

Continuity Between Waking and Dreaming: A Proposal for a Mathematical Model

Michael Schredl, Ph.D.

The so-called continuity hypothesis of dreaming states that waking experiences are reflected in dreams. The formulation of the continuity hypothesis is very broad and vague, however, so that it seems necessary to investigate factors which might affect the incorporation rate of waking-life experiences. A review of the different research paradigms, e. g. assessing temporal references of dream elements, studying the effects of the pre-sleep situation on dreams, will be presented. Various methodological issues which limit the generalizability of the findings in this area will also be addressed. After this overview, several factors such as (a) the time interval between waking-life experience and dream occurrence, (b) emotional involvement, (c) the type of waking-life experience, (d) personality traits and (e) the time of the night (time interval between sleep onset and dream onset) for which empirical data indicates an influence on incorporation rates of waking-life experiences will be listed. A mathematical model is proposed which should enable researchers to identify influencing factors and their interactions making a more precise formulation of the continuity hypothesis possible. **(Sleep and Hypnosis 2003;5(1):26-39)**

Key words: *continuity hypothesis, dream content, dreaming, laboratory references, mathematical model*

INTRODUCTION

Already in 1900, Freud (1) reported that day residues (recent waking-life experiences) are common in dreams. This observation and subsequent empirical studies (overviews: 2-5) have led to the so-called continuity hypothesis of dreaming which states that waking experiences are reflected in dreams; in other words: dreaming is in continuity with waking

life. This hypothesis has to be differentiated from the compensation hypothesis (themes which are neglected in waking life will be found frequently within dreams) and the "random" hypothesis (dream content is random).

The continuity hypothesis in the above formulation is very broad and vague, so that it seems necessary to investigate factors which might affect the incorporation rate of waking-life experiences. A review of the different research paradigms, e. g. assessing temporal references of dream elements, studying the effects of the pre-sleep situation on dreams, will be presented below. Various methodological issues which limit the generalizability of the

From the Sleep laboratory, Central Institute of Mental Health Mannheim, Germany

Address reprint requests to: Dr. Michael Schredl, Sleep laboratory, Central Institute of Mental Health, P. O. Box 12 21 20, 68072 Mannheim, Germany
e-mail: Schredl@as200.zi-mannheim.de

Accepted November 29, 2002

findings in this area will be addressed.

Following this overview, several factors such as (a) the time interval between waking-life experience and dream occurrence, (b) emotional involvement, (c) the type of waking-life experience, (d) personality traits and (e) the time of the night (time interval between sleep onset and dream onset) for which empirical data indicates an influence on incorporation rates of waking-life experiences will be enumerated. These considerations implicate the proposal of a mathematical model which allows precise predictions and is thus open to empirical testing. Such processes of developing a concrete models can be found for the topic of dream generation (6,7) and the explanation of the specific formal characteristics of dreaming such as bizarreness (8). In contrast to these models, the present article delineates a model for the thematic continuity between waking life and dreaming.

EFFECT OF DAYTIME EXPERIENCES ON DREAM CONTENT

In order to test the effect of daytime experiences on dream content, several different methodological approaches have been chosen (see Table 1). The common procedures and major findings of these paradigms will be outlined. Each paradigm possesses specific advantages and disadvantages which are important to the interpretation of the findings in a larger context. Factors such as erroneous recall processes or additional measuring of waking-life thoughts etc. may limit the significance of a study regarding the relationship between waking life and dreaming.

Table 1. Effect of daytime experiences on dream content

Research paradigms
• Assessing temporal references of dream elements
• "Dream-lag" effect
• Effect of the pre-sleep situation
• Effect of life events
• Laboratory references in dreams

Assessing the temporal references of dream elements

In this section, studies are presented in which the temporal references of distinct dream elements to the waking life of the dreamer were investigated. For this, the dreamer was asked to go through the dream report and try to recall whether or not and when an element, e.g., a person, an object, a setting, has occurred in her/his waking life. Almost all studies utilized self-ratings as the measurement technique since ratings by external judges can hardly be performed (9). Several authors (10-14) analyzed their own dreams. Although it is not possible to generalize such findings, these studies provide the first interesting insights regarding the temporal references of dream elements. The proportion of elements which were related to the previous day varies from 35% (13) to 46 % (11). Solely, Hartmann (12) reported a larger proportion (94%).

The most detailed study regarding temporal references of dream elements were carried out by Strauch and Meier (3). Fifty dreams stemming from REM awakenings of five subjects included 80 key role characters, 39 extras (persons playing a minor role in the dream), 74 settings and 298 objects. The ability to relate these elements to waking life varied considerably: 25.6% (extras), 30.9% (objects) and 76.3% (key role characters). The participants were able to find for 76.3% of the key role characters correspondences to their waking life, e. g. they thought about this person or have encountered her/him. Strauch and Meier (3) not only asked about the last occurrence in waking life but also when the dream element has appeared in waking thought. For the subclasses persons, settings and objects, Strauch and Meier (3) obtained the following distribution (Table 2).

Table 2. Temporal references of dream elements

Time intervals	Persons	Settings	Objects
Previous day	67.6 %	42.9 %	52.2 %
Last week	19.7 %	31.4 %	21.7 %
Last year	7.0 %	14.3 %	20.7 %
Over one year	5.6 %	11.4 %	5.4 %

Verdone (15) and Roussy et al. (16) have pointed out that dreams of late REM periods of the night included more elements of the distant past than dreams of early REM periods. Within an information processing framework, it can be postulated that first the actual waking-life experiences are processed and then connections to older material takes place. Botman and Crovitz (17) have investigated the time function of the temporal references and have found an exponential model with very good fit. It is a kind of forgetting function known in classical memory theory, the events are occur less often the longer they date back.

