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Dreaming: The Functional State-Shift Hypothesis

A Neuropsychophysiological Model

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Summary: The different brain functional states during sleep and wakefulness are associated with differences in processing strategies, memory stores, and EEG patterns. Shifts of functional state occur spontaneously or as orienting reactions to processed information, and cause the formal characteristics of dreams. Forgetting of dreams is a function of the magnitude of the difference between states during storage and recall. Based on EEG similarities between sleep stages and developmental stages, brain states during sleep in adults are proposed to correspond functionally with waking states during childhood. Repeated functional regressions occur during sleep, with access to earlier memory material and cognitive strategies unavailable during waking life, so that earlier experiences can be used for current problems. This dream work constitutes the biological significance of sleep.

Reported dreams are the recall of cognition/mentation, i.e. of information processing which occurred during sleep. The purpose of this paper is to outline the sequence of psychophysiological mechanisms which come into play during this processing of information. The proposed model is based on a review of existing physiological and psychological data, and does not invoke dream-specific processes, but views mental activity during sleep as resulting from psychophysiological mechanisms which are common for mentation in all states of consciousness. Evidence from studies in psychopharmacology, electrophysiology, experimental and developmental psychology, behavioural studies, and psychoanalysis is used in this. Some proposals here are speculative, and experimental procedures will have to be developed for testing others. Thus, the model should be viewed as an analogue, and not as a theory to be proven or disproven. Since reconceptualization and integration of known facts often brings progress to a field, we hope that these proposals will elicit further productive discussion and research.

Our model is based on those of Hebb (1961), Sokolov (1963), Lynn (1966), and Douglas (1972) for brain processes determining behaviour. It is consistent with the information processing approach of cognitive psychology (Neisser, 1976), and has similarities in some points with the models of dreaming of Breger (1967) and of Koulack and Goodenough (1976). Literature on dream formation has been discussed by Webb and Cartwright (1978), Wolman (1979), and Strauch (1981), among others.

Our model explains the sources and the formal characteristics of sleep mental activity, in particular of dreaming, and the difficulties of retrieval of dream experiences during wakefulness (the forgetting of dreams). It proposes a physiological basis for the biological significance of dreams, and offers meaningful physiological explanations for the psychological phenomena of dream work (e.g. censorship), which were described by Freud (1955) and by other psychoanalysts. In addition, the model will account for the therapeutic effect of dream interpretation in the treatment of neurosis (Koukkou and Lehmann, 1980; in press).

The concepts of the functional states of the brain and of the orienting response are basic to this model. The physiological measure which we use is the electroencephalogram (EEG) which permits the continuous direct recording of human brain activity, and is a sensitive index of its functional state, e.g. during different levels of vigilance, or during different stages of the individual's development, or during the effect of centrally acting drugs. The EEG-defined functional state might be widespread and of long duration (awake and sleep stages, maturational stages) or very narrowly distinguished and short-lasting in the range up to seconds (spontaneous fluctuations of attention, input-evoked responses). The functional state and the EEG might be changed adaptively by

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incoming information through the orienting response.

The functional state of the brain is related to quality and type of attention, cognition, logical decision, learning, and retrieval; in other words, it determines and constrains the character and quality of information processing. As learning and retrieval depend on the functional state of the brain (state-dependent learning and retrieval) which is reflected in the EEG, the degree of impairment of retrieval of information which was stored in one state (e.g. sleeping) when recalled in another state (e.g. awake) is a function of the magnitude of the difference between the two states, defined by their respective EEG patterns. Finally, based on similarities in EEG patterns, we believe that some functional states of the brain during different sleep stages correspond to functional states of the awake brain during its earlier development. Sleep implies physiological regression to earlier stages of development, and this includes both memories and cognitive strategies for information processing.

State dependent learning and retrieval

Experiments on the state dependency of learning and recall (Overton, 1961, 1978; Weingartner, 1978; for reviews see Bliss, 1974) have shown that performance of a response which was learned during a drug condition may appear impaired during testing in a non-drug condition. However, when the subject receives the original drug again, the learned response can be elicited again. In other words, there are some functional states of the brain during which memory material gets stored in a form which makes retrieval difficult or impossible during other functional states; there are also states during which recall of already stored memory material is blocked.

