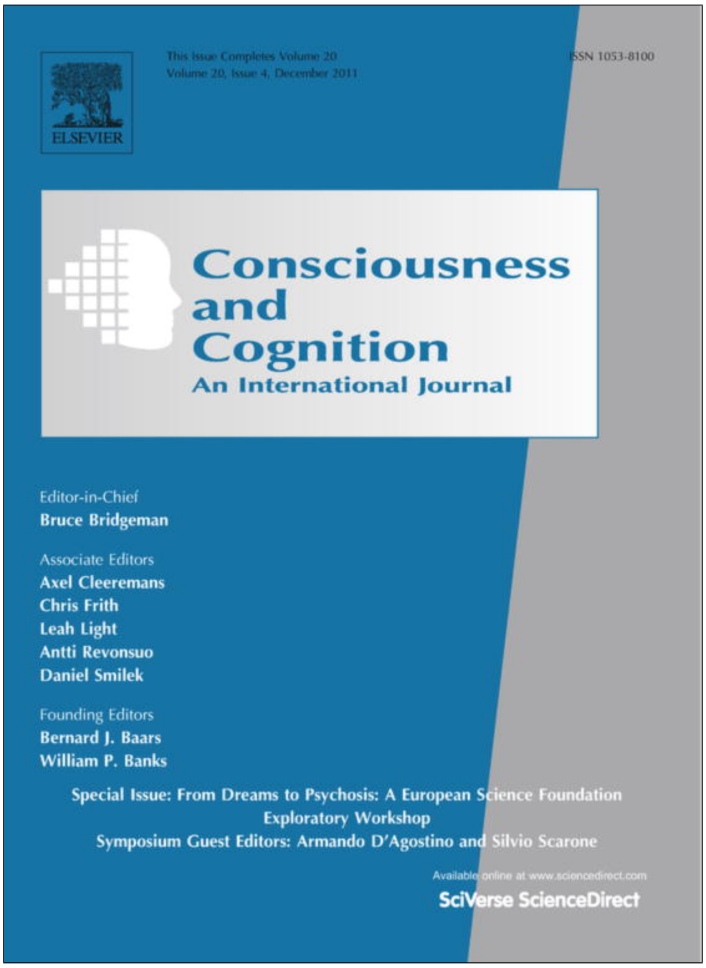
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How to integrate dreaming into a general theory of consciousness—A critical review of existing positions and suggestions for future research ☆

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ABSTRACT

In this paper, we address the different ways in which dream research can contribute to interdisciplinary consciousness research. As a second global state of consciousness aside from wakefulness, dreaming is an important contrast condition for theories of waking consciousness. However, programmatic suggestions for integrating dreaming into broader theories of consciousness, for instance by regarding dreams as a model system of standard or pathological wake states, have not yielded straightforward results. We review existing proposals for using dreaming as a model system, taking into account concerns about the concept of modeling and the adequacy and practical feasibility of dreaming as a model system. We conclude that existing modeling approaches are premature and rely on controversial background assumptions. Instead, we suggest that contrastive analysis of dreaming and wakefulness presents a more promising strategy for integrating dreaming into a broader research context and solving many of the problems involved in the modeling approach.

1. Introduction

What is the function of dream research within the broader context of interdisciplinary consciousness research? The assumption that dream research can contribute to the theoretical understanding and empirical investigation of psychiatric conditions such as psychosis or even of standard wake states has always been a strong motivator for dream researchers. However, despite the seemingly promising integration between dreaming and consciousness studies, the topic of dreaming appears only sporadically in consciousness research and cognitive neuroscience studies. Several existing proposals for how to integrate dreaming into broader theories of consciousness (Hobson, Pace-Schott, & Stickgold, 2000; Revonsuo, 2006) have not, to-date, led to a full-fledged research program investigating dreaming within a broader cognitive neuroscience context.

In this article, we wish to contribute to this integration by examining the background assumptions of existing proposals for how to relate dreaming to standard and pathological wake states. We will show how they hinge upon differing and often contradictory views on the relationship between dreaming and wakefulness. Different perspectives on this relationship, in turn, give rise to different solutions to what we call the Integration Problem (IP): the problem of how to integrate dreaming into broader theories of consciousness. This problem concerns the relationship not only between conscious states, but also between the disciplines devoted to their investigation, i.e. between dream research and consciousness research in general, but also psychiatry and specifically psychosis research.

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A central theme in this discussion is the notion that dreaming might be used as a model system, enabling researchers to transfer insights from dreaming to the wake states it is taken to be a model of. After providing a rough sketch of such proposals and offering some critical remarks in Section 2, we will argue, in Section 3, that existing attempts to conceive of dreaming as a model system are premature. In this section, we formulate three types of objections, focusing, (1) on theoretical concerns about the concept of modeling; (2) adequacy concerns about the phenomenological and neurophysiological similarity between dreaming and pathological or standard wake states and the applicability of the concept of modeling to dreaming; (3) feasibility concerns related to practical issues involved in dream research, raising doubts about the practical use of dreaming as a model system. Based on these objections, we suggest what we believe to be a more modest and for this reason also more promising approach in Section 4, which we call multi-level contrastive analysis of dreaming and wakefulness. As in the modeling approach, the contrastive analysis between dreaming and wake states will typically be restricted to specific aspects of dreaming (such as hallucinatory content, delusions, cognitive insight, etc.) and can be applied on the phenomenal, functional and neurophysiological levels of description. This approach avoids a number of the pitfalls of the modeling approach and has several important theoretical and methodological advantages. It also gives rise to a new way of envisioning the relationship between dream research, consciousness research and psychiatric psychosis research as one of reciprocity and cross-fertilization.

2. The Integration Problem and the modeling approach: examples from the current discussion

At the outset, it is important to note that different solutions to IP are inherently theory-dependent because they depend on background assumptions not only about the phenomenology and definition of dreaming, but also of the states it is supposed to be model of. Consequently, any solution to IP is doubly constrained by background assumption about dreaming and the wake states it is related to. In this section, we selectively focus on two strategies for solving IP. Both of them converge on their use of dreaming as a model system for wake states, but differ as to the envisioned states that dreaming is supposed to be a model of, or the explanatory target. The first claims that dreaming is a model of consciousness as such, whereas the second claims that it is a model of psychosis or other pathological wake states. In both types of proposals, one can distinguish three different ways in which dreaming can function as a model of the explanatory target: one, as a global model, two, as a restricted model, and three, as a model via negative analogy.

The most ambitious possibility for using dreaming as a model system is that of dreaming as what we call a global model of standard wake states. A global model is one that replicates all of the central features of the explanatory target. On its strongest reading, this would imply that dreaming is an analogue of standard wake states. On its weaker reading, a global model does not replicate literally all, but only the universal features of the target, i.e. those features that are part of its most general characterization.

A restricted model is one that, unlike a global model, is limited either to certain selective features of the model and its explanatory target, or to certain subtypes of the proposed modeling system. For dreaming, this could mean that dreaming models some, but not all of the universal features of waking consciousness, or that only certain features or specific types of dreaming fulfill this modeling function. The difference between a global model (on the weaker reading) and a restricted model is one of degrees. It depends on which features of the target are seen as universal and whether the model captures all or only some of these. In the former case, it would be a global model, though still limited in the sense of being relative to a certain description, in the latter a restricted one.

Unlike global and restricted models, which rely on positive analogy or the similarity between the model and the target, models relying on negative analogy assume that the ways in which the model is dissimilar from the target will fulfill the modeling function.

2.1. Dreaming and standard wake states: a new model system for consciousness research?

In this section, we discuss different proposals for using dreaming as a model system of standard wake states from the existing literature. Of these, the most detailed proposal for regarding dreaming as a model of waking consciousness has been worked out by Revonsuo (1995, 2000, 2006). The example of dreaming plays a pivotal role in his work, because he considers the identification of an adequate model system to be a central step towards a successful research program on consciousness.

2.1.1. Dreaming as a global model of standard wake states: isolating "pure" consciousness

According to Revonsuo (2006), a suitable model system is one in which "the explanandum manifests itself in a crystal clear form" (p. 73); by limiting the explanandum to maximally clear cases, the model system "may quickly reveal the fundamental theoretical principles needed in the explanation of the phenomenon" (Revonsuo, 2006, p. 74). He gives two examples of the successful use of such a modeling approach, namely the role of the fruit fly in genetics and the role of visual awareness in consciousness research. It is with these two examples in mind that Revonsuo introduces dreaming as a promising model system in the context of his own research program on consciousness.

