Behaviour which is triggered by *non-conscious* motives is *not* regarded as *action*.

Intentional Structures

Motive Subsystem

So far, we have discussed the different kinds of cognitive performance of human beings. The cognitive components in the model are those which allow us to experience reality subjectively and to interpret it in the light of the needs of our own existence. But the whole of our experiencing and interpreting of reality is not sufficient to ensure existence. In order to protect our existence through our knowledge, we have to be able to have an effect upon reality. We have to eat, to defend ourselves against other organisms and natural forces, either on our own or in co-operation with others. For this we must act. But to be able to act efficiently, we have to develop action possibilities *in our mind*, and we have to examine how suitable they are *before we try them out in reality*. To do this, we have to consider several goals – some of which cannot be pursued simultaneously – and we have to organize our actions in view of those goals.

Experiencing and interpreting reality – i.e. *cognition* – does not suffice. In addition, human existence depends on the organized pursuit of goals – i.e. *intention*. Obviously, cognition and intention are necessary complements. The pursuit of goals – both conscious and unconscious – is based on three different processes: on *thinking*, *imagination* and *the generation of behaviour*. The motive subsystem is thus the control unit of behaviour, thinking and imagination. The thinking and imagination activity produced by the motive subsystem, but taking place outside the motive subsystem, and the behaviour elicited do not depend entirely on our genes and on former and present stimuli. Rather, thinking, imagination and behaviour also depend on our free will. Whether stimuli automatically lead to behaviour or whether emotions can make an individual show a certain behaviour, is decided by the subject – within the limits of its effectiveness. With its free will, the subject influences the psychophysical system. The question as to which sites within the psychophysical system can be influenced directly by the subject is difficult to answer. It is most plausible that the subject has a direct impact on the emotion subsystem. However, direct influence on the representation subsystem (attention processes) as well as on the concept subsystem and the motive subsystem are also conceivable.

Motives are *goals* to which *thinking*, *imagination* and *behaviour* are directed. Motives are abstracted from concrete thinking and imagination processes or behaviour programmes. However, the degree of abstraction can vary widely, and we have to suppose that there is a *hierarchy of motives*. A highly abstract motive can be oriented towards a relatively unspecific goal. Only with the help of several less abstract motives – i.e. motives closer to specific behaviour programmes or thinking and imagination operations – can more global goals be achieved. Different strategies can lead to the goal. Different sequences of thinking and imagination operations differ in suitability to achieve the global motive.

For an understanding of the model presented here, it is crucial to see that motives themselves are not accessible to consciousness. The motive subsystem does not belong to the structures whose activity is connected to subjective experience. As already emphasized, only the contents of the representation subsystem and the emotion subsystem are directly accessible to consciousness. But motives are – indirectly via concepts or directly – connected to *emotions*. And emotions are accessible to conscious experience. But although motives are *not directly* accessible to conscious experience, this does not imply that one cannot know their content. However, as *abstractions from behaviour commands, thinking and imagination operations*, motives are realized in a non-phenomenal language. Behaviour commands themselves – localized within the behaviour subsystem – can be regarded as highly structured sequences of commands to single muscle fibers. Thinking operations themselves take place within the concept subsystem, imagination operations within the representation subsystem.

Motives are goals. Which goal will be most important and to be pursued at any given moment will depend on several factors. Bischof (1985, p. 291-292) discusses the question of how different motives can be coordinated with each other and recounts Huxley's (1941, p. 24-25) parable of the battle of the captains arguing about steering the ship. The captains are the motives, the ship is the individual. Bischof points out the limitations of this parable because it does not consider that some motives do not hinder certain other motives. The factors determining directly which goal or which goals (i.e. motives) are active at the moment are the following:

1. currently active *concepts* and the emotions elicited by them

2. the *emotions* elicited by active motives (feed-back via emotion subsystem)

3. activating and inhibiting influences by other *motives*.

Whether the subject's free will *directly* influences the activity of motives or whether its influence is only *indirect* via one of the influences mentioned above, is a difficult issue. But in any case, I assume that free will has an impact upon our current goals.

We have characterized motives as abstractions from behaviour commands, thinking and imagination operations, realized in a non-phenomenal language. But what we experience of a motive are *not* these *command abstractions*. For example, of a motive aimed at change of location – say the motive to go up the stairs – we do not experience the numerous muscle fiber commands. Rather we experience an *imagination* of the movement of our body within a subjective phenomenal space. We may also experience a linguistic transformation of a motive, produced by the concept subsystem. However, this will include only its sensory-modal expression side, active in the representation subsystem. In this way, a motive becomes accessible as a phonetic or visual imagination, perhaps even as a somatosensorily perceivable or imagined *motor realization*.