Dissociation of learning produced by drugs is asymmetrical, i.e. behaviour learned without the drug may be recalled during the drug state, but behaviour learned during the drug state may be recalled only partially without the drug, provided the magnitude of difference between drug state and non-drug state is small (Overton, 1979).

The functional model of the brain which we propose (Fig 1) includes these mechanisms of state-dependent learning and retrieval. Separate storage spaces which correspond to functional states are illustrated, although one might think of a graded storage continuum. The different storage spaces do not imply different physical locations; the 'space' may well be a common apparatus, which is treated with different tools. The entire system in the illustration is shown in a functional state called '7', which implies that access to long-term storage space '7' is open to the logic/decision/analysis system and to the motivation system for identification and recall, storage, and cognitive

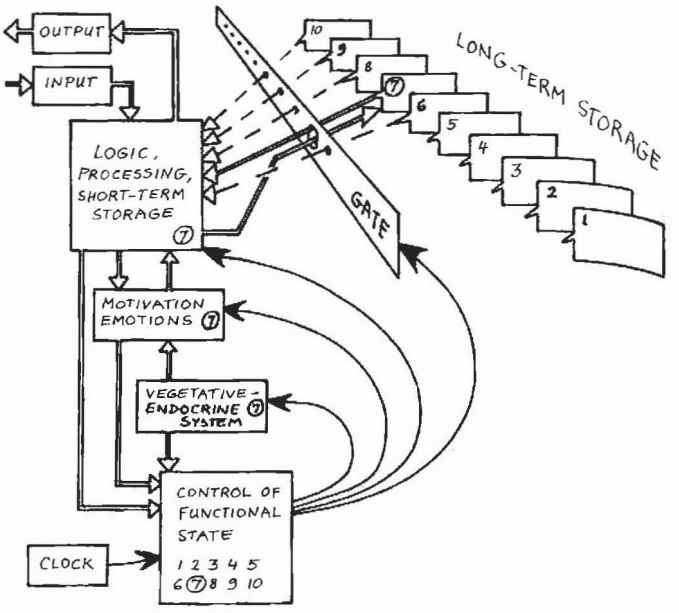


FIG 1.—Functional model of the brain. Double lines: open information channels; dashed lines: partially open information channels; solid, thin lines (with black arrow heads): control channels. The functional state of the entire system (illustrated is state 7) is set by the control system according to clock input, and to input received from the logic/processing (analysis) system with its short-term memory, from the motivation/emotion system, and from the vegetative system. The control system in return adjusts the function of logic and motivation and vegetative system to the current functional state, and opens the gate to the associated long-term memory space for deposit and recall (in the picture, space 7). Memory of higher arousal levels (8 to 10) can be partially recalled; of the lower levels, only the next neighbor space 6 is partially open for recall. Shifts of the functional state put different memory spaces and processing strategies into use.

treatment, as indicated by the open channels. Storage spaces of higher order (which are indicated by higher numbers) are partially open for identification and recall, as indicated by broken read-out channels, but they are not accessible for storage; this illustrates the asymmetry of the phenomenon. Storage spaces of lower numbers are not open for recall or storage, except that the next lower number is accessible for partial recall only.

Of direct interest to our model are reports of differences in retention when training and testing occur at different times during day-time waking (Stroebel, 1967), during EEG-defined sleep stages (Evans *et al*, 1969), and during different phases of psychotic disorders (Reus *et al*, 1979). We also note that all centrally acting drugs are known to be associated with distinct changes of EEG patterns from the normal awake state (Itil *et al*, 1979).

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Amnesia in hypnosis could also be a phenomenon based on state-dependent learning and recall, i.e. a problem of retrieval (Evans and Kihlstrom, 1973). According to the model, there should be different brain states during hypnosis and recall, and an EEG study which tested this hypothesis (Evans *et al*, 1969) supported the expectation of the model. However, other studies on EEG and hypnosis do not consider this problem (for review see Cooper, 1979).