Revonsuo's statement that dreaming "reveals consciousness in a very special, pure, and isolated form" (Revonsuo, 2006, p. 75) suggests that dreaming is an exemplar or a paradigmatic case of consciousness. At first sight, this suggests that dreaming is a global model of phenomenal consciousness on the stronger reading of the term. In fact, Revonsuo claims that "the qualities of dream experience are identical with the qualities of waking experience" (Revonsuo, 2006, p. 84): dreams contain the full range of multimodal sensory qualities (though the frequency with which they occur differs in dreams from wakefulness), visual dream imagery is mostly in color, and dreams at least occasionally include realistic pain sensations. More importantly, the structural organization of dreaming is the same as that of waking consciousness in that dreams involve the experience of a world, which within the dream state is taken as the real world and has a representation of the dreamer at its center. Consequently, "dreaming is nothing but consciousness—or to be more precise, the macro-level of consciousness—at its barest, operating on its own" (Revonsuo, 2006, p. 45). Dreaming and waking consciousness differ with respect to the causal paths of production, but otherwise "the ontology of dreams is the ontology of consciousness" (Revonsuo, 2006, p. 46). Moreover, because dreams, according to the virtual reality metaphor, can be seen as *offline* simulations of waking consciousness arising from internal brain activity, this means that consciousness *itself* is essentially a process of simulation; "[...] not only are dreams experiences but, in a way, all experiences are dreams" (Revonsuo, 2006, p. 55).

On this reading, dreaming is an idealization not so much in that it is stripped of certain structural features of consciousness—this would contradict the claim that dreaming brings about the full range of phenomenal experience seen in wakefulness—but rather only in the sense of isolating consciousness from additional and potentially confounding features such as sensory input and motor output, which modify conscious experience without changing its structure. Dreams show what consciousness would be like in the absence of the constraints imposed by the perception of and interaction with the physical world. As pointed out above, this stronger reading of dreaming as a global model faces the problem of isomorphism, according to which dreaming would be identical to waking consciousness. Revonsuo (2006, p. 340) later distances himself from this interpretation, and several other passages suggest that this strong reading of a global model may not be what Revonsuo has in mind. When he speaks of the specific modeling function of dreaming, he tends to do so with reference to what he already identified as the universal features of consciousness at the outset. Specifically, dreaming reveals presence and full immersion (Revonsuo, 2006, p. 119), or the conscious experience of being a self in a world, as universal characteristics of consciousness as such, and the modeling function of dreaming is restricted to this specific structural. This weaker reading of what it means to be a global model escapes the problem of isomorphism, but raises the question of whether the experience of being a self in a world (Revonsuo, 2006) actually characterizes a majority of dreams (see Windt, 2010).

Finally, Revonsuo's use of dreaming as what we have been calling a global model extends beyond theoretical description to first-person experience. In a thought experiment introducing the so-called *Dream-Catcher Test*, he envisions that a future explanatory model of consciousness would allow researchers "to literally *see* how the phenomenal level works in the brain" (Revonsuo, 2006, p. 342). Here, the explanatory relationship between the experiential model and its explanatory target is not a theoretical one of surrogative reasoning, but an experiential one, bound to the first-person perspective. By experiencing such a model state and familiarizing themselves with its phenomenological characteristics, participants will gain first-person knowledge of the explanatory target as well. Moreover, the modeling function is not restricted to the phenomenal level of description, but includes the neurophysiologial level of description as well (Revonsuo, 2006). Rather than being a research model in the traditional sense, this sense of modeling is more akin to a demonstration model that unfolds its explanatory or pedagogical function by demonstrating certain target properties, as for instance a model of a DNA chain that a biology teacher might show to his pupils during class. Rather than learning by seeing or doing, the use of dreaming as an experiential model would, on this account, quite literally involve learning by dreaming.

2.1.2. Dreaming as a restricted model of specific features of standard wake states

A proposal for using dreaming as a model system that is restricted either to certain features or certain subtypes of dreaming can be found in Revonsuo and Tarkko's (2002) work on bizarreness. Here, the proposal is that different types of dream bizarreness can be seen as instances of binding errors, for instance on the level of feature binding (such as in a dream of seeing coconuts hanging in an oak tree), semantic-conceptual binding (such as the widespread misidentification of dream strangers as friends or family members), or serial binding across time (as in discontinuous jumps or transformations in the dream narrative). By analyzing the respective frequencies of different types of dream bizarreness, one can draw inferences about the degree of modularity of the underlying binding processes (Revonsuo & Tarkko, 2002, p. 14). In other words, this specific feature of dreaming allows for surrogative reasoning about general, state-independent cognitive processes underlying the unity of perception as such and may even be used to generate testable predictions. Aside from being restricted to the bizarre features of dreaming, dreaming as a research model for binding processes is also restricted to bizarre dreams. If certain types of dreaming, as has been proposed for lucid dreams and false awakenings (Green & McCreery, 1994; Windt & Metzinger, 2007), systematically lack bizarre features, they will not fulfill the proposed modeling function.

2.1.3. Dreaming as a model via negative analogy: the dissimilarity between dreaming and standard wake states

In a programmatic 1988 paper, Patricia Churchland discusses the theoretical background assumptions involved in a reductionist research program on the neurobiological basis of consciousness. A central step is to narrow the explanandum to a more closely circumscribed domain, in which both a conceptual framework and neuroscientific techniques are at hand (Churchland, 1988, p. 287) and whose supporting infrastructure and surrounding theory are sufficient to enable scientific discovery (Churchland, 1988, p. 290). Churchland does not use the concept of a research model, but states that research efforts should be concentrated on a simplified domain. Like Revonsuo (2006), she takes genetics as an example of such an approach, and states that "The domain which perhaps comes closest is the cycle of waking-synchronized sleep-REM sleep [...]" (Churchland, 1988, p. 287).

Churchland's (1988) discussion of what she also calls the "sleep–dream–awake cycle" (p. 290) draws heavily from the early work of Allan Hobson (Hobson, Hoffman, Helfand, & Kostner, 1987; Hobson, Lydic, & Baghdoyan, 1986; Hobson & McCarley, 1977), who advocates a close relationship between rapid eye movement (REM) sleep and dreaming and holds that there are distinctive differences, both in phenomenological and neurophysiological terms, between dreaming and wakefulness. Consequently, Churchland (1988) takes a stance quite antagonistic to Revonsuo's (2006) on the relationship between dreaming and wakefulness. Whereas for Revonsuo, it is precisely the alleged similarity between dreaming and wakefulness that turns dreaming into an interesting model system, for Churchland, it commends itself as a model for quite the opposite reasons. She argues, for instance, that the characteristic differences between dreaming and wakefulness such as the bizarre features of dreaming illustrate the diversity of consciousness and may ultimately reveal that consciousness lacks a homogeneous underlying organizing principle, rather than constituting a single, unified or natural kind (Churchland, 1988, p. 287). Thus, while Churchland's and Revonsuo's approaches to dreaming converge upon the common goal of integrating dreaming into a broader research program on consciousness, they diverge both on their background assumptions on the relationship between dreaming and wakefulness and on the resulting role dreaming may play as a model of consciousness.

Yet another and somewhat more complex position on IP is endorsed by Hobson and colleagues (2000), who argue that precisely because of its distinctive phenomenological and neurophysiological characteristics, REM sleep dreaming serves as a model of psychopathological wake states, principally of psychosis. The relevance of dreaming as a model system thus extends beyond its general role within an integrated research program on consciousness to a more specific one in the context of theories of psychosis and delusional wake states.

2.2. Dreaming and psychosis: a new model system for psychosis and pathological wake states?

The analogy between dreaming and mental illness has a long history and has been remarked upon by philosophers and psychologists alike. Kant (2002) likened the madman to a waking dreamer, and Schopenhauer (1998) thought dreams to be a brief madness. Going beyond mere analogy, Hughlings Jackson suggested that dreams may actually be used to learn about mental illness, thus anticipating the basic assumption of the modeling approach to dreaming. Freud (2003) quoted him as stating: "Find out about dreams and you will find out about insanity".

While Freudian dream theory (Freud, 2003) turned dream research away from its focus on the cognitive and psychophysiological mechanisms of dreaming towards the interpretation of dream content, the association between dreaming and mental illness continued to be an important theme in the 20th century. After the discovery of REM sleep and its close association with dreaming (Aserinsky & Kleitman, 1953), a number of psychiatry journals embraced cognitively-oriented empirical dream studies. Arguably, one of the main interests of researchers was, and continues to be, the close phenomenological similarity between dreaming and pathological psychosis, which gave rise to the hope that sleep mentation might shed some light on the nature of psychopathology.

2.2.1. Dreaming as a global model of psychosis: from delirium tremens to schizophrenia

Similarly to Revonsuo's (2006) suggestion of treating dreaming as a global model of waking consciousness, but disagreeing as to the type of wake states dreams should be a model of Hobson (1996) proposed that dreaming be regarded as what we have been calling a global model of pathological psychosis, such as delirium tremens. Specifically, Hobson (1999) suggested that: "Dreaming [...] is not *like* delirium. It *is* delirium. Dreaming is not a *model* of a psychosis. It *is* a psychosis. It's just a healthy one" (p. 44). On this view, which corresponds to the stronger reading of global models introduced above, dreaming, in virtue of being isomorphic with psychosis rather than merely similar, would indeed cease to be a model in the sense of being an idealized or simplified version of the explanatory target state.