The motive subsystem structures its contents temporally. It refers exclusively to the *future*, for the past and the present – in a strict sense – cannot be changed by motives. Motives can only form the future, which will start immediately and which is separated by the present at the least by neural reaction times.

Behaviour Subsystem

Behaviour is muscular activity. Muscle activity is controlled by behaviour programmes, i.e. by sequences of commands to single muscle fibers. Behaviour comprises all stored behaviour-programme elements and sequences. Our behaviour can be separated into a large number of short elements that can be combined to form an unlimited variety of actually produced behavioural chains. A single behaviour element can be more or less complex and more or less abstract from actual motor activity. The command pattern in order to press a computer key with the middle finger is an example of a relatively simple behaviour programme, i.e. a relatively simple behaviour element. In contrast, running is far more complex and is hierarchically higher than several simpler behaviour patterns. These simpler patterns have to be connected in a more complex sequence so as to make a human being run.

Important kinds of behaviour programmes are found in the context of language production, such as articulation programmes for speaking (phoneme production) and hand motor programmes for writing (grapheme production).

Besides an enormous variety of learned behaviour programmes, even in man there are also numerous inherited behaviour programmes. Among these there are expressive behaviour programmes which project from the emotion subsystem as hard-wired connections. Despite these connections, however, – even when emotions are active – the corresponding expressive behaviour can be *actively* suppressed.

With regard to the representation subsystem, we saw above that space is a phenomenal perception and imagination space which refers to one's own body or any other real or fictitious point. For the behaviour subsystem this is different. Its spatial dimensions form a *motor* space referring to the movements performable by the human body. This motor space is structured by the movement possibilities of our joints and muscles; and this motor space is not accessible as subjective experience. What we experience spatially is always a content of the representation subsystem.

Output of the Intentional Structures

Behaviour elements, as motor commands, are transformed into behaviour by muscle fibers. Whatever we come to know about another human being depends exclusively on this muscle activity. Hearing people speak, seeing their facial expressions and gestures, is only possible because human beings give somatic expression to their subjective reality.

The Arousal Subsystem as a Modifying Structure

The human psychophysical system does not only consist of cognitive and intentional components. The activity of those subsystems shows enormous variation in intensity and content. Different brain structures, united in this model into a so-called arousal subsystem, influence the activity of the other subsystems in a global manner by the secretion of neuromodulators and hormones. Neuromodulators are substances which reinforce or inhibit the activity of entire neuron groups unspecifically not by being locally released at single synapses – as it is the case for neurotransmitters – but in a diffuse way. Hormones, additionally, can have quite specific motivational effects.

Arousal determines the activity of the autonomous nervous system, i.e. the sympathetic and the parasympathetic nervous systems. The higher the arousal, the more active the *sympathetic* nervous system is, and the less active the parasympathetic nervous system. – Simple emotions *increase the arousal* of the psychophysical system.

The arousal subsystem stands at a key position in the system, for it is connected directly to all the other subsystems. The extent of our directedness towards sensory information depends on how *attentive* we are at the moment. Our attention can even be turned away from sensory perception to a large extent, namely when we are sleeping. The activity of the arousal subsystem depends largely on the number and the emotional value of activated representations. Additionally, an internal clock with a circadian rhythm has a strong impact on the activity of the arousal subsystem. By *voluntary* influencing of the emotions and the focus of our attention, we can also deliberately enhance or inhibit arousal subsystem activity. Thus we can focus our attention on information-rich stimuli, or we can relax. The arousal subsystem controls the *extent* of our alertness and attentiveness and the depth of our sleep, but *not* the *content selectivity* of our attention. Figure 5 shows the typical course of alertness during sleep.