Mental activity and experience during sleep are difficult to recall in waking life (Goodenough, 1978). The same is true for mentation (experiences) during early stages of childish development which are impossible or difficult to recall in later stages of development and in adulthood (Hetherington and McIntare, 1975; Flavell, 1977). Even events which repeatedly occurred during the first years of life, and for which the child at that age has shown distinct proof of retention, cannot be retrieved in older ages (Reese, 1976). Retrieval difficulties for early experiences of the first years of life increase with the growing age difference between storage and recall of an experience. Likewise, wakeful cognitive strategies become increasingly different with maturation. Both situations—sleep and early stages of development—are characterized by distinct differences in the EEG state of the brain, as compared with the adult's awake brain. Accordingly, we propose that the different functional brain states (EEG states) during sleep and early development give rise to phenomena of state-dependent learning and retrieval. This would account for the impairment when awake of recall of dreams or hypnagogic hallucinations, and for the impairment of adult recall of events which occurred during development.

Functional states of the brain and information processing

The orienting response

Different functional states of the brain are manifest in the scalp electroencephalogram as different spectral distributions of EEG wave frequencies. The EEG mean frequency increases with progressing maturation and with higher levels of vigilance in a circadian rhythm. Parallel to these changes, cognition progresses from preoperational thinking to propositional operations, from early childhood to adulthood (Piaget and Inhelder, 1969), and reality-remote and relaxed rules for cognition during sleep (Antrobus, 1978) change to tightly constrained thought sequences when awake. The progressive development of self-reflection, observable in children's verbal behaviour, and the impossibility of having self-reflective thoughts in adult dreams are also relevant. In this context, Lopez da Silva *et al* (1974) have shown in a modelled neuronal population that increase of synaptic connectivity, i.e. increase of functional complexity, led to higher frequency of integrated electric activity.

These gross brain states are not homogeneous. Psychological parameters such as perception ('fluctuations of attention'—Woodworth and Schlossberg, 1954) or performance (e.g. Continuous Performance Test—Rosvold, 1956) display continuous fluctuations within short epochs in the range of seconds, like the EEG characteristics shown in autoregression EEG studies (Barlow *et al*, 1981). In fact, even inspection with the naked eye easily reveals that typical EEG wave patterns recorded in one channel change quickly, particularly during sleep or immature consciousness. Sleep EEG spindles and alpha EEG spindles are classical examples of such short patterns.

The observations of different types or classes of cognition observed during short episodes, characterized by different EEG wave frequency spectra, are of particular interest. The EEG power spectra were significantly different in 36 subjects during 16-second epochs immediately preceding reports of spontaneous reality-oriented abstract thinking, reality-remote non-visual fantasies, and reality-remote visual fantasies (Lehmann *et al*, 1981b). Similarly, other studies reported EEG differences between epochs when different cognitive activies were requested (Ehrlichman and Wiener, 1980). Hypnagogic hallucinations are experienced during an EEG stage (stage 1 Non-REM) which is similar in spectral power distribution, but very dissimilar in spectral coherence between scalp areas, when compared with the state (stage 1 REM) in which dreams are most frequently recalled (Lehmann *et al*, 1979). Arriving information evokes potentials which depend on the EEG state at the time of input (Basar, 1980); likewise, the subjective perception of the information depends on the momentary EEG state (Lehmann *et al*, 1965; Keesey and Nichols, 1969).

The functional state of the brain of an adult person with his specific genetic make-up is determined at a given moment in time by the interaction between (a) incoming information from the environment and the body, (b) previous experiences (memory content which includes learned motivation), (c) drives (inherent motivations which include curiosity and metabolic or hormonal factors such as hunger and sexuality), (d) vigilance (sleep/wake rhythm) and (e) before adulthood, the stage of brain development. To these physiological factors must be added modification by drugs, and by mental or physical illness which can produce very large inter-individual differences (Koukkou and Lehmann, 1976; Angst, 1974).

The mechanisms mediating the interaction of these factors are modelled in Fig 1. The control system

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(which anatomically might be equated with the reticular formation, or ascending cholinergic and aminergic systems of the brain stem) allows changes of the functional state of the brain within months, hours, minutes, or seconds, according to clock time and to information coming from other brain structures (e.g. developmental phase, circadian rhythm, REM stage cycle duration), and within fractions of seconds according to the demands made on the system by incoming information, after its initial interpretation (Norman, 1976; Neisser, 1976). The readjustment of the functional state of the brain becomes manifest as modification of the level of organization, with associated change of the EEG patterns, which is the central component of the orienting response (Lynn, 1966; Koukkou, 1980).