The proposed similarity between dreaming and psychosis ranges from phenomenological features, such as vivid hallucination and intense emotions, to cognitive deficiencies such as disorientation, inattention, impaired recent memory, and confabulation, to common changes in neurochemical modulation (Hobson, 1996). On the neurochemical level, both dreaming and clinical delirium are marked by a rapid shift towards cholinergic neuromodulation (Hobson, 1999). Hobson and his colleagues propose that waking, dreaming, and psychosis take a similar position in the coordinate system of the AIM model (Hobson, 2001; Hobson et al., 2000), whose three axes (A = activation; I = input/output gating; M = neuromodulation) map the essential differences between the three major conscious states—wakefulness, non rapid eye movement (NREM) and REM sleep—onto a three-dimensional state-space. The three dimensions of the AIM model trace the highly stereotyped trajectory of global state changes from wakefulness, through the stages of NREM sleep, to REM sleep, and back into wakefulness, but also help localize a number of dissociated states such as lucid dreaming or hypnosis (Hobson et al., 2000; Kahn & Hobson, 2003). Baseline wake states are characterized by a high overall activation level of the brain, the opening of the sensory input–output gates, and the dominance of aminergic modulation. Both psychosis and REM sleep dreaming are characterized by high levels of brain activation, but the former is marked by a partial opening of the input–output gates and the mixture of aminergic and cholinergic modulation, while the latter is characterized by a near-complete closure of the input–output gates and the predominance of cholinergic modulation. Interestingly, these neurophysiological differences between dreaming and psychosis seem to contradict the previous suggestion that "dreaming [...] *is* a psychosis" (Hobson, 1999, p. 44), which implies global similarities and an isomorphic relationship between the two states. This contradiction could be partially solved by restricting the modeling function to the phenomenal level of description, at the same time recognizing that important differences exist in the neural processes underlying the phenomenology of dreaming and psychosis.

Several other researchers have argued that dreaming and REM sleep may help understand the positive symptoms of schizophrenia. One of the earliest suggestions for a common neurobiological mechanism between dreaming and schizophrenia was that the disinhibition of serotonergic dorsal raphe nuclei may result in a mixture of endogenous and exogenous information in dreaming, schizophrenia as well as LSD hallucinations (Rifat, 1979). A number of later neuroimaging studies reported abnormal brain activation patterns, such as selective deactivation of the dorsolateral prefrontal cortex (e.g. Maquet et al., 1996; Potkin et al., 2009), which are characteristic to both schizophrenia and REM sleep. The phenomenological resemblance of schizophrenia and dreaming, which usually takes place during REM sleep, was recently complemented by a detailed review of the neurobiological similarities between schizophrenia and REM sleep (Gottesmann, 2006). This review provided an impressive list of dysfunctional neurophysiological processes taking place both during REM sleep and schizophrenia, including the uncoupling of EEG activity in fronto-temporal networks, the impairment of sensory processing, and the ability of dopaminergic agonists as well as glutamate antagonists to induce psychotic symptoms and vivid dreaming. Gottesmann (2006) concludes his review by suggesting that REM sleep exemplifies a remarkable collection of schizophrenia endophenotypes. Though the proposed modeling function concentrates on certain neurobiological commonalities between REM sleep and schizophrenia, the implication is that these are widespread and may lead to the identification of further, yet undiscovered similarities. This, and their alleged correlation with phenomenological properties common to dreaming and schizophrenia, suggests the classification of this proposal as an example of global, rather than restricted, modeling.

As in Revonsuo's (2006) work, the use of dreaming as a global model of psychosis suggests that dreaming might serve as an experiential model as well. Hobson (2001) proposed that dreaming might fulfill a pedagogical function by allowing healthcare personnel to empathize with the psychotic experiences of their patients, for instance by paying attention to bizarreness and the lack of metacognition in their own dreams. Although intuitively appealing, this proposal, however, should be confirmed by psychiatry patients themselves, in order to determine whether their waking mentation is actually similar to nocturnal dreaming in this respect. Unfortunately, such a test is hard to implement, as patients' dreams may differ from those of controls (Hadjez et al., 2003; Stompe et al., 2003). Consequently, even if psychotic patients did confirm their daytime mentation to be similar to their nocturnal dreams, the same could not be inferred for the physicians' dreams (see also Section 3.3). For this reason, it is not clear that the dreams of healthy subjects can be fruitfully used as a global experiential model of psychotic wake states.

Finally, it is interesting to note that a similar proposal has been put forward in hallucinogen studies. Soon after the synthesis of alkaloid mescaline in 1919, a hallucinogen that was originally isolated from the Mexican peyote cactus, German psychiatrist Beringer proposed that mescaline intoxication could be used as a model of psychosis (Langlitz, 2006). Beringer (1927) also suggested that physicians should experience mescaline intoxication in order to better understand the subjective experiences of schizophrenia patients and thereby enhance their professional proficiency. Yet, the mind-set and surroundings of such experimental psychopathology sessions were so different from actual psychosis that according to Langlitz (2006) they cannot be straightforwardly compared to the experiences of psychotic patients. Even though hallucinogen-induced experiences may be indistinguishable from paranoid-hallucinatory psychoses when the drugs are given without informing the recipient (Gouzoulis-Mayfrank, Hermle, Thelen, & Sass, 1998), this is unacceptable for ethical reasons. Eventually, especially after the introduction of animal models, hallucinogen research focused on neurobiological rather than experiential modeling of psychosis (Langlitz, 2006). Despite the initial attractiveness of the proposal, the practical feasibility of either mescaline intoxication or nocturnal dreaming as an experiential model of psychosis remains uncertain.

2.2.2. Dreaming as a restricted model of specific features of pathological wake states

A number of researchers investigating the relationship between schizophrenia and dreaming have restricted their research to specific similarities between these mental states rather than claiming an overall similarity between them. Hadjez et al. (2003) compared the dreams of three adolescent groups: hospitalized schizophrenia patients, inpatients with other mental disturbances, and healthy controls. Schizophrenia patients reported less involvement and emotional expression in their dreams than controls, whereas non-schizophrenic patients scored in-between. Interestingly, the lack of involvement and emotional expression in the dreams of schizophrenia patients correlated significantly with their symptom severity as measured by the negative subscale of the Positive and Negative Syndrome Scale (PANSS; Kay, Fiszbein, & Opler, 1987). In another study, the dreams of schizophrenia patients were shown to involve increased levels of inward-directed hostility and death- and mutilation-related anxiety, resembling the structure of persecutory delusions in pathological wake states (Stompe et al., 2003). Indeed, several types of delusions characteristic of schizophrenia often take place in dreams, such as age disorientation, paranoid experience of threats, and delusional misidentification (Kelly, 1998; Schwartz & Maquet, 2002). When compared to the laboratory REM dreams of depressed patients, schizophrenia patients more frequently report encountering strangers in their dreams (71% vs. 24%) and more rarely family members (11% vs. 54%) (Kramer & Roth, 1973). Social interactions in schizophrenia patients' dreams are dominated by aggression, and the most common emotion is apprehension, reflecting their waking mental states.

In addition to the view that dreaming might be a model of psychosis, there are several other suggestions in the literature of viewing specific types of dream bizarreness as an analogue of neuropsychological syndromes. Schwartz and Maquet (2002) argue that mis- or hyperidentification of faces that seem familiar even though they are not in dreams may well be associated with changes in regional activity in temporal and frontal regions similar to those seen in lesion patients with Frégoli syndrome. Analogous explanations for reduplicative paramnesia or misidentification of places, micropsia and macropsia (seeing things as too big or too small, respectively), palinopsia and polyopia (multiplication of a visual percept in time or space), and (hemi-)achromatopsia (or the loss of color saturation in all or half of the visual field) are suggested. This proposal is interesting not only as an example of a modeling relationship between dreaming and wake states focused on specific structural features, i.e. specific types of dream bizarreness, but also because, unlike the examples discussed so-far, the direction of the modeling relationship has been reversed: here, it is not dreaming that is the model, but rather the proposed neuropsychological syndromes. More specifically, a given neuropsychological syndrome, say the Frégoli syndrome, is identified as a potential model of misidentification phenomena in dreams on the basis of their rough phenomenological similarity. Then, the known causes of the syndrome, i.e. lesions in the fusiform face area, are used to predict regional changes in brain activity in the dream state, whose confirmation would depend both on the availability of corresponding dream reports and imaging data. A general point illustrated by this approach is that the direction of the modeling relationship is determined by the phenomenon that is better understood in terms of its neural correlates, and in this case, this is the waking pathology rather than nocturnal dreaming. While such a neuropsychological assessment of dream content might impose new constraints on the analysis of REM sleep data and yields straightforward hypotheses concerning the neural correlates of specific types of dream content, the practical feasibility of this type of study, especially given the unpredictability of dream content, is negligible.