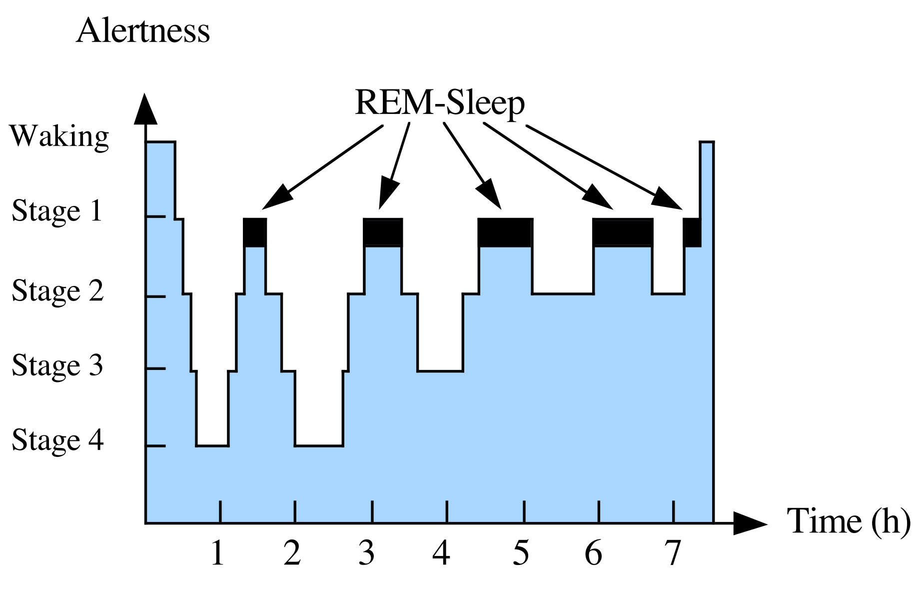


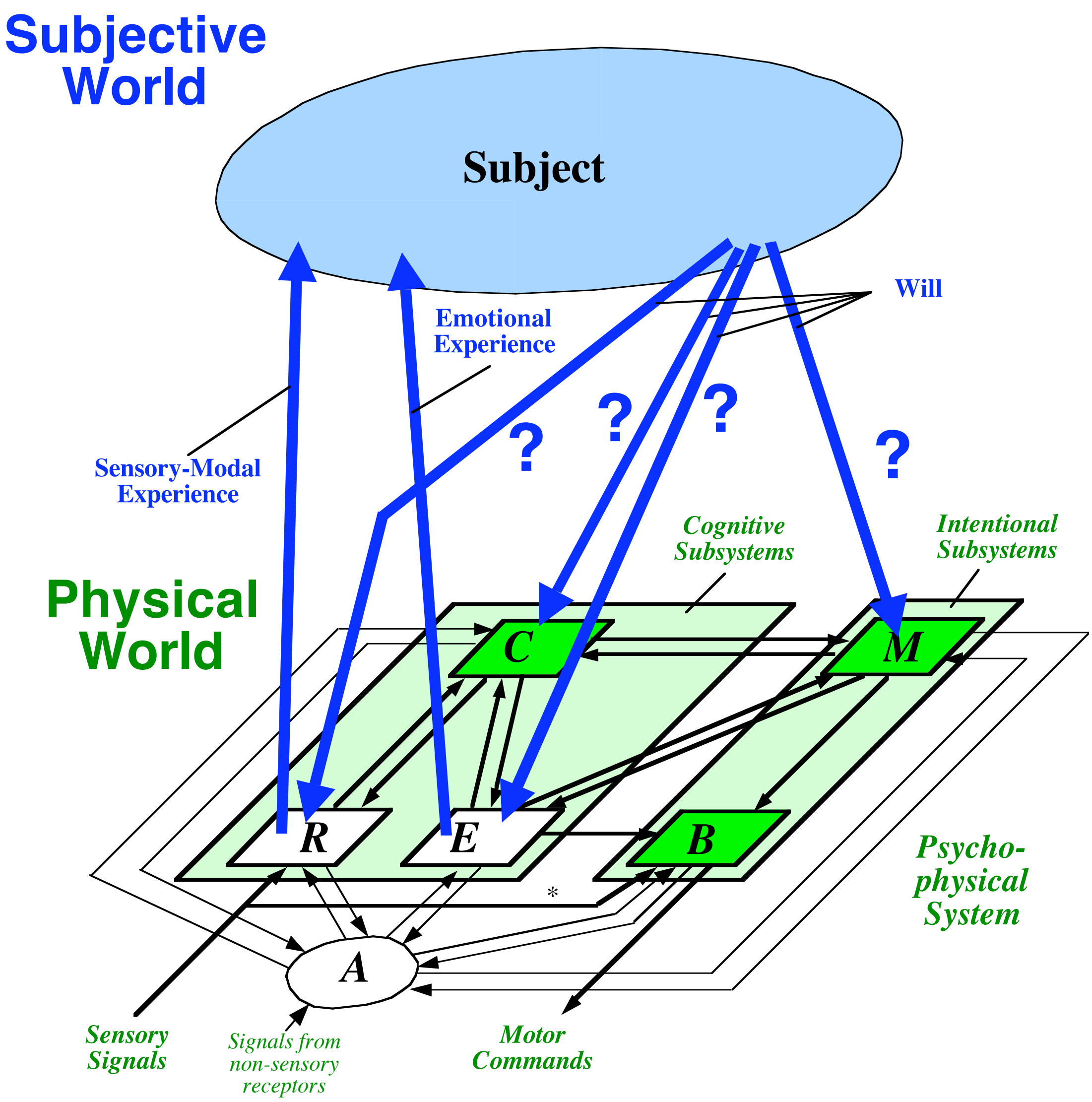
Figure 5: Cyclical pattern of alertness and sleep depth (simplified and modified after an illustration by Kelly, 1991, Figure 51-2)