Incoming information reaches the analysing system and the motivation system. The analysing (processing) system provides intellection elaboration of the information, e.g. 'it is a very bright light'. The motivation system tests the stimulus for specific emotions, e.g. 'it is unpleasant' (because it is very bright). Then, a very fast evaluation of the information occurs from previous experiences, with similar events retrieved from long-term memory store, and from the motivational condition of the person at that moment (Sokolov, 1963; Lynn, 1966; Douglas, 1972). These processes lead to the identification of the stimulus and correspond to the automatic, pre-attentice, initial interpretation of the information (Neisser, 1967; Shiffrin and Schneider, 1977). The memory storage space which is open at the moment of arrival of the information must be used, because at any given time, a limited set only of the total memory storage is available for search. To some extent, storage spaces of higher functional states and of the immediately neighbouring lower state are also accessible for search (indicated by broken arrows in Fig 1), following the phenomena of asymmetrical state-dependent recall, discussed above. The long-term memory store may be thought of as a very large capacity store, which is hierarchically organized (Norman, 1976) and which includes control elements of stimulus representation. The latter consist of the intellectual and emotional characteristics of the stimuli associatively related in episodes or contexts, i.e. also including the context in which the information was encountered (Mandler, 1975; Öhman, 1979).

The initial interpretation sorts out stimuli which require a more or less intense orienting reaction from those which require no orienting reaction (Öhman, 1979). This process depends heavily on the current motivational condition of the system (Bernstein, 1979; Douglas, 1972). An orienting reaction is frequently required merely because the stimulus is new ('non-signal orienting response'—Öhman, 1979); this is a graded judgement, since natural stimuli are complex, and may contain few or many new parts, or differ from a range of already familiar stimuli by only a hair or by an extreme divergence. Repeated presentation of a new stimulus will lead to adaptive changes, either the simple disappearance (habituation) of the orienting reaction (Sokolov, 1963; Horn, 1969), or, when necessary, the development of a specific reaction (Lynn, 1966). The latter is stored in long-term memory, and gradually becomes automated with repetitions, i.e. the specific reaction occurs instead of the orienting reaction (for a review of the physiology, see Pribram, 1971; of the psychology, see Shiffrin and Schneider, 1977).

Necessary reactions to well-known stimuli are retrieved from this or from the storage space of a higher state, and are executed without state change as automated reactions (for instance: driving a car during a conversation, or avoidance of obstacles during sleep-walking). In our model, this means that further processing and decision-making about the known stimulus and the reaction to it, the choice of further reactions and associations to them—i.e. the full interpretation (cognitive processing) of the information which follows the initial interpretation (Craik, 1979)—continue with the cognitive strategies on hand, and with the priorities which were set before stimulus arrival (Shiffrin and Schneider, 1977).

Orienting reactions to very intense stimuli or to stimuli which are specific for the drive condition of the system at the moment do not easily habituate. Stimuli which have an acquired, learned importance for the individual, e.g. signal stimuli such as the individual's first name (Oswald, 1962) or the warning 'watch out' keep the orienting reaction, since the orienting reaction in this case is the learned response, and ensures the necessary shift of attention. The orienting reaction to signal stimuli has a particular importance for the proposed model of sleep mental activity.

The orienting reaction to a stimulus which is unknown (Lynn, 1966) or important for the individual (Bernstein, 1979; Velden, 1978) is associated with a number of well-known peripheral physiological changes, in addition to increased EEG wave frequencies (Sokolov, 1963; Lynn, 1966; Koukkou, 1980; 1981; Öhmann, 1979). For optimal efficiency the shift of attention requires a shift of the functional state to a more activated state (Lynn, 1966); in Fig 1, this is in the direction towards state 10. This shift of arousal level implies the switch to another memory storage space, and to different cognitive strategies, of which some are inherent to the state, and others are retrieved from the state's storage. This means that further cognitive processing, the kind of association material which will be activated, and the fate of the information in the

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system (i.e. its later accessibility) may now well be different from what it would have been in the previous functional state before the orienting reaction.