Although it seems that this approach can be handled very easily, the findings have to be interpreted with caution. Several methodological issues which are listed in the following limit the generalizability of the studies. First, the problem of matching arises. i.e., when can a relationship between dream element and a waking-life experience be coded. If, for example, the mother appears in the dream but differs from the real mother, this may not be a reference to the mother of the dreamer. Like this, waking-life elements can occur in more or less transformed form and, thus, are difficult to match. Of similar complexity is the problem of multiple correspondences of dream elements; i.e., a person has dreamed of his/her brother; this may be a reference to a recent telephone conversation or reflect childhood memories. Epstein (14) has solved this problem by considering only new events such as the acquaintance of a previous unknown person. This issue is still much more complicated if not only the occurrence in waking life is coded but also the occurrence in waking-life thinking. It may be possible that memories of a recent holiday which were going through one's mind are incorporated into the dream or the previously experienced real impressions. In this case, the issue of multiple correspondences cannot be handled adequately. The model of the exponential decrease of time references over time (17) may be an artifact since the method of measuring temporal references requires the

memory capacity of the dreamer in order to match dream elements to waking-life experiences. If one has forgotten something (forgetting functions are also exponential), it is not possible to find a correspondence and an exponential curve for the temporal references will thus result. Many times more difficult is the recollection of one's waking thoughts: who can report what she/he has been thinking yesterday, let alone recount the thoughts that occurred last week. This emphasizes the limits of this approach.

Schredl, Kleinferchner and Gell (18) stressed another factor which might affect the correspondence between dream elements and waking-life experiences. They have shown that persons with thin boundaries incorporate waking-life problems more often than persons with thick boundaries. The time period between occurrence in waking life and occurrence in the dream may be modulated by personality factors. Interestingly, Hartmann (12) who developed the concept of "thin vs. thick boundaries" reported the highest incorporation rate (94%) of events of the previous day. It must be concluded that this approach is valuable for exploratory studies, but the interpretation of the findings is very complicated due to the methodological problems.

'Dream lag' effect

The "dream lag" effect designates the possibility that events are not incorporated immediately into the dream but play a role after a distinct period of time (19). In contrast to the approach measuring time references of dream elements, these authors started from a daytime experience and coded the subsequent dreams for the frequency of incorporations of this specific experience. In two studies, Nielsen and Powell (19) have demonstrated that at first a decrease of the incorporation frequency of a specific event (self-selected significant event, e.g., a quarrel with the partner) decreases to the fifth day as expected but there was a marked peak on the

sixth day following the event which was even larger than on the day after. A replication study (20) over a two-week period also found peaks of the incorporation rate 6 and 12 days after the significant experiences, but the highest rates were measured on the first day. Another study (21) revealed that a film (ceremonial slaughter of water buffalo) was processed very differently from participant to participant. Whereas one group hardly ever dreamed of the film contents, the other group exhibited an U-shaped pattern with significantly higher scores on Nights 1, 6, and 7 than on Night 4. This finding may be interpreted in terms of different personality traits of the participants (see preceding section). This peak after about 6 days was labeled by Nielsen and Powell (19,20) a "dream lag" effect. However, two methodological issues have to be taken into consideration. The cited studies utilized dream diaries, i.e., the participants mainly recorded the last dreams of the night. Verdone (15) and Roussy et al. (16) have shown that the last dreams of the night tend to incorporate elements with longer time intervals between waking-life experience and dream correspondence than dreams of the first part of the night and, thus, the hypothesis that it is not a real dream lag effect but a reflection of the time which the waking-life events need to "work through" from the first to the last REM period, is plausible. A recollection of all REM dreams of a night can not be realized without severely disturbing the natural sleep rhythm, and this procedure strongly affects dream content (see section below on laboratory references in dreams).

The occurrence of the specific event in daytime thinking was not taken into account in the studies by Nielsen and Powell (19,20) and might explain the increases in the incorporation rates on Night 6 and 7 (e.g., thinking about the end of the study). The statement of Nielsen and Powell (20) that the "dream lag" effect might be event-specific is congruent with the findings of Strauch and Meier (3) that the time references are different for different kinds of dream

elements (e. g. persons, objects etc.). A study of Jouvet (13) is interesting within this context. He observed his dreams on journeys and found that he did not dream of his new surroundings for the first 6 days. These longer latencies are also comparable to the longer time periods for time references of dream settings reported by Meier and Strauch (3). Despite the different approach (observing the dreams after the waking-life event vs. retrospective assessment of time references), the findings regarding the "dream lag" effect also have to be interpreted with caution.

Experimental manipulation of the pre-sleep situation

In order to assess the effect of the pre-sleep situation, films, relaxation instructions, suggestions etc. were used for experimental manipulation and the dreams subsequently obtained were compared to dreams of control nights. Cartwright et al. (22) have presented a film with erotic content to their male participants and have shown that persons, background and actions of the film were incorporated into the dreams of the subsequent nights. Direct incorporations (e. g., bed, breasts, penis) were rare but dreams after the film presentation more often included phallic symbols (e. g. gun, knife) and vagina symbols (e. g., tunnel, box) than baseline dreams. A film with aversive content (circumcision rituals) also did not yield direct incorporations but the emotional tone of the dreams was markedly more negative (23). This was replicated by Lauer et al. (24) but negative dream emotions were only found for dreams of the first REM period. Foulkes and Rechtschaffen (25), De Koninck and Koulack (26) and de Jong and Visser (27) did not find any increased negative emotions following the viewing of an aversive film. Only 9 out of 179 dreams of the Foulkes and Rechtschaffen study included elements of the pre-sleep film. Lauer et al. (24) have shown that the stress film yielded more incorporations (56%) than the neutral film (11%). In a study of

children aged 6 to 14, Foulkes et al. (28) were unable to demonstrate a substantial effect of a violent film in contrast to a neutral film on dream content. However, in a field study using eight- to ten-year-old children, Viemerö and Paajanen (29) have shown that TV watching behavior was related to dream content. Children who often watched violent series often have more negatively toned dreams.