In neurobiology and psychology there is still argument about the functions of sleep. In my view, sleep fulfils two different types of functions. On the one hand sleep has *restoring* functions and, on the other hand, *memory consolidation* functions. During the deeper sleep stages, homeostatic processes are central (see Achermann et al., 1993). In the more active sleep stages, especially during REM sleep (which, however, with regard to *external* wakeability is a very deep form of sleep) the consolidation of memory contents – subjectively experienced as dream elements – is central.[1]

Outlook

The structural model, built up step by step, says something about physical reality, namely the connection of those neurons involved in processing sensory information and in generating behaviour. Figure 6 depicts the model. Basically, the single components of this structure model can be referred to structures that can be *localized neuroanatomically*. Kupfermann (1991b) gives a vivid overview of the localization of cognitive and intentional functions. The anatomical equivalent of the most important distinction within the psychophysical model is the distinction between *posterior* and *anterior* in the central nervous system. As a rule of thumb one can say that cognitive structures, anatomically, have a posterior position, while intentional structures have an anterior position. In the neocortex, the *central sulcus*, which separates the primary somatosensory cortex from the primary motor cortex, forms the border between posterior and anterior. The same distinction can also be made within the spinal cord, but not, however, within the brainstem. This rule is only a rule of thumb after all, and we find that the cerebellum is anatomically at the back of the brain, although it is doubtlessly an intentional structure.

[1] See Winson (1991), for whom the function of dreaming lies in selective forgetting, whereas I see it in selective consolidation of memory contents by repeated activation in an activated state of the organism, namely REM sleep. Smith & Lapp (1991) summarize the present state of research and report that REM deprivation leads to learning deficits. REM deprivation refers to the selective waking of experimental subjects or animals during REM sleep. On the other hand, intensive learning activity during the day leads to an increase in REM sleep *duration*. See also the finding of Smith & Lapp (ibidem) that intensive learning increases the *number* of rapid eye movements (REMs) during subsequent nights. Christianson (1992, p. 327) reports on evidence that access to emotions connected with certain events is more difficult after REM deprivation.



Explanation of Symbols
R = Representation Subsystem
E = Emotion Subsystem
C = Concept Subsystem
M = Motive Subsystem
B = Behaviour Subsystem
A = Arousal Subsystem

**) the arrow marked with an asterisk refers to simple reflexes in which sensory input can directly activate motor neurons in the spinal cord*

→ *= Connections between specific contents*
→ *= Diffuse connections*
➡ *= Psychophysical causal relations*

Figure 6: Synopsis of the pschophysical system and the subject

Figure 6 also shows the localization in the model of the *psychophysical level*, i.e. the subsystems whose activity directly underlies subjective experience and whose activity can be directly influenced by the subject. The arrows pointing upward show that the activity of the representation subsystem and the emotions subsystem exclusively can be experienced subjectively. The arrows pointing down have question marks, since it is not clear exactly which subsystems – i.e. which brain areas – can be directly influenced by the subject.

The model proposed is of considerable *heuristic* value in developing an integrative psychological approach to man. It is empirically testable – however always on the basis of the underlying axioms – which becomes clear in the light of Duhem's theorem according to which hypotheses are never tested in isolation (see e.g. Lambert & Brittan, 1987, p. 72). For closer examination of my model, I suggest several hypotheses on the localization of its single components and on their phenomenal accessibility in Table 2.

Model Component	**Neuroanatomical Localization**	**Subjective Correlates**
representation subsystem	thalamus (1), primary visual cortex (2), primary auditory cortex (2), primary somatosensory cortex (2) (1) activity not accessible to consciousness (2) activity accessible to consciousness	sensory-modal experience in a spatial reference system [isomorphic to a state dependant part of representation subsystem activity (sensory-modal part of the psychophysical level)]
emotion subsystem	limbic structures	experience of simple emotions [emotional part of the psychophysical level]
concept subsystem	visual, auditory and somatosensory higher order cortex, parietal-temporal-occipital association cortex	none
motive subsystem	prefrontal association cortex	none
behaviour subsystem	premotor cortex, primary motor cortex, cerebellum, several brainstem and spinal cord structures	none
arousal subsystem	several diencephalon and brainstem structures plus hippocampus	none

Table 2: Rough hypotheses about the neuroanatomical localization of the components of the psychophysical system (these hypotheses still have to be refined and empirically tested)

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