2.2.3. Dreaming as a model via negative analogy: the dissimilarity between dreaming and psychosis

The third way in which dreaming is used as a model system for psychosis is by comparing the dreams of patients and healthy controls both to each other and to waking mentation reports. The aim of such contrastive studies is to chart systematic differences between patients and controls and investigate whether waking symptoms can be explained with reference to dream experiences. The rationale, then, is not so much to use dreaming as a global or restricted model but rather to investigate its potential feasibility as an explanatory model. Though promising, studies using this approach, however, have yielded contradictory results.

Cartwright (1972) proposed a model of the predominant mode of thought in waking, NREM and REM sleep, which predicts that schizophrenia patients, healthy controls prone to schizophrenia and healthy controls with low schizophrenia scores will show different forms of thinking across the sleep–wake cycle. In fact, hospitalized patients received significantly lower Dreamlike Fantasy scores than the other two groups (Cartwright, 1972). Controls with low schizophrenia scores attained the highest scores in REM dream fantasy, whereas controls prone to schizophrenia reported the highest fantasy scores in NREM dreams. Cartwright (1972) suggested that schizophrenic patients may ease their REM sleep dream pressure during wakefulness, thus receiving lower fantasy and bizarreness scores during both REM and NREM sleep. Similarly, healthy participants with high schizophrenia scores presumably received high fantasy scores for NREM dreaming because their REM dream pressure increased the bizarreness of NREM dreams, but probably did not intrude on their waking lives as was the case for hospitalized schizophrenia patients. These findings seem to confirm the old hypothesis that the symptoms of schizophrenia result from the intrusion of REM sleep and dream mechanisms on wakefulness (Dement et al., 1969). This approach is also interesting because it investigates the relationship between dreaming and psychosis via the regulation mechanisms of internally generated fantasies rather than by their phenomenal similarities.

Somewhat different results were reported in a recent study by Scarone et al. (2008), who found that the bizarreness of waking fantasies is much higher in patient than control groups, whereas the level of bizarreness in dreams does not differ between these two groups. These findings suggest that schizophrenia patients may differ from controls not so much in dream experience as in subjective wake states, which tend to be dreamlike for schizophrenia patients. However, Noreika, Valli, Markkula, Seppälä, and Revonsuo (2010) found that the dreams of schizophrenia inpatients are more bizarre than the dreams of psychiatry nurses used as controls, and that waking mentation reports are more difficult to distinguish from dream reports for the group of schizophrenia patients than for controls. In sum, Cartwright's (1972) initial findings have never been replicated and were even contradicted by later studies, leaving her model somewhat premature and lacking elaboration.

3. Why not to use dreaming as a model system: three types of concerns

As the discussion of the different types of modeling approaches in the previous section has shown, the existing proposals are diverse, in terms of the explanatory target that dreaming is supposed to explain (i.e. pathological vs. standard wake states), the type of model (i.e. global, restricted or via negative analogy) and the explanatory level (i.e. the phenomenology of dreaming vs. the neurophysiology and/or neurochemistry of REM sleep). In this section, we focus on several more general considerations about the concept of modeling, the uses of model systems, and the modeling relationship. Based on these considerations, we then voice several more pointed concerns about the adequacy and practical feasibility of dreaming as a model system.

3.1. Theoretical concerns about the concept of modeling

A model is a system that adequately represents a particular explanatory target or certain of its properties and their relation, thereby providing new insights or contributing to its better understanding. While models can be considered as one of the principal instruments of modern science, the philosophical discussion on models has led to an almost inflationary conceptualization of many different types of models (for a detailed discussion, see Frigg & Hartmann, 2006). Moreover, models raise a number of distinct theoretical problems, pertaining to the representational relationship between the model and its target and the use of the model. The use of models and metaphors has a long tradition throughout the history of philosophy, ranging from Plato's cave allegory (1998) to mechanistic models, such as the particularly universal brand of mechanism promoted by Hobbes' (1985) *Leviathan*, or the computer model of the mind and neural network models in the more recent discussion. In addition, a number of specific models are related to prominent and much discussed theories, such as Baars' global workspace theory (Baars, 1988), or Edelman and Tononi's dynamic core hypothesis (Edelman & Tononi, 2000; Tononi & Edelman, 1998; for a detailed discussion of different models of consciousness, see Seth, 2007). Without entering into a detailed discussion, it is worth drawing attention to some of the main problems associated with the use of scientific models in general and models in consciousness research in particular.

First, the ontological status of models ranges from physical or fictional objects to theoretical or conceptual structures or descriptions. A model need not be distinct from its explanatory target, but rather may be an exemplar or a paradigmatic case. This type of model has the same ontological status as the target, because it is simply an ideal token of the type it is taken to be a model of. Finally, in psychology and consciousness research, there is a long tradition of using conscious states as models or stand-ins of other conscious states. As indicated above, it is not completely correct to say that the conscious state itself, or the experience of being in a particular conscious state, as is the case for experiential models, performs the modeling function; rather, the modeling function is performed by a theory- and interest-dependent description of the conscious state in question, focusing either on its universal features (for global models) or a subset thereof (for restricted models and models via negative analogy).

Second, there is a wide range of possible representational relationships in virtue of which something can be taken to be a model of another; the strongest is isomorphism, which, however, results in an identity of the model with the explanatory target (Revonsuo, 2006). While it makes sense to define the representational relationship between a model and its target in terms of similarity, this requires a specification of the relevant respects and degrees of similarity. In order to be efficient, a model will have to leave certain aspects out—otherwise it would cease to be a model in the commonly used sense of the word. It will not only model certain aspects of the target, but also will tend to be an idealization or simplification of certain of its properties. This, in turn, can be achieved by stripping away or abstracting from the properties that are taken to be irrelevant—i.e. by isolating precisely those properties that seem to require explanation—or by deliberately distorting certain of these properties. In fact, many models probably involve both types of idealizations. In other cases, the modeling relationship depends less on systematic representation than on analogy, ranging from systematic (structural or formal) analogies (e.g. the sense in which the computer model of the human mind is taken to point out analogous forms of information processing) to lose, metaphorical analogies, as in Plato's cave allegory.

An important problem, in all of these cases, has to do with determining the *relevant* degree of similarity: any two things can be taken to be similar or dissimilar in an infinite number of ways (Wartofsky, 1979), so this may actually turn out to be the central problem in determining the adequacy of a given model. Similarity is not something inherent in the phenomena, but something that is picked out; thus, an adequate model system will not so much be discovered as determined by the researcher. An interesting distinction, in this context, is the one between positive, negative and neutral analogies, e.g. between the properties or relations the model shares or fails to share with the target, and those for which is it not yet known whether or not they are common to both of them (Hesse, 1963). In addition, other considerations, such as simplicity, efficiency, potential areas of application, manipulation, and flexibility should also be taken into account.

The representational relationship between a model and the target may be one of imitation or mimicry, implying a certain causal history in terms of deliberate construction or design, or of merely incidental similarity or correspondence. For the use of conscious states as models in general and of dreaming in particular, the latter is the case. At the same time, the danger of a confound lurks here: while the conscious state as such can be used as a model in virtue of incidental similarity or correspondence, its description, which performs the actual modeling function, bears the marks of deliberate construction or design in view of explaining a particular target.

Finally, there is a sense in which the descriptions of both the model and target should themselves be considered as models. These descriptions of the relevant (universal or global vs. specific or restricted) properties of the conscious states in question can be considered as first-order models. In using one conscious state, i.e. dreaming, as a model of another, i.e. psychosis or standard wake states, a first-order descriptive model of dreaming is used as a second-order research or experiential model of the target, again under a first-order descriptive model. This means that such a model is always twice removed from the target it is taken to explain.

Third, the motivation for using a model system often is that it is supposed to allow for surrogative reasoning (Swoyer, 1991). That is, insights gained from reasoning about the model can be transferred to the target. However, the epistemic use of a model system may also be located at earlier stages. The very act of constructing a (physical or descriptive) model—or, more abstractly, of choosing an adequate model—can already be regarded as an important part of the learning process itself (Langlitz, 2006). Once a suitable model has been determined, systematic observation and experimental manipulation of the model serve as a vehicle for the generation of new insights, the explanation, demonstration or verification of already-known facts or hypotheses, or new methods for optimization or variation.

While models typically function either as vehicles of epistemic progress or serve demonstrational purposes, an interesting point is that, though the model facilitates or indeed generates epistemic progress, the knowledge that is derived from this model is only interesting insofar as it concerns the explanatory target. The epistemic (or indeed functional) interest in the model, then, tends to be asymmetric: the knowledge generated by the model is not sought for the sake of the model itself, but rather points beyond the model. The question of how to translate this knowledge about the model into knowledge about the target, then, is of central importance. In a sense, one can say that the adequacy of a model depends on whether or not it is epistemically transparent—that is, whether the insights it generates can be transferred from the model to the target itself or certain of its properties.