De Koninck and Brunette (30) presented female participants who reported a strong dislike of snakes (criteria for participation) two suggestions with two situations and two animals. The first was positively toned: calm, beautiful and sunny day and the animal is observed in a relaxed state. The second was negatively toned: bad weather, panic stricken state, and the animal is near the feet. A snake or a squirrel was used as the animal. The animals of the suggestion did not appear in the subsequent dreams. Also, the snake vs. squirrel manipulation did not affect dream content in a sense that the snake condition yielded dreams with more intense anxiety. The overall emotional tone of the suggestion, however, showed the expected influence independent of the specific content. The unpleasant suggestion resulted in more negative dream emotions and the pleasant one more positive dream emotions. This manipulation was even more effective than exposure to a real snake prior to bedtime (30). In another study (31) stress was induced by giving a negative feedback about the performance of an intelligence test which was taken by the participants. Indeed, dreams of failure, inadequate behavior and injury were reported. Cohen (32) induced stress by announcing that the students should participate in an electroshock experiment the next day. They heard faked punishments from an adjacent room during the conversation with the experimenter. This group showed hostility more often in their dreams than the control group (73.4% vs. 43.7%, $p < .04$). Intense physical exercise (but TV watching, record listening and/or magazine reading was

permitted) did not result in direct incorporations into the dreams of the following night (33). A replication study (34) even revealed a slight decrease in sports related dream themes and an increase in sexual content. Similarly, intensive mental work (IQ tests, teaching films over a period of six hours) was reflected in only one out of 100 dreams and was followed by dreams with less thinking but more interaction and a tense mood (33). Regarding these two studies, it must be said that the inner world of the participants was not included in the analyses, e.g., TV film content, appraisal/anxiety regarding IQ testing, etc. Depending on the kind of thoughts the participants had, this might explain the lack of continuity between waking and dreaming. Simple sentences presented prior to sleep onset have often been incorporated into the subsequent dreams (35).

An interesting experiment was carried out by Baekeland, Resch and Katz (36) in which they asked their participants to associate freely (with speaking out loud) in a relaxed state half an hour prior to bedtime and found that especially the REM dreams from the first part of the night included many elements of the pre-sleep material. The "field independence" personality dimension had a moderating effect on the incorporation rate during the night. The field independence dimension reflects the person's capacity to overcome the influence of a surrounding field or separate an item from its context in perceptual test situations (36). For field independent participants, the incorporation rate was stable over the night, whereas a decrease was present for field dependent participants. In a similar study, the language used (German vs. English) within the pre-sleep procedure of free associating had the corresponding effect on the language in the dreams for bilingual persons (37).

Dream incubation, as it is known, dates back to the traditions of ancient Greece (Asklepios cult; e.g., 38). Prior to sleep, the person formulates a wish to dream about something particular, e.g., of the solution to an actual

problem, something creative or hints for healing physical illnesses. Foulkes and Griffin (39) and Griffin and Foulkes (40), however, were not able to demonstrate that the participants were able to dream about something on which they had deliberately concentrated in the pre-sleep situation. Similar, the task to dream about a specific personality trait was not successful (3). If participants were asked to visualize an actual personal problem in the evening, 40% of the subsequent dreams included references to this problem, whereas in the control condition without visualization only 20% of the dreams were related to the problem (3). In another study (41) the discrepancy between a self-description and the ideal self of the participants was elicited in a pretest. Prior to sleep onset, participants were asked to say over and over a sentence about their high discrepancy trait, e.g., I wish I were not so hostile. For the analyses, two control conditions were introduced: another discrepant trait which was not rehearsed prior to sleep and a neutral trait of this person. Fifteen of the 17 participants had some evidence of the target trait but 9 or 11 of 17 participants had dreams with references to the traits used as the two control conditions respectively. The additional task to dream about what one would like to be did not function at all. If a participant dreamed of the selected trait, most often the actual state of this trait was reflected in the dream.

If one summarizes the research findings of studies designed for experimental manipulation of the pre-sleep situation, it is apparent that the direct effect on dream content is quite small. At most, unspecific effects, e. g., more negative dream emotions can be detected. Tasks which were related to the actual waking life are more promising (3). A problem mentioned above is the dismissal of the inner world of the participant. The studies investigating the effect of pre-sleep thought on dream content clearly indicate that there is an influence of waking thoughts on dreams and it thus seems very important to elicit actual thinking (e. g., after

viewing a stress film). The possibility of the moderating effect of personality traits in the relationship between waking-life experience and dreaming which was already addressed in previous sections has to be taken into consideration.

Effect of life events

The findings presented in the previous section stimulated Breger, Hunter and Lane (42) to investigate "real" stress (intense psychotherapy and forthcoming surgery). Additional studies regarding the influence of stressful life events, e. g. divorce, sexual abuse, violence, will be reviewed briefly in this section.

The studies of Breger, Hunter and Lane (42) have shown that real stressors have a marked effect on subsequent dreams. All 29 dreams elicited after a session of intensive psychotherapy in which the dreamer was the focus showed references to the session topics. In addition, the dreams were characterized by more negative interactions. In the second study, they investigated the dreams of 5 persons awaiting major surgery (e. g. vascular surgery of the leg, vagotomy and gastric resection of an ulcerated stomach, removal of gall bladder). The following dream example of a 34-year-old male who was anxious about the forthcoming stomach surgery may illuminate how the subjective stress before the operation is incorporated into the dream.

"Dream example: I was in the hospital still and there was an older patient that would go with me. We would go to where my car is locked up in the parking lot ... and this location wasn't at the hospital, it was around where I grew up as a kid, and this one guy was chained to a bed where we kept our car and I was almost afraid to get into the car because I was afraid maybe this guy might catch hold of me or something ... no, the car was chained not the patient, it seemed like I had to undo the chain before I could get the car ... yeah, that was it. The patient was in bed and I guess he couldn't get up because he did grab ahold of me almost like it was a dog on a leash

he was trying to get ahold of ... (42); pp. 132-133”

Overall, the dreams before the surgery were characterized more often by references to body parts and more hostility, and the hospital setting was more often present (42).

The research of Rosalind Cartwright (43,44) investigated the effect of divorce on women. Subsequent to divorce, women tend to experience-as expected-more negatively toned dreams than the control group of married women (45). Women suffering from depression showed inadequate coping behavior and unwanted roles in their dreams (46). After one year, the dream differences diminished almost completely and this may be interpreted as signs of successful coping with the negative life event (44). Similarly, divorce of the parents affects the dreams of the children (47). Children ranging from 10 to 13 years of age whose parents divorced within the last year do not have predominantly negative dreams in general but their dreams were characterized by inadequate coping behavior. As reported above for women, children whose parents were divorced longer for more than one year did not show marked dream differences with those of children from intact families.

Another life event which was often studied is pregnancy. The dreams of pregnant women reflect worries regarding birth, the health of the child, conflicts with the father of the child but also positive emotions about motherhood (48). Similarly, dreams of expectant fathers incorporate the forthcoming event and the related emotions (49). Abortions also affect dream life and yielded in some women to very negatively toned dreams, e.g., explosion of a hearth or the experience of a stillbirth (50,51).