EEG and information processing during sleep and ontogenesis

With decreasing levels of vigilance, there is a shift to lower frequencies in the EEG, where slower and faster wave elements are combined in differing percentages, and fluctuations of these percentages appear during each sleep stage in the different brain regions (Williams *et al,* 1964; Pivik, 1978; Borbély *et al,* 1981). REM sleep, with its frequent dream reports, exhibits a wave frequency spectrum which is close to that of sleep stage 1 Non-REM, but differs from it in interhemispheric EEG coherence (Dumermuth and Lehmann, 1981).

The human EEG recorded in wakefulness from birth to adulthood shows a shift of the dominant component to faster wave frequencies, with difference between regions in the rate of change (Matousek and Petersen, 1973; Samson-Dollfus and Goldberg, 1979; Katada *et al,* 1981). Although typical adult EEG patterns may be seen for brief periods as early as the age of three or four years, the maturation of the EEG is not completed before the end of puberty (Dumermuth, 1976). Slower and faster wave elements are combined in differing percentages at each maturational stage, but the percentage varies widely during a given child's day, within short times. This means that varying amounts of adult EEG patterns may be present in a given child's EEG during a day's wakefulness, and that varying amounts of less developed waking EEG patterns may be present during a person's (child, adolescent, adult) different sleep stages. Accordingly, we hypothesize that during sleep, functional states of previous developmental stages can be repeated.

During behavioural and EEG sleep, the transmission of sensory information to the central nervous system (as evidenced by evoked potentials) is maintained, the arriving information is compared with stored memory contents (recognition), and the selection and execution of reactions (including motor responses) originally acquired during waking life are possible (Oswald, 1962; Jacobson *et al,* 1965; Williams, 1973; McDonald *et al,* 1975). However, both the initial interpretation and the subsequent cognitive processing of the information are different in sleep from when awake, and later recall, when awake, of events reacted to during sleep is virtually impossible. A pertinent, very dramatic observation is the obvious ability of a sleep-walking person to process information and to react to it during the somnambulistic episode, which is associated with slow wave sleep EEG patterns, and the inability of the same person to recall these events later during consciousness (Jacobson *et al,* 1965).

On the other hand, if a transient waking period—as defined by the EEG—occurs immediately following the arrival of information, later recall of the event will be possible during full wakefulness (Emmons and Simon, 1956; Koukkou and Lehmann, 1968). The quality of recall is a function of the duration (Koukkou and Lehmann, 1968; Oltman *et al,* 1977) and degree (Lehmann and Koukkou, 1974) of the EEG arousal which followed the arrival of the information during sleep, as well as of the degree of familiarity of the information (Lehmann and Koukkou, 1974). These observations are in very good agreement with the results of dream recall studies, which show that dream recall is a function of the amount of relative arousal some time before asking for dream recall (Goodenough, 1978; Webb and Cartwright, 1978): Dream recall is more likely after awakenings which occur during or immediately after the REM stage of sleep, with its higher, (nearer waking) EEG wave frequencies, than during slow wave (NREM) EEG sleep stages 2, 3, and 4 (Foulkes, 1962). However, awakenings from NREM sleep stages at the end of the night, during which the organism has lighter sleep, as compared to the early NREM stages, yield more dream reports than from the early NREM stages (Foulkes, 1966). Light sleepers, who have more activated EEGs during all sleep stages, report dreams from NREM awakenings almost as often as they do from REM sleep awakenings (Zimmerman, 1970). Moreover, awakenings which are made some time after the REM period has begun yield more dream-like content than awakenings made at the beginning of the REM period (Foulkes, 1966). As dream reports are known from awakenings before the occurrence of the first REM phase (Kuhlo and Lehmann, 1964; Vogel *et al,* 1972; Vogel, 1978), dream-like mentation may well be continuous during all sleep stages (Foulkes, 1966; Webb and Cartwright, 1978), but later waking recall of those experiences which occurred during less activated states is impaired (Koukkou and Lehmann, 1968; Koulack and Goodenough, 1976). In a dream recall study, where subjects were awakened after each stage REM epoch, EEG spectra of those with dream recall differed significantly from those without (Lehmann *et al,* 1981a). Increasingly better subsequent waking recall of presented information is achieved where there has been more EEG activation after the presentation (Lehmann and Koukkou, 1974). Its degree of impairment depends on the magnitude of differences between the EEG state during mentation and during recall, which is in accordance with our hypothesis.