In sum, both for research and descriptive models, a central problem is the question of how to determine the relevant degree of similarity between a model and its explanatory target. There is no clear-cut answer to this, and for every given modeling relationship, it will depend on the precise scope of the model and its target properties (global or restricted) and on its use (demonstrative, educational, experiential, or for research). It is equally important to realize that this process is always inherently theory- and interest-dependent. Rather than relying on some intrinsic similarity between the model and the explanatory target, the process of determining an adequate model system always bears the marks of an active construction process. This is true for both first-order descriptive models and second-order models, i.e. using a given conscious state under a certain description as a model of another, again under a certain description. The matter of determining the adequacy of a given model system requires the possession of a theory about this system, and thus can be considered as part of the heuristic benefit itself. Thus, the epistemic profit from using a model system is not limited to surrogative reasoning about the explanatory target, but also involves the process of determining the adequacy of a given model state and assembling an adequate first-order descriptive model. In this context, the limits of the model system seem as important as the positive representational relationship between the model and its target (Langlitz, 2006).

3.2. Adequacy concerns about the applicability of the concept of modeling to dreaming

What, then, could it mean to use dreaming as a model system of another conscious state? First, it is not dreaming itself that will serve this function, but a description of dreaming. This description of dreaming will be restricted in several ways: to the level of description intended (i.e. phenomenology, neurophysiology, neurochemistry, etc.), specific aspects (i.e. presence, immersion, bizarreness, etc.; overall levels of brain activation vs. regional patterns of brain activation), and types of dreaming (all dreams vs. bizarre dreams; lucid or nonlucid dreams, etc.).

This shows the notion of using dreaming as a global model to be problematic for several reasons: first, using dreaming as a global model of either standard or pathological wake states cannot, for theoretical reasons, target an actual similarity or, on its strongest reading, isomorphism between the two states, because the determination of such similarities always depends on the specific research context. Second, it is not the experience of dreaming (or of a certain type of dream) itself that serves as a model, but rather a descriptive model of certain characteristics of dreaming. In other words, even for dreaming as a global model, the first-order descriptive model will be restricted to certain of its universal features, whose determination is theory-dependent and determined by a specific research context. As pointed out above, this means that dreaming can function as a global model only on the weaker reading of the term. The same is true for the explanatory target, or the state dreaming is supposed to be a model of; here, again, a first-order descriptive model will focus on some or all of the features of the target and function on different levels of description. These theoretical considerations show why even global models are restricted in important respects, explaining why the difference between global and restricted models is gradual.

Seen in this way, the adequacy of a given model not only depends on its ability to reflect the properties of the explanatory target, but on the additional adequacy of the first-order descriptive models of both states. As the previous sections have shown, the different existing proposals for solving IP and using dreaming as a model system rely on very different assumptions of what dreaming is like. Specifically, the proposal for using dreaming as a model of standard waking consciousness presumes that dreaming is a paradigmatic or pure case of consciousness and thus inherently similar to standard waking consciousness, whereas the proposal of dreaming as a model of psychosis or other pathological wake states presumes a similarity with the states in question. The uncertainty as to whether dreaming is continuous with standard waking consciousness (on the continuity hypothesis, see Schredl, 2002) is symptomatic of the existing controversies in dream research and suggests that an adequate first-order descriptive model of dreaming is not yet in place. At least part of this problem results from different research interests and the focus on different explanatory targets. In any case, existing modeling approaches will have to deal with this problem by presenting a separate argument for their advantages over alternative views. In view of the fact that all existing first-order descriptive models of dreaming are controversial, what is needed, first, is a solid theory about what dreaming itself is like.

This problem also poses itself on a more basic level. For it is not just that researchers disagree about a given theoretical description of dreaming, both in terms of the phenomenology and underlying neurophysiology, but they also disagree about the explanandum itself. Existing definitions range from wide definitions, viewing dreaming as any type of mental activity in sleep, to narrow definitions of dreaming in terms of specific kinds of hallucinatory experiences during sleep (Hobson et al., 2000; Nielsen, 2000; for a general discussion, see Pagel et al., 2001). Without entering into an extended discussion on definitions of dreaming here (but see Windt, 2010), this lack of a clear, commonly accepted definition is an important desideratum for current dream research. It may also have direct bearings on research results, as the type of definition employed in a given dream study will determine which types of sleep mentation reports are scored as reports of dreaming and nondreaming, respectively. For this reason, at least part of the controversy on what dreaming is like and whether it is similar to or different from standard waking consciousness stems from diverging opinions on how to define the concept of dreaming and what to count as a dream report. In view of the uncertainty of how to describe or even define dreaming, the ability of dreaming to generate testable hypotheses, which is an important motivation for using it as a research model, is not clear and in fact, most current modeling proposals have remained programmatic rather than showing how dreaming actually renders new insights about the proposed explanatory targets.

This uncertainty about the appropriate phenomenological description of dreaming is paralleled by differing positions on the relationship between the neural mechanisms underlying dreaming and those of REM sleep. This relationship is often overstated, sometimes to the point of asserting a virtual identity between dreaming and REM sleep. For instance, Churchland's (1988) suggestion that empirical research efforts should concentrate on the waking – NREM sleep - REM sleep cycle assumes that dreams are, essentially, REM sleep phenomena. In fact, however, most contemporary researchers working on dreams, and while disagreeing on the exact neural correlates of dreaming, agree that there is a double dissociation between dreaming and REM sleep, with dreams occurring in NREM sleep and REM sleep occurring without dreaming (Nielsen, 2000; Solms, 2000).

Most studies claiming that dreaming and schizophrenia share the same neurophysiological mechanisms have also focused on the neurophysiology of REM sleep. For instance, Gottesmann's (2006) argumentation starts with psychological similarities between dreaming and schizophrenia, but ends with a detailed comparison between the neural mechanisms of REM sleep and schizophrenia. As dreaming can also take place during NREM sleep (Noreika, Valli, Lahtela, & Revonsuo, 2009), it is uncertain whether the suggested processes are specific to dreaming or related to REM sleep and whether one should talk about a ''dreaming model'' or a ''REM sleep model'' of psychosis. In particular, Gottesmann (2006) does not consider REM sleep periods in which schizophrenia-like neurobiological processes take place, but psychosis-like dreaming might be absent, which would seem to be crucial test cases for his theory. Notably, comparisons between schizophrenia and REM sleep mechanisms may be a promising perspective for future research, but as dreaming cannot be equated with REM sleep, the attempt to view REM sleep dreaming as a global model of psychosis rests on an equivocation of the phenomenal and neurophysiological levels of description.

On the phenomenal level of description, several obvious phenomenological differences between schizophrenia and dreaming, such as the dominance of auditory vs. visual hallucinations in schizophrenia, raise further doubts as to whether dreaming can be regarded as a global model of schizophrenia. Another disparity consists in the combination of externally and internally generated experiences in schizophrenia, whereas dreams typically do not incorporate external events (though external stimuli do at least occasionally become incorporated in dreams). Thus, dreaming and waking mentation in schizophrenia can be described both in terms of continuity and discontinuity, depending on the type of experiences under investigation and the type of question asked (Noreika, 2011). Whether the systematic comparison of subjective experiences in delirium tremens and dreaming, suggested by Hobson (1999), could avoid such a critique awaits future investigation.

Similar concerns can be raised for the phenomenological comparison between dreaming and standard wakefulness. A particularly important challenge to the use of dreaming as a model of standard wake states comes from the imagination model of dreaming, according to which dream imagery is more akin to waking fantasy and daydreaming than perception (see Section 4.2.1). Consequently, dreaming would not model alert, outward directed wake states, but rather a particular type of inward-direct imagery seen in wakefulness. Another challenge is related to the position that nonlucid dreams are only weakly subjective states and that self-experience in the dream state is different in important respects from standard wakefulness (Metzinger, 2003; Windt & Metzinger, 2007). In pointing out dissimilarities between dreaming and standard wake states, these positions also raise concerns about the adequacy of dreaming as a model system.

3.3. Feasibility concerns related to practical issues in dream research

Another decisive feature of a successful research model is its practical feasibility. A good model system should allow for easy observation and manipulation, its usage should provide maximally large data samples in a short period of time, and its running costs should be relatively low. A successful example is the drosophila melanogaster (fruit fly) model used in developmental biology and genetics (Arias, 2008; Beckingham, Armstrong, Texada, Munjaal, & Baker, 2005). Keeping these practical requirements in mind, dreaming may actually be one of the least feasible models of all experimental paradigms currently used in cognitive neuroscience.

In sleep laboratory studies, typically only four or five dream reports are collected during an entire night, involving not only the presence of the participant, but also of one to two researchers. A recent attempt to speed up data collection by the early-night serial awakenings (ENSA) paradigm, which enables the collection of up to 10 NREM sleep reports in approximately three hours (Noreika et al., 2009), is still a giant step away from the efficacy of visual awareness paradigms in consciousness research, where several hundreds of subjective reports can be collected via joystick button press in as little as 10 min. Due to these practical difficulties, most sleep laboratory experiments end up with extremely small participant groups and just a few dream reports per participant. Difficulties of collecting large quantities of high-quality data might lead to both Type I and Type II errors, as well fail to replicate original findings, which is indeed symptomatic of psychophysiological studies of dreaming (Pivik, 1991). Also, it is possible that the laboratory environment might interfere with the type of dreams reported, and thus that laboratory reports are not representative of spontaneously recalled dreams in the home environment (Hobson et al., 2000). At the same time, the possibility of conducting timed awakenings means that the laboratory affords a more controlled environment for the study of dreaming than the home environment.