Traumata play a special role in the research on the effects of life events on dreams (4). Trauma is defined as an extremely terrible event-most often beyond the person's capability to process-such as sexual abuse, war experiences, natural disasters etc. These types of events can cause a posttraumatic stress disorder (PTSD) whose main features are

depression, flashbacks and recurrent nightmares (52). But also traumata which are not followed by full-blown PTSD still affect dreams to a marked extent. Women after sexual assault, for example, reported frequent (25% of those queried) or occasional (50%) nightmares which are related to the traumatic experience (53). Many studies have investigated the effect of childhood sexual abuse on mental health in adulthood (54-57). The findings clearly indicate that even after a long time period following the terrible experiences, nightmares were experienced more often than in comparable control groups. For therapists, the study of DeDonato, Belicki and Cuddy (58) is of interest since the authors have demonstrated that sexual abuse in childhood can be detected above chance by analyzing nightmare content. Sexual themes, the dreamer's own death or burglars are characteristic for nightmare of persons who had a history of childhood sexual abuse. Similarly, Sinnott (59) who analyzed 372 diary dreams of 93 women ranging from 45 to 55 years was able to demonstrate differences. Women who were abused sexually in their childhood tended to dream more often about self-aggression, sexuality against will, and the dreams were overall more negatively toned. These themes do not dominate dream life after such a long time after trauma but they were still detectable. The occasional reports of dreams from children after sexual abuse clearly indicate that the victim suffers increasingly from nightmares, so that nightmares may be a hint of traumata (60,61).

The effect of a kidnapping of a group of 25 school-aged children aged 5 to 14 was studied very intensively by Lenore Terr (62-64). The children were kept 27 hours and were subsequently able to free themselves from the buried truck-trailer. The children developed subsequently anxieties about cars, darkness etc. afterwards and were very pessimistic in their evaluation of their future. The effects on sleep were the following: Directly after the event, night terrors were present in 13 children and

the experienced nightmares were exact reenactments of the trauma. Over the course of time, the nightmare content changed, their frequency decreased but dream anxiety was as intense as in the beginning. Overall, 24 of the 25 investigated children suffered from night terrors and/or nightmares following the trauma. After four to five years after the kidnapping, the children still were afflicted by the trauma (64). The author pointed out that a large number of children (N=14) have reported dreams about their own death. Terr (64) interpreted this as consequence of the complete helplessness against the armed kidnappers. In a control group (N=25), eight children also dreamt about their own death (65). In six cases, Terr was able to detect a trauma (severe accident of the father, very severe illness, experience of an earthquake which results in injury of the own body, direct experience of a dying grandfather). Similarly, other traumata such as a natural disaster (66), war experiences (67) and severe burnings by accidents (68) can cause nightmares in children. War experiences (e.g., World War II) are followed many years later by an increased number of negatively-toned dreams (69,70).

Studies investigating the effect of positive life events on dreams have not yet been published; however, several research projects have focused on the effect of psychotherapy on patients' dreams. Within a larger sample (N=64), Maultsby and Gram (71) have demonstrated that the therapy had positive effects on dreaming. However, Melstrom and Cartwright (72) studied the effect of therapy on REM dreams obtained in the laboratory and were unable to find differences between the dreams of clients (N=4) who had successfully finished therapy and the dreams of unsuccessfully treated patients (N=6). On one hand, this negative finding might be explained by the selection procedure; only persons with low motivation for psychotherapy were included since the major aim of the study was to test whether REM awakenings have a positive effect on therapy motivation (73). All clients, however, had dreams with more expressions of emotions and

involvement than at the beginning of their psychotherapy (72). Similarly, in 13 persons the training in a relaxation technique (progressive muscle relaxation) or regular meditations yielded less aggression and more good fortune in their dreams (74). In a single case study over a period of 5- years (N=754 dreams), Corriere et al. (75) showed that therapy whose major purpose was to express feelings more freely are paralleled by corresponding changes in dream content. Corriere et al. (76) have replicated this finding for a sample of 10 participants. Fischer (77) has compared 120 dreams of four patients who underwent a Freudian psychoanalysis to 120 dreams of four patients treated by Jungian therapists. The dreams of the Freudian analysis and were indeed characterized more often by "Freudian" contents: aggression, sexuality, arguments and intense emotions. Jungian dreams, on the other hand, were often mythic and comprised a lot of elements which dated back to childhood. Even the dreams of Freud (N=28) and Jung (N=31) which were published by both analysts, are different in similar ways (78).

To summarize, major life events and especially severe traumata strongly affects dream content; an effect which can be detected even decades after the occurrence of the trauma.

Laboratory references in dreams

Findings about dreams which are affected by the experimental setting (sleep laboratory) provide answers to two questions. First, measuring the amount of the incorporation of laboratory elements into dreams is a paradigm for studying the effect of waking-life experiences on dreams. Second, this reflects also a methodological issue since the incorporation of the experimental setting represents a bias which may limit the generalizability of the findings based on laboratory dreams (for a detailed discussion see 5)

In Table 3, several selected studies utilizing the REM-awakening technique are depicted. Essentially, two kinds of measures are

Table 3. References in dreams obtained by REM awakenings

Study	Dreams (N =)	Direct references	Dir. + indir. references
Roussy et al. [79]	64	6.2 %	---
Baekeland [80]	81	7.4 %	32.2 %
Hall [81]	559	14.2 %	---
Cartwright et al. [22]	179	16.8 %	---
Hauri [33]	164	17.6 %	---
Corsi-Cabrera et al. [82]	70	20.0 %	---
Fukuma [83]	378	21.0 %	---
Piccione et al. [84]	754	---	34.0 %
Dement, Kahn & Roffwarg [85]	695	21.9 %	37.3 %
Domhoff & Kamiya [86]	163	30.0 %	---
Strauch & Meier [3]	112	---	51.8 %
Whitman et al. [87]	111	32.0 %	68.0 %

distinguished: direct references and indirect references. Direct references are dream elements which are directly related to the experimental setting such as laboratory surroundings, electrodes, EEG machine, and/or experimenter. For coding indirect references, the categories are broader, e.g., the occurrence of laboratories in general, elements related to sleep or dreaming or participating in an experiment.