State dependency has been proposed before as an explanation of failure of dream recall (Overton, 1973;

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Goodenough, 1978). Such theories have not been widely accepted because it is not possible to learn material during sleep for later waking recall (Emmons and Simon, 1956; Lehmann and Koukkou, 1974). However several studies have reported evidence of habituation of the EEG arousal responses (Oswald, 1962) and of other physiological responses like K complexes or galvanic skin responses (Owald *et al*, 1960; Firth, 1973) during sleep, which must be classed as cases of learning. Strictly speaking, therefore, there is no difficulty of storage during sleep, but a failure of retrieval on waking (Koulak and Goodenough, 1976). Studies directed specifically to learning and retrieval in the same sleep stage have been made by Evans *et al* (1969; 1970).

It was pointed out above that the identification of information and a well-learned reaction to it are possible during sleep via the initial interpretation. But the characteristics of the later cognitive processing (full interpretation of the information) depend on the functional state which was introduced after the initial interpretation. Studies on dreams and on incorporation of stimuli in dream content (Rechtschaffen and Foulkes, 1965; Koulack, 1969) indicate that in spite of apparent similarities between mentation during waking and sleep (Rechtschaffen, 1980), cognitive strategies during sleep differ from those during wakefulness (Antrobus, 1978; Schwartz *et al*, 1978). Mentation during sleep is very frequently imagistic, and often characterized by perceptual fantasies, by reality-remoteness (Cartwright, 1981), and non-reflectiveness (Rechtschaffen, 1980); it has been said to have similarities with the reality-remote fantasy play of children (e.g. Piaget, 1962).

Information received in early childhood is initially treated by inherent, built-in, basic strategies (Vaughan, 1975; Flavell, 1977), but the continuously stored new information leads to the formation of new cognitive strategies, which are maintained and stored in newly developed functional states. New strategies are used to process the new information and to reprocess still accessible old information (Piaget, 1962; Pribram, 1971; 1976; Nelson, 1974; Flavell, 1977). Generally speaking, the older the child, the more adaptive and reality-including is its dealing with the environment (Flavell, 1977). Studies of dreaming during cognitive development (Foulkes, 1982) indicate that dreaming requires cognitive skills. Dream recall appears to begin after the preverbal age, i.e. at about three years of age; the younger the child, the smaller are the differences between mentation during sleep (dreams) and during wakefulness, in parallel with the EEG, which shows smaller differences between wakefulness and some sleep stages in early childhood than in adults.

The developmental changes of the EEG and their fluctuations during waking life may be compared with the vigilance changes of the EEG and their fluctuations during different sleep phases. There are some similarities of cognition between sleep and childhood (mainly in reality-remote visualizing cognition). We therefore propose that repeated functional regressions to previous developmental stages occur during sleep. Implied in this proposal is the notion that a functional state is associated with a specific memory storage, and with specific cognitive strategies (Fischer, 1971). This means that during sleep, an individual will go repeatedly through previous developmental (ontogenetic) functional stages, using processing strategies and memory contents which are associated with earlier developmental stages. We do not conceive these EEG states as corresponding to conventional EEG sleep stages or years of age, but short episodes, possibly in the range of seconds or even shorter, and represented by brief series of EEG waves of particular type, may constitute a functional state (Lehmann and Koukkou, 1980; Pivik, 1978; Grosser and Siegal, 1971). Differing short-lasting EEG episodes at sleep onset (Koukkou *et al*, 1975), or during day dreaming (Koukkou *et al*, 1981; Lehmann *et al*, 1981b) are associated with distinct differences in mentation style.