A further practical limitation has to do with the questionable epistemic status of dream reports relative to previous dream experiences. Dream amnesia, or the rapid deterioration of dream recall following awakening, is a well-known phenomenon.

Moreover, it is not just memory for previous dreaming that is poor, but both mnemonic and attentional functioning are reduced in the dream state as well (Hobson et al., 2000), raising further questions about the reliability of post-awakening dream reports. This concerns not only the reliability of data generated from dream reports, but also the use of dreaming as an experiential model. In particular, limited introspection during the dream state and the common failure of subjects to realize that they are dreaming during the dream state means that at least nonlucid dreams can only serve as experiential models by giving rise to memories of previous dreaming, with all their limitations and uncertainties. While lucid dreams avoid this problem, they also differ from nonlucid ones in important respects (Noreika, Windt, Lenggenhager, & Karim, 2010; Windt & Metzinger, 2007), and to our knowledge, there are no detailed proposals of lucid dreaming as a model system of standard or pathological wake states.

Limited introspection during the dream state and dream amnesia after awakening may have especially detrimental effects for studies involving psychotic patients. Several studies demonstrated that schizophrenia patients do not experience reportable dreams to the same extent as matched controls (Scarone et al., 2008; Stompe et al., 2003). Okuma, Sunami, Fukuma, Takeo, and Motoike (1970) showed that healthy controls who had been awakened during the night to give dream reports were still able to remember most of these dreams in the morning. By contrast, schizophrenia patients were much worse at recalling their dreams in the morning, even though they had reported them following timed awakenings during the night. These findings provide objective evidence that morning dream recall of schizophrenia patients is less reliable than that of healthy participants. Consequently, schizophrenia studies of dreaming are confounded by patients' difficulties in recalling and/or reporting dreams. In addition, the disease itself as well as medication may have profound effects on sleep (Chouinard, Poulin, Stip, & Godbout, 2004) and possibly on dreaming. As long as it remains unclear whether the comparative poverty of the patients' dream reports truly reflects their previous dream experiences, it is also unclear what to make of the ways they differ from those of healthy subjects. This also raises the question of whose dreams, i.e. those of healthy or schizophrenic participants, are supposed to fulfill the modeling function.

Another source of contradictory findings in laboratory dream research, with the partial exception of lucid or recurrent dream studies, is the practical inability to control or experimentally manipulate specific forms of dream content. As dreams are a unique combination of internally generated subjective experiences, each independent sample is formed by different types of varying experiences. A common, but only partially successful method for reducing such phenomenological diversity is to investigate dream form rather than dream content (Hobson, 2001). This problem is particularly pronounced for studies interested in certain types of dream phenomena, such as specific forms of bizarreness, as their occurrence in the analyzed dream reports is unpredictable. This practical limitation may apply to the use of dreaming as a restricted model focused on specific phenomenal features more than to global modeling approaches focused on the universal features of dreaming.

Alternatively, dream content is sometimes controlled by experimental manipulation with sensory stimuli of a sub-awakening threshold during sleep. Ideally, a specific external stimulus during sleep, such as the smell of coffee, would produce one and the same mental representation within participants' dreams, which could later be correlated with neurophysiological measures from the corresponding sleep phases. Yet, most of the reported cases of sensory stimulation during sleep either fail to affect dream content, or the effects are rather unspecific and differ from dream to dream (Nielsen, 1993; Rechtschaffen & Foulkes, 1965; Schredl et al., 2009). Arguably, it will remain impossible to hone in on the precise neurophysiological mechanisms underlying specific types of dream experience until new methods are developed that would allow for a better experimental manipulation of dream content and a more efficient collection of larger dream samples (Noreika et al., 2009).

A final concern about the practical feasibility of dreaming as a model system concerns its ability to yield straightforward predictions for empirical research projects. Both in the discussion on hallucinogen-induced model psychosis and related animal studies, the value of the model system is primarily evaluated in terms of its predictive power: either the model eventually leads to the identification of a new antipsychotic drug that ultimately proves effective in the treatment of a patient population or it must be regarded as a failure. This was in fact one of the major shortcomings of hallucinogen-induced model psychosis (Langlitz, 2006). With the exception of the atypical antipsychotic risperidone (Colpaert, 2003; Meert, de Haes, & Janssen, 1989), it did not contribute to any such discoveries (Nicolas Langlitz, personal communication). The dream model of psychosis, to our knowledge, has yielded no specific predictions related to the introduction of novel therapeutic measures, and so-far, its predictive value has remained negligible. If it is to move beyond the programmatic stage, the successful use of dreaming as a model system will depend on its use in the development of novel therapies. Whether it indeed has this potential, however, remains an open question.

Despite the large potential of dream research to contribute to consciousness and psychosis studies, the reviewed theoretical, adequacy and feasibility concerns provide no reason to assume that dreaming may serve as a research model with the same success as, for example, the visual awareness model of consciousness, which continuously advances the understanding of the neural correlates and cognitive mechanisms of subjective experience (Block, 2007; Koch, 2004). As long as dreaming is compared to such diverse mental disturbances as schizophrenia (Gottesmann, 2006), delirium (Hobson, 1996) or even hallucinations in Parkinson's disease (Cochen et al., 2005), as well as standard wake states (Revonsuo, 2006), we believe it is premature or even principally impossible to identify it as a model for standard waking consciousness or some concrete psychiatric disorder. Also, to the degree that these are better understood in terms of the underlying neurocognitive mechanisms, they may serve as a model of dreaming rather than vice versa. Thus, given the current state of dream research, dreaming may serve primarily to formulate new theoretical and experimental questions rather than produce definite answers (for a similar evaluation of other contemporary models of psychosis, see Langlitz, 2006).

4. How to solve the Integration Problem: contrastive multi-level analysis of dreaming and wakefulness

Existing suggestions for using dreaming as a model system are hampered by theoretical problems and deep controversies in dream research, as well as concerns about the adequacy of dreaming for such an approach and its practical feasibility. For the reasons stated above, we conclude that attempts to use dreaming as a model system, at least at this point, are premature. At the same time, this does not undermine the potential of dreaming to pay an important contribution to consciousness research in general and research on psychiatric conditions in particular. As a second global state of consciousness aside from wakefulness, dreaming is an important comparison condition for general theories of consciousness, because it shows that a complex, phenomenally rich form of conscious experience can arise in the near-complete absence of sensory input processing and behavioral functioning, as well as under changed conditions of neural processing. However, a satisfying solution for IP is not yet in place, and we suggest that research should focus on solving this problem before pursuing further modeling suggestions. In this section, we propose the contrastive analysis of dreaming and wakefulness as a more modest, but also more promising framework for solving IP and possibly as a first step towards identifying potential modeling relationships.

4.1. Contrastive analysis

The central idea behind contrastive analysis (CA) is to develop a framework within which dreaming can be compared to pathological and non-pathological wake states without presuming that a complete theory of consciousness in the dream state is already in place. Instead, CA contributes to the development of such a theory and helps solve existing theoretical questions.

CA, as such, is certainly not a new idea. Baars introduced the term to consciousness studies as a suggestion for understanding the differences between conscious and nonconscious processing:

"To operationalize a scientific construct we must at least be able to specify its conditions of occurrence and non-occurrence. [...] In the case of consciousness, we can do this by carrying out a "contrastive analysis" of comparable conscious and unconscious events. By comparing two things that are very similar except for the fact that one is conscious while the other is not, we can hone in on just those elements that are uniquely associated with consciousness. Thus we should be able to specify the distinctive properties of conscious processes *as such*" (Baars, 1994).

A central advantage of this approach is that it suggests how contrasting, which is a standard procedure in other areas of scientific research, can be introduced into consciousness studies, thus rendering important questions about consciousness empirically tractable. It is closely related to the methods of agreement, difference and concomitant variation first formulated by Persian philosopher and physician Avicenna in the 11th century. The principles, which became the cornerstones of scientific method, were later described by Mill (1843/2002) in *A System of Logic*. The idea is that systematically contrasting different instances of a given phenomenon and identifying ways in which they either are found to consistently agree, agree in all circumstances save one, or jointly vary, can help identify the causes or effects of the given phenomenon. To give a simple and straightforward example, dreaming shows that conscious experience is related to certain regional patterns of brain activation rather than behavioral responsiveness and the processing of external stimuli, because in dreams, conscious experience arises largely independently of these factors. Though this may sound trivial, the discovery of spontaneous, internally-driven brain activation during sleep, showing that brain activity was not simply a reaction to external stimulation, initiated a sort of paradigm change away from behavioristically oriented psychology (Hobson, 1988).