The percentage of dreams with direct laboratory references varies from 6.2% to 32.0%; the weighted mean for all studies amounted to 19.4% (N=2464 dreams). If indirect references were also measured, the incorporation rate nearly doubles (weighted mean for all studies: 38.4%; N=1753 dreams). These percentages reflect the number of dreams which included at least one laboratory reference. Hall (81) estimated the number of dreams which were strongly influenced by the experimental situation as amounting to 6.2%, whereas Strauch and Meier (3) reported that up to 16.1% of the laboratory dreams were strongly affected. Domhoff and Kamiya (86) analyzed 219 REM dreams elicited in the laboratory regarding the occurrence of different aspects of the experimental setting: 20.1% referred to the experimental situation, 11.4% to the experimenter, 5.9% to the laboratory, 1.8% to the EEG machine, and 4.1% to the electrodes.

Since both the variability of the incorporation rate between studies (Table 3) as well as the differences between participants (e.g., 2.5% to

41%; Hall [81] or 0 % to 44 %; Dement, Kahn & Roffwarg [85]) is very large, it will be worthwhile to look for possible influencing factors. A marked difference was reported by Whitman, Kramer and Baldrige (88) who carried out REM awakenings with patients and their psychotherapists. Whereas the incorporation rate of the laboratory setting amounted to 6.9% (N=29 dreams) for the patients, the rate for the therapists' dreams (N=28) was much higher (53.6%). Similarly, Hall (81) reported a higher incorporation rate for the participating psychologists (20.5%) than for the student sample (10.6%), and Fukuma (83) found that psychiatrists (N=14) incorporated the experimental setting more often into their dreams than students (N=20). Fukuma (83) interpreted his finding as reflecting more interest and more knowledge about sleep and dreaming. Another explanation might be the closeness of the relationship between participant and experimenter because the psychiatrists were colleagues of the author and, therefore, closer related than the students who were investigated.

If one takes a close look at the figures shown in Table 3, it is striking that the highest incorporation rates (direct references) were reported in the earlier studies. Indeed, Whitman et al. (87), Domhoff and Kamiya (86) and Strauch (89) pointed out that some subjects reported fears regarding the laboratory procedure (EEG machine, electrodes etc.). One participant dreamed that "... a machine had been connected to her ears and mouth, and was squirting water into her ([86], p. 526)". Although the example provided by Strauch and Meier (3) also reflect worries (see above), it can be hypothesized that worries about sleep recording technique play a minor role in recently performed sleep studies since common knowledge regarding sleep and dream research has increased considerably over the last decades.

Another factor which has not been studied systematically is the duration of other procedures (e.g., pre-sleep film, blood sampling, cognitive tests) also carried out in the

laboratory setting. Schredl et al. (90) found that 33.3% of N=44 dream reports obtained by REM awakenings of sleep apnea patients included at least one direct laboratory reference. In comparison with more recent studies (79), the percentage is elevated. This finding might be explained by the more extensive recording technique (including measures of nasal and oral airflow, chest and abdomen movement, blood oxygen saturation) and possible worries associated with their sleep complaints and daytime sleepiness. Baekeland (80) reported that the incorporation of laboratory references into dreams was related to a "field dependence" personality trait. Dreams of low and high field dependent participants included laboratory references more often than those of field intermediate participants. Whereas it seems plausible that field dependent persons incorporate the laboratory setting, it remained unclear why the same pattern was found for field independent persons.

The review of the major studies investigating laboratory references in dreams indicates that the experimental setting strongly affects dream content. Since the incorporation rates are higher than those for experimental manipulation of the pre-sleep situation, it can be assumed that participation in a laboratory experiment is "real" stress since the incorporation of waking-life stressors is comparable (42). The observed influencing factors (therapists vs. patients, psychologists/ psychiatrists vs. students, early vs. recent studies) support the hypothesis that the person's involvement modulates the incorporation rate.

FACTORS WHICH AFFECT THE CONTINUITY BETWEEN WAKING LIFE AND DREAMING

The following factors which might affect the continuity between waking life and dreaming and are thus of importance for a mathematical model, can be extracted from the literature review presented in this article (see Table 4).

Table 4. Factors which affect the continuity between waking life and dreaming

Factors
<ul style="list-style-type: none"> • Exponential decrease with time • Emotional involvement • Type of waking-life experience • Personality traits • Time of the night (time interval between sleep onset and dream onset)

Many studies (3,17) have shown an exponential decrease of the incorporation rate of waking-life experiences into dreams with elapsed time between experience and dream. Although the model of Botman and Crovitz (17) is plausible, the assumption of exponential decrease with time should be treated as a hypothesis which must be tested empirically with different approaches (for limitations of Botman & Crovitz's study, see above).

The difference between experimental stress and "real" stress (42), the influencing factors regarding laboratory references in dreams (5) and trauma research (64) indicate that emotional involvement affects the incorporation rate. Especially, the findings of Strauch and Meier (3) suggest that different types of waking-life experiences, e.g., meeting a person or viewing a landscape, are incorporated with different probabilities. It may be the case that some part of the variance is explained by the different emotional involvement in these waking-life experiences, but it seems necessary to investigate this factor systematically and it was, therefore, added to the model.

Hartmann (91) has hypothesized that highly focused cognitive activities such as reading, writing, calculating and typing occur less often in dreams than other activities such as talking with friends, walking, or sexuality since the state of the brain during dreaming (cholinergic activation; cf. [92]) is not well suited for such activities in comparison with the waking state (aminergic activation). Three studies (91,93,94) have now shown that these activities (reading, working with a computer) occur less frequently in dreams than activities such as talking with

friends etc. These results also indicate that the type of activity (focused thinking activity) may be of importance for the continuity between waking life and dreaming.

The time of the night or the time interval between sleep onset and dream onset has affected the incorporation rate of waking-life experiences in two studies (15,16). Dreams of the second part of the night comprise more elements of the distant past. Dreams of the first part of the night incorporate mostly recent daytime experiences (24,95), whereas dreams at the end of the night also include elements which occurred throughout the person's past.

The last factor which has been studied rarely is the interaction between personality traits and incorporation of waking-life experiences. It seems plausible that personality dimensions such as field dependence (36,80) or thin boundaries (18) moderate the magnitude of continuity between waking and dreaming.