Dream formation

The change from waking to sleep does not interrupt the flow of mentation; dreaming in the sleeping brain is the equivalent of thinking in the waking brain. But mentation becomes different during sleep (Antrobus, 1978; Rechtschaffen, 1980; Cartwright, 1981), with activation of cognitive strategies and memories from storages not directly accessible to the waking adult. Open access to lower-order storage contents and lower-order processing strategies might correspond to Freud's hypothesized primary process.

When there is no spontaneous state change (clock time), and when no signal stimuli are found among the incoming stimuli or in the retrieved material and in the associations newly formed during sleep, the functional state persists unchanged, further associated material is retrieved, and further new associations stored. In lower functional states, much of this processing may be as image treatment, according to the cognitive tactics of childhood (Piaget and Inhelder, 1969; Farnham-Diggory, 1972; Flavell, 1977). However, when the material or new association is recognized as a signal stimulus for the sleeping person at that moment, a smaller or larger state shift ensues as an orienting reaction, its magnitude depending on the sleep stage. Such state shifts may correspond to the phasic EEG events which appear with different form, magnitude and duration throughout sleep (Pivik, 1978).

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A state shift makes the material in the short-term store available for processing in a new, higher functional state, where it activates new associations, is treated with different more advanced cognitive strategies, and is then stored in the storage appropriate to the higher state. State shifts account for the typical discontinuity of content in dreams. If, after processing, the material again shows signal characteristics, the orienting reaction will continue and may lead to complete waking.

Since a signal stimulus results in an orienting response, with an associated shift to a higher functional state tapping higher storage spaces, further processing of the signal stimulus by drawing on its entire original association material in the lower storage spaces becomes impossible (asymmetry of the state dependency of recall). This sequence of processes might correspond to the phenomenon of dream censorship and repression, while the same processes may lead to repression and forgetting in waking life.

Another later spontaneous decrease of the vigilance level may bring some of the new context material or even portions of solutions to problems which reside in the short-term store back into the lower functional states, and so on. Such repeated shifts of processing strategies and accessible memory spaces for retrieval and storage will result in the characteristics of sleep thinking, when examined with adult waking logic, and may respond to the processes of condensation and displacement in Freud's dream work.

Our model does not postulate an independently acting decision-making unit in 'dream work' for the preservation of sleep, but it proposes the action of common psychophysiological mechanisms in all vigilance states (wakefulness and sleep). These mechanisms, using acquired and innate state-dependent processing strategies and state-dependent storage, result in what may be described operationally as unconscious decisions, related to automatic behaviour during waking life (Shiffrin and Schneider, 1977; Shevrin and Dickman, 1980).

A prerequisite for dream recall, of course, is storage of the sleep mentation material in a functional state which is close enough to adult wakefulness, so that it can be retrieved on waking. The salience of a dream is also important for its recall (Goodenough, 1978; Strauch, 1969) since it introduces near-waking states via the orienting reaction. But very striking dreams lead at once to high levels of arousal wakefulness and thereby to 'forgetting' of dreams because of the exceedingly large differences in state between the start of the striking dream in sleep and the finish in high-arousal waking. Thus, dream recall during waking life is restricted, and favours ideas stored during brain functional states which are close to waking.

After awakenings from NREM sleep stages early in the night (functional state very far from wakefulness), brief thoughts rather than dreams are reported, and this might be explained as a read-out of material which momentarily resided in short-term memory during awakening. The typical shortness of these thoughts close to reality suggests this idea.

Dream recall can be further complicated by the identification of signal-stimuli in a dream's content, during narration when awake. This will lead to an orienting reaction, thereby to a shift to a still higher functional state, and thereby to an increase in the magnitude of difference between the two functional states, and thus to a loss of access to the storage space where the dream is stored. This is experienced as a forgetting of a part or whole of the dream, the process corresponding also to Freud's censorship and to forgetting or repression. The same result can, of course, be produced by an external stimulus such as a telephone bell during recall (interference effect). The same psychophysiological mechanisms can also account for the phenomenon of forgetting of a dream and remembering it again later in the day.