While CA as introduced by Baars (1994) focuses on the distinction between conscious and nonconscious states, the approach can be extended to cover more fine-grained aspects of dream experience and the underlying neural mechanisms as well. This strategy is supported by the increasingly recognized fact that consciousness is not an all-or-nothing affair. Metzinger (2003, 2009) has suggested that consciousness and more specifically self-consciousness can be described in terms of varying degrees of constraint satisfaction. Both dreams and waking consciousness, for instance, can be described as resulting from the activation of a transparent, coherent world-model within a virtual window of presence, and indeed this may be a necessary condition for consciousness (Metzinger, 2003; Windt & Metzinger, 2007). With the possible exception of lucid dreams and derealization, phenomenal transparency guarantees that the phenomenal world, which is experienced both in dreaming and in wakefulness, is not experienced as a model, but simply as real. The temporal quality of *nowness* also plays an important role in this context.

Nonetheless, dreams differ from waking consciousness along a number of other dimensions, for instance by the weak degree of external-stimulus correlation (supporting the claim that dreams are instances of offline rather than online world-simulation, as in the wake state). Due to the hyperassociativity and bizarreness of dreaming, which likely result from functional deficits in binding operations on different levels of granularity, dreams can be considered as more unstable and dynamic than waking consciousness, whereas the holistic and internally coherent character of the overall experience is expressed to a weaker degree. Taken together with differences in self-related processing, this brief analysis suggests that dreams are conscious experiences in a weaker sense than standard wake states in terms of the degree of constraint satisfaction (for details, see Windt & Metzinger, 2007). This graded view of dreaming and waking consciousness also commends dreaming as a particularly interesting contrast condition for standard wake states by illustrating the variability of conscious experience and perhaps also helping identify the necessary and sufficient conditions for its occurrence.

Theoretically, CA differs in important respects from modeling approaches. First, whereas the epistemic relationship between a model and its target is unidirectional, with insights gained from reasoning about the model transferred to the target, CA allows for bidirectional reasoning. By systematizing the similarities and difference between two contrasts, insights can be transferred in either direction, allowing them to be mutually informative. For studies contrasting dreaming and wake states, this means that research on dreaming and its neural correlates not only serves as a window on waking consciousness and the waking brain, as is the case for traditional modeling approaches, but also vice versa. For instance, theoretical accounts of delusional wake states can help conceptualize some of the cognitive deficiencies typically seen in dreams. An example is Hobson's (2002) suggestion of applying the mental status exam, which is typically used for an initial assessment of psychiatric patients, to dream reports.

As is the case for modeling approaches, the contrasts are not provided by the conscious states themselves, but rather by descriptions of both of these states, which will, once more, be theory-dependent. Strictly speaking, it is not the states themselves, but instances of these states under a certain description that make up the contrasting relationship. Analogous to the distinction between global and restricted models, these descriptions may target the supposed universal features of both states or only certain of their features, and depending on the particular research question one can accordingly speak of global or restricted contrasting relationships as well as of those focusing on differences between the two states, analogous to models via negative analogy.

A possible outcome of CA is the identification of potential modeling relationships, for instance if one of the contrasts not only proves to be sufficiently similar to the other for a given research question and is identified, based on theoretical considerations, as an adequate model, but also has practical feasibility on its side. If one of the contrasts allows for easier experimental manipulation and easier data collection than the other, and if it is explained by a better worked-out theory, it might allow for the type of surrogative reasoning that is typically the aim of modeling approaches. Because of this, we propose that CA is a means for solving IP and a first step towards identifying potential modeling relationships. By contrast, modeling approaches often assume that an answer for IP is already in place, and often without explicitly defending this claim.

Finally, and again as in the modeling approach, CA can not only focus on a wide range of universal to more fine-grained features of conscious states, but can also be performed on different levels of analysis. These include the phenomenal level of analysis as well as the cognitive, functional and neurobiological levels, but could also be extended to other intermediate levels of description. An example of phenomenal-level contrastive analysis is the systematic comparison of phenomenological reports of psychosis and dreaming, for instance in terms of hallucinations and emotions within both states. A similar approach could also be applied within sleep, for instance by describing the differences between dreaming and other types of experiences during sleep—such as hypnagogic imagery often experienced at sleep onset (see Germain & Nielsen, 2001; Mavromatis, 1987; Nielsen, 1992)—and thus contributing to an empirically informed definition of dreaming. Neurobiological-level contrastive analysis affords a systematic comparison in terms of differing levels of overall and regional brain activity, either between dreaming and standard wake states (a well-known example is the neuroimaging study of sleep and wakefulness by Braun et al., 1997) or dreaming and psychosis (Gottesmann, 2006). The contrast between dreaming and non-dreaming, which Noreika et al. (2009) found to make up similar proportions of Stage 3 sleep, may help discern the neural correlates of dreaming independently of sleep stages.

Interesting contrasting relationships on the cognitive level of description can target differences in information processing and binding processes, for instance as in Revonsuo's studies of bizarreness in dreams (Revonsuo & Salmivalli, 1995; Revonsuo & Tarkko, 2002). Functional-level contrastive analysis could focus on shifts in input–output gating and the relationship between internally experienced and outwardly enacted behavior in dreaming and wakefulness. As a further contrast, it could include REM sleep Behavior Disorder (RBD) dreams, in which participants seem to outwardly enact their dreams without being aware of this fact due to a loss of the motor output blockade characteristic of REM sleep in healthy subjects (see Mahowald & Schenck, 1999; Schenck, 2005; Schenck & Mahowald, 1996).

Finally, these levels can be brought together in multi-level contrastive analysis, for instance for determining not only the phenomenological similarities between dreaming and psychosis, but also their cognitive and functional profiles and underlying neurophysiological mechanisms. An important insight is that CA of two conscious states may yield quite different results depending on the level of description. This has important consequences for modeling approaches as well: while both CA and modeling approaches may allow for surrogative reasoning, this type of epistemic transparency only works horizontally, by contrasting two states on the same level of description. However, assuming that phenomenal and neurophysiological similarities between dreaming and psychosis are sufficient to enable surrogative reasoning, this does not mean that this epistemic transparency also allows for the vertical transfer of insights to intermediate levels of description. Specifically, dreaming differs from both psychosis and standard wake states quite drastically on the functional level of description, and assuming, leaving adequacy and feasibility concerns to the side for now, it were a good phenomenal and neurophysiological model, it is certainly not a good functional model of wake states. This is an important note of caution for modeling approaches, which sometimes assume that similarities noted on one level – i.e. neurophysiology – can be transferred vertically to the phenomenal level or vice versa (e.g., Gottesmann, 2006). While this is possible and maybe even probable in certain instances, this remains an open question and requires further research.

4.2. Possible contrasts

In this concluding section, we briefly suggest several possibilities for contrastive analysis between dreaming and other conscious states. These are not exhaustive, but only present a selection of possible contrasting conditions we find interesting in view of current discussions in the literature and promising for future research.

4.2.1. Dreaming and standard wake states

A particularly interesting perspective for CA of dreaming and standard wake states is to focus on the phenomenal self (Windt & Metzinger, 2007). Specifically, dreams differ from waking consciousness along a number of dimensions related to self-consciousness. Delusional, ad hoc reasoning, attentional and mnemonic deficiencies and the lack of metacognitive insight into the dream state suggest that important aspects of the cognitive, agentive, and autobiographical or narrative self are lacking in many dreams. Within the framework proposed by the self-model theory of subjectivity (Metzinger, 2003), the phenomenal-functional property of agency, which involves the ability to deliberately control one's thoughts and actions, is only instantiated to a weak degree, and the first-person perspective is highly unstable, preventing the dreamer from forming a cognitive model of her current relationship to the dream world and realizing that she is dreaming. In terms of self-related processing, lucid dreams, in which the dreamer not only knows that she is dreaming, but often also remembers important facts about her waking life and can engage in deliberate dream control, can be considered as subjective experiences in a much stronger sense. Though a more fine-grained analysis of different types of nonlucid and lucid dreams will show that the distinction is gradual rather than absolute, fully lucid dreams more closely resemble wakefulness than nonlucid dreaming in this respect. Because of these differences, CA of self representation in wakefulness, lucid and nonlucid dreams can produce important conceptual insights for theories of self-consciousness and may also help formulate empirically investigable research questions (Noreika, Windt, et al., 2010).

Another area for which CA of dreaming and standard wake states commends itself is the contrast between dreaming and waking imagination or daydreaming. In the recent discussion on dreaming, both in philosophy and neuroscience, several authors have suggested that dreaming should be conceptualized as imagination during sleep. On this view, dreaming differs from waking perception on the phenomenal level of description, for instance in terms of the color saturation and detail of visual imagery (Schwitzgebel, 2002, 2003; Schwitzgebel, Huang, & Yifeng, 2006), but also by giving rise to the type of fictional absorption experienced when watching a movie or reading a novel (Ichikawa, 2009; McGinn, 2004, 2007). All of these involve varying degrees of detachment from the actual environment and cognitive absorption in the mentally simulated environment. In view of the fact that the precise mechanism of detachment during REM sleep dreaming remains unknown (for alternative explanations, see Nir & Tononi, 2010), it is at least conceivable that the type of detachment seen in sleep–dreams could be an extreme version of the familiar type of detachment seen in daydreaming as well. Indeed, Nir and Tononi seem to lean toward an imagination view of dreaming, according to which dreaming results from top-down processes in terms of the direction of signal propagation. Indeed, this may be a third way of solving IP, aside from conceiving of dreaming as a model either of standard or pathological wake states, first by relating dreaming to imaginative rather than alert wake states, and second by stressing the cognitive simulational rather than the sensory and quasi-perceptual aspects of dreaming.