PROPOSAL FOR A MATHEMATICAL MODEL

Figure 1 presents a mathematical equation for a model which seems to be appropriate for further empirical testing. The multiplying factor includes the effects of emotional involvement (EI), type of the waking-life experience (TYPE) and the interaction between personality traits and incorporation rates (PERS). The relationships between these factors will be determined by future studies. The slope of the exponential function may be moderated by the time interval between sleep onset and dream onset (time of the night; TN).

In order to evaluate the proposed model empirically, the following issues should be taken into consideration. First, the definitions for matches between waking-life experiences and dream elements have to be precise and explicit as possible (the difference between direct and indirect laboratory references) since slight alterations may have strong effects on the incorporation rates. As demonstrated by the studies investigating laboratory references in

Incorporation rate = a (EI, TYPE, PERS) * e^{-b(TN)^t} + Constant	
a (EI, TYPE, PERS)	multiplying factor which is a function of emotional involvement (EI), type of the waking-life experience (TYPE) and the interaction between experience and personality traits (PERS)
b (TN)	Slope of the exponential function which is itself a function of the time interval between sleep onset and dream onset (TN)
t	Time interval between waking-life experience and occurrence of the dream incorporation

Figure 1. Mathematical model for the continuity between waking life and dreaming

dreams, it is possible to include indirect references in a model (assuming appropriate control conditions for the empirical tests), e. g. it is possible to test the mechanisms of psychoanalytic dreamwork (1) empirically (22). Within this context, the problem of multiple correspondences has to be taken into account, i.e., a dream element can be related to several waking-life experiences. For simplification, Epstein (14) suggested studying new events. A methodological problem which cannot be handled easily is to elicit waking-life thoughts since the measurement method (writing down, telling an interviewer) likely influences the contents to be measured. But the measurement of waking thoughts is essential for the evaluation of the continuity between waking and dreaming. For example, waking-life thoughts may account for the occurrence of traumatic experiences in dreams years after the trauma, e. g. during a psychotherapeutic treatment. The paradigm of assessing temporal references of dream elements is not appropriate for testing the model since retrospective recall of waking-life events and especially of waking-life thoughts is subject to similar exponential functions (17).

To summarize, the proposed mathematical model of the continuity between waking life and dreaming should enable researchers to identify influencing factors and, thus, a more precise formulation of the continuity hypothesis will be possible. However, one has to keep in mind that it is not possible to measure all factors which affect

the continuity between waking and dreaming simultaneously and, thus, error variance is large. Nevertheless, it can be hypothesized that the model will demonstrate higher heuristic value

than simply testing for non-zero correlations between waking and dreaming (for a lucid discussion of problems associated with null hypothesis testing see Meehl (96, 97).

REFERENCES

1. Freud S. *Die Traumdeutung* (1900). Frankfurt: Fischer, 1987.
2. Domhoff GW. *Finding meaning in dreams: a quantitative approach*, New York: Plenum Press, 1996.
3. Strauch I, Meier B. *In search of dreams: results of experimental dream research*, Albany: State University of New York Press, 1996.
4. Hartmann E. *Dreams and nightmares: the new theory on the origin and the meaning of dreams*. New York: Plenum, 1998.
5. Schredl M. *Die nächtliche Traumwelt: Eine Einführung in die psychologische Traumforschung*, Stuttgart: Kohlhammer, 1999.
6. Solms M. *The neuropsychology of dreams: a clinical-anatomical study*, Mahwah: Lawrence Erlbaum, 1997.
7. Solms M. *Dreaming and REM sleep are controlled by different brain mechanisms*. *Behavioral and Brain Sciences* 2000;23:843-850.
8. Hobson JA, Pace-Schott EF, Stickgold R. *Dreaming and the brain: towards a cognitive neuroscience of conscious states*. *Behavioral and Brain Sciences* 2000;23:793-842.
9. Schredl M, Schröder A, Löw H. *Traumerleben von älteren Menschen - Teil 2: Empirische Studie und Diskussion*. *Zeitschrift für Gerontopsychologie und -psychiatrie* 1996;9:43-53.
10. Hacker F. *Systematische Traumbereobachtungen unter der besonderen Berücksichtigung der Gedanken*. *Archiv für die Gesamte Psychologie* 1911;21:1-130.
11. Köhler P. *Beiträge zur systematischen Traumbereobachtung*. *Archiv für die Gesamte Psychologie* 1912;23:415-483.
12. Hartmann E. *The day residue: time distribution of waking events*. *Psychophysiology* 1968;5:222.
13. Juvet M. *Mémoires et "cerveau dédouble" au cours du rêve: A propos de 2525 souvenirs de rêve*. *Revue du Practicien* 1979;29:29-32.
14. Epstein AW. *The waking event-dream interval*. *American Journal of Psychiatry* 1985;142:123-124.
15. Verdone P. *Temporal reference of manifest dream content*. *Perceptual and Motor Skills* 1965;20:1253-1268.
16. Roussy F, Raymond I, Gonthier I, Grenier J, De Koninck J. *Temporal references in manifest dream content: confirmation of increased remoteness as the night progresses*. *Sleep* 1998;21:285.
17. Botman HI, Crovitz HF. *Dream reports and autobiographical memory*. *Imagination, Cognition and Personality* 1989-90;9:213-224.
18. Schredl M, Kleinferchner P, Gell T. *Dreaming and personality: thick vs. thin boundaries*. *Dreaming* 1996;6:219-223.
19. Nielsen TA, Powell RA. *The 'dream-lag' effect: a 6-day temporal delay in dream content incorporation*. *Psychiatric Journal of the University of Ottawa* 1989;14:561-565.
20. Nielsen TA, Powell RA. *The day-residue and dream lag effects: a literature review and limited replication of two temporal effects in dream formation*. *Dreaming* 1992;2:67-77.
21. Powell RA, Nielson TA, Cheung JS, Cervenka TM. *Temporal delays in incorporation of events into dreams*. *Perceptual and Motor Skills* 1995;81:95-104.
22. Cartwright RD, Bernick N, Borowitz G, Kling A. *Effect of an erotic on the sleep and dreams of young men*. *Archives of General Psychiatry* 1969;20:262-271.
23. Goodenough DR, Witkin HA, Koulack D, Cohen H. *The effects of stress films on dream affect and on respiration and eye movement activity during rapid-eye-movement sleep*. *Psychophysiology* 1975;12:313-320.
24. Lauer C, Riemann D, Lund R, Berger M. *Shortened REM latency: a consequence of psychological strain?* *Psychophysiology* 1987;24:263-271.
25. Foulkes D, Rechtschaffen A. *Presleep determinants of dream content*. *Perceptual and Motor Skills* 1964;19:983-1005.
26. De Koninck J, Koulack D. *Dream content and adaption to a stressful situation*. *Journal of Abnormal Psychology* 1975;84:250-260.
27. de Jong MA, Visser P. *Mood, dream content and secondary revision after different pre-sleep stimuli*. *Sleep Research* 1983;12:175.
28. Foulkes D, Pivik T, Steadman HS, Spear PS, Symonds JD. *Dreams of the male child: An EEG study*. *Journal of Abnormal Psychology* 1967;72:457-467.
29. Viemerö V, Paajanen S. *The role of fantasies and dreams in the TV viewing-aggression relationship*. *Aggressive Behavior* 1992;18:109-116.
30. De Koninck J, Brunette R. *Presleep suggestion related to a phobic object: successful manipulation of reported dream affect*. *Journal of General Psychology* 1991;118:185-200.