Sleep mentation shows unusual characteristics, when compared with adult awake thinking: it is image-based, less well organized, reality-remote, bizarre, and non-reflective; emotions have not yet been studied systematically for similarities or differences. However, it is meaningful for the individual, since its content reflects the individual's past history and current motivational condition (Greenberg, 1981). Of course, all shifts of functional state during sleep are embedded in the gross circadian changes of vigilance. Although sleep mechanisms in general and REM mechanism in particular are quite sensitively adaptive to experimental requirements (Hartmann, 1976), the cyclic occurrence of REM stages is pre-programmed (Hobson and McCarley, 1977) by clock time. However, as dreams occur in all sleep phases, including the times before the first REM stage (see above), REM-specific mechanisms (McCarley and Hobson, 1977) cannot account for basic dream characteristics.

The physiological significance of sleep and sleep mentation

Thus, the sequential occurrence of gross sleep stages (non-REM/REM), with their continuous fluctations, might have the purpose of renewing access to memory stores of previous developmental stages, to compare and if necessary assimilate old material and information-processing strategies with new ones. The integration of new information into existing structures, the matching and linking of significant past and present events, has been proposed as the adaptive function of dreaming (Pearlman, 1970; Palombo, 1978). Our

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model indicates how and why this process can take place during sleep. The temporary re-establishment of lower-order functional states with re-opened access to earlier memory stores and processing strategies, and the possibility of shifts to other states with other stores and strategies, mean that the individual during sleep has a wider spectrum of 'solutions' available for tentative application to new problem material. The physiology and content of dreaming are influenced by the demands of the information which the brain is processing during sleep (Greenberg, 1981). Manipulations increasing vigilance have been shown to trigger REM sleep (Sitaram *et al,* 1976), while an increase of REM sleep time occurs after days of stress, worry and intense learning, and generally, after emotionally demanding events during the day (Hartmann, 1976; Greenberg, 1981). The re-processing of the stressful material during sleep would lead to repeated orienting responses, i.e. shifts to higher arousal levels and increased REM sleep time.

The sequence of brain states in sleep may also offer, at regular intervals during Non-REM sleep, the possibility of restorative, synthetic processes (Adam and Oswald, 1977) and, during REM sleep, those functional states where memory storage is close enough to adult waking life for retrieval into consciousness of some of the store. This, if it occurs, would give the REM phase a special physiological significance for the brain's information handling—not only in the direct way of selecting, sorting and consolidating new experiences received during waking life (Shapiro, 1967; Koulack and Goodenough, 1976; Palombo, 1978; Bloch *et al,* 1979), but also through optimizing the use and linking together of old and recent experience. This idea is supported by what is known of the phylogenesis of the REM stage (Tauber, 1974), with its systematic increase in more complex animals, and the ontogenesis of REM, with its decrease with decreasing scores of experiences which have not been brought into waking life.

The physiological organization of the REM stage includes cortical activity of near-wakefulness (EEG and single units), associated with a relative, functional de-afferentation and de-efferentation of the brain from the periphery (Gücer, 1979; Pompeiano, 1967). The disconnection prevents emotion-related peripheral activity and its feedback (Fig 1), and thus may prevent the reinforcement via peripheral loops which is necessary for the complete emotional experience (Arnold, 1960), reducing the conditions for further arousal (Palombo, 1978).

The treatment of information during sleep, along the lines described in this paper, might be of importance for the maintenance of sleep. It permits the comparison of information with the contents of the current memory storage space and of higher storage spaces, without awakening, yet without correction for external reality and without reflection, as in fantasy. It is of interest that the greatest inter-hemispheric coherence of the EEG is observed during REM phases (Lehmann *et al,* 1979), conceivably indicative of high inter-hemispheric transfer. This would mean increased access of the adult dominant (left) hemisphere to memory material stored in the right hemisphere in early childhood, before functional left dominance was established, and the possibility of verbalization of material generated in the right hemisphere, which might be dominant during dreaming (Galin, 1974).

The proposed mechanisms of repeated access during sleep to the memory storages of earlier developmental stages, and of the possibility of transferring some relevant (signal) material through orienting reactions to higher-order storage spaces mean that, eventually, earlier material can get treated in consciousness. Information once acquired thus remains useful to the individual, and important past experiences are at least partially incorporated into adult waking life (Freud, 1955; Hebb, 1961); the functional regression during sleep has a physiological and also a psychological significance to the individual.

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