This type of view has gained strong support from lesion studies (Solms, 1997, 2000) as well as from developmental studies focusing on children's dreaming (Foulkes, 1993, 1999; for a critical discussion of the cognitive psychological modeling of dreaming, see Blagrove, 1996). The imagination view of dreaming has a long history, being raised in Aristotle's *Treatise on Dreams* (Gallop, 1990) and promoted by Hobbes (1985) in the *Leviathan*, who viewed dreams as "the imaginations of them that sleep" (p. 90). It has also resurfaced in the recent philosophical discussion on dreaming (Ichikawa, 2009; McGinn, 2004; O'Shaughnessy, 2002; Sosa, 2007). While we do not want to take an explicit position on this point in this paper (but see Windt, 2010), we do want to point out that this discussion is directly relevant for IP, showing once more how diverse the current discussion of this problem is. While a modeling view, to our knowledge, has not been explicitly defended in this respect, the possibility of using dreaming as a model of imaginative processes and specifically visuospatial imagery—or vice versa—certainly seems suggestive, but needs further clarification.

4.2.2. Dreaming and pathological wake states

Despite the concerns about using dreaming as a model of psychosis voiced above, we take CA of dreaming and pathological wake states, and psychosis in particular, to be an extremely promising perspective for future research. While dreams differ from psychosis through the predominance of visual over auditory imagery (Hobson et al., 2000), whereas schizophrenia patients more frequently report auditory hallucinations of voices (Aleman & Larøi, 2008), there are a number of other striking similarities. For instance, both in dreams and schizophrenic psychosis, internally generated stimuli are perceived as having an external cause, suggesting a common disturbance in source-monitoring and the ability to make self-other distinctions. Agency attribution is also disturbed, as seen in schizophrenia patients claiming that others are controlling their thoughts (for a philosophical analysis, see Stephens & Graham, 2000). This bears a striking similarity to the involvement of non-self dream figures in a majority of dreams. One study found that the mean average of dream figures in dream reports was 3.9 (Kahn, Pace-Schott, & Hobson, 2002), and they are often described as agents that are not under the control of the dreamer (this may even lead to philosophical questions about the identity and autonomy of dream figures; see Metzinger, 2009). While certain delusions, such as persecutory delusions, are frequent in dreams (many studies have found dreams of being chased to be among the most frequent dream themes; see for instance Nielsen et al., 2003), phenomena such as thought control and thought insertion are rarely reported by dreamers. This suggests that while both dreaming and psychosis involve disturbances in agency attribution, monitoring and self-other distinction, the effects of these disturbances are quite different. Clarifying the ways in which these states differ from each other may prove as if not more informative than a traditional modeling approach. Again, CA of psychosis, dreams and lucid dreams, in which agency attribution and reality monitoring seem largely intact, provides an additional contrasting condition: At least fully lucid dreamers realize that other dream figures are not acting on their own, but can be controlled voluntarily (Brooks & Vogelsong, 1999). Understanding these mechanisms and the transitions between lucid and nonlucid dreams may even open new therapeutic perspectives.

4.2.3. Dreaming and altered states of consciousness

A surprising conclusion from our discussion is the lack of proposals for potential modeling relationships between dreaming and other altered states of consciousness (for an introduction on altered consciousness in philosophy, see Windt, in press). Here, dreaming offers a wide range of possibilities for CA, both within sleep and in wakefulness.

CA of dreaming and hypnagogic imagery may help distinguish dreaming from nondreaming during sleep and can prove informative for a minimal definition of dreaming (see Windt, 2010). CA of dream imagery and both hypnagogia and waking hallucinations could focus on the varying degrees of complexity that characterize hallucinations across the sleep–wake cycle. Also, as both dreaming and LSD intoxication have been proposed as models of psychosis, all three conditions could be contrasted in terms of hallucinations and cognitive functioning. Virtual reality (VR) setups may provide a further interesting contrast for the sense of immersion and reality experience both for dreams and spontaneous or drug-induced waking hallucinations (on the relevance of presence in VR for consciousness research, see Sanchez-Vives & Slater, 2005; Lenggenhager et al., 2007).

Another altered state that has received considerable attention in the discussion on self-consciousness is the out-of-body experience (OBE), which involves the experience of having left one's physical body and often of seeing it from above. Whereas many participants report experiencing a phantom body in the OBE state, some also experience themselves as lacking a body or being an extensionless point in space (Blanke & Arzy, 2005; Blanke & Mohr, 2005). Lucid dreamers occasionally report a similar experience of lacking a body (LaBerge & DeGracia, 2000), and the degree to which even nonlucid dreams involve bodily experiences has not been fully investigated. While most dreams involve a phenomenal self, this self may not be a phenomenally embodied self in the sense of giving rise to the detailed and integrated experience of having a body (Windt, 2010). This suggests that dreams, along with OBEs, may help discern the minimal conditions for phenomenal selfhood, or the experience of having a self. Bodily experiences, or the experience of ownership for or identification with a body as a whole, for instance, may not be a necessary condition for phenomenal selfhood, as suggested by Blanke and Metzinger (2008). The contrastive analysis of dreaming, OBEs and standard wakefulness may help understand the relationship between phenomenal selfhood and bodily experiences.

5. Conclusions

Our interim conclusion from the discussion of existing modeling approaches is that the attempt to use dreaming as a model system is problematic, at least at this point. Many of the background assumptions involved in such suggestions continue to be controversial in the current discussion. In addition, theoretical concerns about the adequacy of dreaming as a model and its practical feasibility suggest that current attempts to use dreaming as a model system are premature.

This is not to deny that certain types of dreams and a range of psychiatric disorders share common characteristics; yet, we contend that these can only be confirmed by systematic multi-level contrastive analysis of these states. Instead of speculative arguments for using dreaming as a global or restricted model of other mental states, detailed content-analysis studies are first needed in order to quantify and compare subjective experiences across different stages of sleep and wakefulness. Such comparisons are relatively common in dream studies contrasting subjective reports gathered after NREM vs. REM sleep awakenings (for a review, see Nielsen, 2000); yet, there is a pressing lack of studies directly comparing dream and waking mentation (for a recent exception, see Scarone et al., 2008).

Furthermore, a deeper integration of dream research with research on standard or pathologically or non-pathologically altered wake states could be achieved by focusing on the neural processes directly involved in the generation of dream experiences, rather than relying on general descriptions of REM sleep neurophysiology, such as the activation of the limbic system or higher visual areas, independently of dream reports (Schwartz & Maquet, 2002). Arguably, recently developed methods and rapidly accumulating findings on the neural substrates of subjective experience go largely unnoticed by dream researchers, and only few authors have recently aimed to integrate dream studies with consciousness research (e.g. Hobson, 2009; Nir & Tononi, 2010). Presumably, a closer assimilation of consciousness, psychosis and dream research could further the development of "neuro-phenomenological" or "multi-level" rather than purely phenomenological or purely neurobiological CA. Such multi-level CA would compare the neurobiology of subjective states of psychosis and standard waking mentation with the neural mechanisms of subjective experience in dreaming, which would require using both cognitive psychology and cognitive neuroscience methods.

In this sense, the proposed approach is both a plea for caution and an attempt to enhance the feasibility of the envisioned program. Arguably, the modeling approach has not yet guided research efforts in this field, or only on a very general level, nor has it produced testable predictions or led to the development of new therapeutic interventions; yet, we believe there is a sufficient research background to start developing such a program. Especially at the beginning, such a program will be mainly theoretical, involving systematic contrasts between different conscious states, as outlined in the previous section. Later, it may also yield testable hypotheses and research questions. For instance, and bearing in mind the practical difficulties involved in dream research, it may be possible to develop paradigms for the experimental manipulation of dreams and to compare the effects of such experiments with their effects on other altered states. It has recently been suggested that electrical brain stimulation of prefrontal areas may be a way to induce lucid dreams and alter the sense of presence and immersion in the dream state (Noreika, Windt, et al., 2010). Similar experiments could be performed, for instance, in virtual reality setups, and their outcome compared. Finally, one of the possible outcomes of CA is the identification of modeling relationships. This could either mean using dreaming as a model of standard, pathologically or non-pathologically altered wake states, or vice versa using wake states as models of dreaming. Our position, however, is that in order to identify fruitful and promising modeling relationships, much preliminary work and a stronger integration of dream research with interdisciplinary consciousness research is needed as a first step, and that CA may provide the framework for such an approach.

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