31. Weingarden AM. (Persistence of carthexis: a requisite condition for the incorporation of recent experiences into dreams. *Dissertation Abstracts International* 1972;33(5-B):2361-2362.
32. Cohen DB. Presleep experience and home dream reporting: an exploratory study. *Journal of Consulting and Clinical Psychology* 1972;38:122-128.
33. Hauri P. Evening activity, sleep mentation and subjective sleep quality. *Journal of Abnormal Psychology* 1970;76:270-275.
34. Browman CP, Cartwright RD. The influence of evening activity and psychological state on dream life. *Journal of Psychiatric Treatment and Evaluation* 1982;4:307-311.
35. Cipolli C, Salzarulo P, Baroncini P, Fagioli I, Fumai A, Maccolini S, Touzzi G. Incorporation of pre-sleep sentence stimuli in different halves of the night. In: Koella W. *Sleep* 1982. Basel: Karger, 1983;375-377.
36. Baekeland F, Resch R, Katz D. Presleep mentation and dream reports: I. Cognitive style, contiguity to sleep and time of the night. *Archives of General Psychiatry* 1968;19:300-311.
37. Foulkes D, Meier B, Strauch I, Kerr N, Bradley L, Hollifield M. Linguistic phenomena and language selection in the REM dreams of German-English bilinguals. *International Journal of Psychology* 1993;28:871-891.
38. Garfield PL. *Kreativ träumen (Creative dreaming)* 1974. München: Knauer, 1980.
39. Foulkes D, Griffin ML. An experimental study of "creative dreaming". *Sleep Research* 1976;5:129.
40. Griffin ML, Foulkes D. Deliberate presleep control of dream content: an experimental study. *Perceptual and Motor Skills* 1977;45:660-662.
41. Cartwright RD. The influence of a conscious wish on dreams: a methodological study of dream meaning and function. *Journal of Abnormal Psychology* 1974;83:387-393.
42. Breger L, Hunter I, Lane RW. *The effect of stress on dreams*, New York: International Universities Press, 1971.
43. Cartwright RD, Lamberg L. *Crisis dreaming: Using your dreams to solve your problems*, New York: Harper Collins, 1992.
44. Cartwright RD. Dreams and the adaption to divorce. In: Barrett D, ed. *Trauma and dreams* Cambridge: Harvard University Press, 1996;179-185, 262-63.
45. Cartwright RD, Lloyd S, Knight S, Trenholm I. Broken dreams: a study of the effects of divorce and depression on dream content. *Psychiatry* 1984;47:251-259.
46. Trenholme I, Cartwright RD, Greenberg G. Dream dimension differences during life change. *Psychiatry Research* 1984;12:35-45.
47. Proksch K, Schredl M. Impact of parental divorce on children's dreams. *Journal of Divorce and Remarriage* 1999;30:71-82.
48. Maybruck P. Pregnancy and dreams. In: Krippner S, ed. *Dreamtime and dreamwork: Decoding the language of the night*. Los Angeles: Jeremy P. Tarcher, 1990;143-151.
49. Zayas LH. As son becomes father: Reflections of expectant fathers on their fathers in dreams. *Psychoanalytic Review* 1987;74:443-464.
50. Cheek DB. Some newer understandings of dreams in relation to threatened abortion and premature labor. *Pacific Medicine and Surgery* 1965;73:379-384.
51. Merz M. Die seelische Verarbeitung des Schwangerschaftsabbruchs bei Jugendlichen. In: Fevers-Schorre B, Poettgen H, Strauber M, eds. *Psychosomatische Probleme in der Gynäkologie und Geburtshilfe*. Berlin: Springer, 1986;121-126.
52. American Psychiatric Association. *Diagnostisches und Statistisches Manual Psychischer Störungen (DSM IV)*, Göttingen: Beltz, 1996.
53. Krakow B, Tandberg D, Barey M, Scriggins L. Nightmares and sleep disturbance in sexually assaulted women. *Dreaming* 1995;5:199-206.
54. Hilton DJ. *Characteristics of adult psychosexual functioning in women sexually abused during childhood*, University of Houston: Dissertation, 1984.
55. Garfield PL. Nightmares in the sexually abused female teenager. *Psychiatric Journal of the University of Ottawa* 1987;12:93-97.
56. Draijer N. Die Rolle von sexuellem Mißbrauch und körperlicher Mißhandlung in der Ätiologie psychischer Störungen bei Frauen. *System Familie* 1990;3:59-73.
57. Cuddy MA, Belicki K. Nightmare frequency and related sleep disturbance as indicators of a history of sexual abuse. *Dreaming* 1992;2:15-22.
58. DeDonato A, Belicki K, Cuddy M. Rater's abilities to identify individuals reporting sexual abuse from nightmare content. *Dreaming* 1996;6:33-41.
59. Sinnott MA. *Dream content differences between Roman catholic women religious (nuns) and married women during menopausal transition*, Berkeley: Dissertation of California School of Professional Psychology, 1994.
60. Raddock FD. Nightmares, problem sleep and peculiar bedtime behavior in children. In: Kellerman H, ed. *The nightmare: psychological and biological foundations*. New York: Columbia University Press, 1987;127-156.
61. Catalano SJ. *Children's dreams in clinical practice*, New York: Plenum, 1990.
62. Terr LC. Children of Chowchilla: A study of psychic trauma. *Psychoanalytic Study of the Child* 1979;34:552-623.
63. Terr LC. Psychic trauma in children: Observations following the Chowchilla schoolbus kidnapping. *American Journal of Psychiatry* 1981;138:14-19.

64. Terr LC. Chowchilla revisited: The effects of psychic trauma four years after a schoolbus kidnapping. *American Journal of Psychiatry* 1983;140:1543-1550.
65. Terr LC. Life attitudes, dreams and psychic trauma in a group of "normal" children. *Journal of the American Academy of Child Psychiatry* 1983;22:221-230.
66. Dollinger SJ. Lightning-strike disaster among children. *British Journal of Medical Psychology* 1985;58:375-383.
67. Nader K. Children's traumatic dreams. In: Barrett D, ed. *Trauma and dreams*. Cambridge: Harvard University Press, 1996;9-24, 250-252.
68. Stoddard FJ, Chedekal DS, Shakun L. Dreams and nightmares of burned children. In: Barrett D, ed. *Trauma and dreams*. Cambridge: Harvard University Press, 1996;25-45, 252-253.
69. Lavie P, Kaminer H. Dreams that poison sleep: dreaming in Holocaust survivors. *Dreaming* 1991;1:11-21.
70. Kaup BA, Ruskin PE, Nyman G. Significant life events and PTSD in elderly world war II veterans. *American Journal of Geriatric Psychiatry* 1994;2:239-243.
71. Maultsby MC, Gram JM. Dream changes following successful rational behavior therapy. *Rational Living* 1974;9:30-33.
72. Melstrom MA, Cartwright RD. Effects of successful vs. unsuccessful psychotherapy outcome on some dream dimensions. *Psychiatry* 1983;46:51-65.
73. Cartwright RD, Tipton LW, Wicklund J. Focusing on dreams - a preparation program for psychotherapy. *Archives of General Psychiatry* 1980;37:275-277.
74. Busby K, De Koninck J. The effects of transcendental meditation on dream content. *Sleep Research* 1977;6:133.
75. Corriere R, Hart J, Karle W, Binder J, Gold S, Woldenberg L. Toward a new theory of dreaming. *Journal of Clinical Psychology* 1977;33:807-820.
76. Corriere R, Hart J, Karle W, Switzer A, Woldenberg L. Application of the process scoring system to waking, dream and therapy reports. *Journal of Clinical Psychology* 1978;34:700-706.
77. Fischer C. *Der Traum in der Psychotherapie: Ein Vergleich Freudscher und Jungscher Patiententräume*, München: Minerva Publikation, 1978.
78. Hall CS, Domhoff BJ. The dreams of Freud and Jung. *Psychology Today* 1968;42-45, 64-65.
79. Roussy F, Camirand C, Foulkes D, De Koninck J, Loftis M, Kerr NH. Does early-night REM dream content reliably reflect presleep state of mind? *Dreaming* 1996;6:121-130.
80. Baekeland F. Dreams with laboratory references: effects of cognitive style and the time of the night. *Psychophysiology* 1969;6:251.
81. Hall CS. Representation of the laboratory setting in dreams. *Journal of Nervous and Mental Disease* 1967;144:198-206.
82. Corsi-Cabrera M, Becker J, Garcia L, Ibara R, Morales M, Souza M. Dream content after using visual inverting prisms. *Perceptual and Motor Skills* 1986;63:415-423.
83. Fukuma E. A study of dreams by using "REMP-awakening technique" - Psychophysiological study of dreams in normal subjects: The first report (English summary). *Psychiatria et Neurologia Japonica* 1969;71:1026-1027.
84. Piccione P, Thomas S, Roth T, Kramer M. Incorporation of the laboratory situation in dreams. *Sleep Research* 1976;5:120.
85. Dement WC, Kahn E, Roffwarg HP. The influence of the laboratory situation on the dreams of the experimental subject. *Journal of Nervous and Mental Disease* 1965;140:119-131.
86. Domhoff B, Kamiya J. Problems in dream content study with objective indicators: II. appearance of experimental situation in laboratory dream narratives. *Archives of General Psychiatry* 1964;11:525-528.
87. Whitman RM, Pierce CM, Maas JW, Baldrige BJ. The dreams of the experimental subject. *Journal of Mental and Nervous Disease* 1962;134:431-439.
88. Whitman RM, Kramer M, Baldrige BJ. Experimental study of supervision of psychotherapy. *Archives of General Psychiatry* 1963;9:529-535.
89. Strauch I. Der Einfluß der Versuchssituation auf experimentell kontrollierte Träume. Bericht über den 14. Kongreß der Deutschen Gesellschaft für Psychologie 1965:270-274.
90. Schredl M, Kraft-Schneider B, Kröger H, Heuser I. Dream content of patients with sleep apnea. *Somnologie* 1999;3:319-323.
91. Hartmann E. We do not dream of the 3 R's: implications for the nature of dream mentation. *Dreaming* 2000;10:103-110.
92. Hobson JA, Stickgold R, Pace-Schott EF. The neuropsychology of REM sleep dreaming. *NeuroReport* 1998;9:R1-R14.
93. Schredl M. Continuity between waking life and dreaming: are all waking activities reflected equally often in dreams. *Perceptual and Motor Skills* 2000;90:844-846.
94. Schredl M, Hofmann F. Continuity between waking activities and dream activities. *Consciousness and Cognition* 2002 (accepted).
95. Roffwarg HP, Herman JS, Bowe-Anders C, Tauber ES. The effects of sustained alterations of waking visual input on dream content. In: Arkin AM, Antrobus JS, Ellman SJ, ed. *The mind in sleep: Psychology and Psychophysiology* Hillsdale, New Jersey: Lawrence Erlbaum, 1978;295-349.
96. Meehl PE. Theoretical risks and tabular asterisks: Sir Karl, Sir Ronald, and the slow progress of soft psychology. *Journal of Consulting and Clinical Psychology* 1978;16:806-834.
97. Meehl PE. Appraising and amending theories: the strategy of Lakatosian defense and two principles that warrant it (and comments). *Psychological Inquiry* 1990;1:108-180.