The Simulation Theories of Dreaming: How to Make Theoretical Progress in Dream Science

A Reply to Martin Dresler

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Among the most pressing challenges for dream science is the difficulty of establishing theoretical unification between the various theories, ideas, and findings that have been presented in the literature to answer the question of how it is possible to construct a solid scientific theory with predictive and explanatory power in dream science. We suggest that the concept of "world-simulation" serves as the core concept for a theoretically unified paradigm to describe and explain dreaming. From this general concept, more specific theories of the function of dreaming can be derived, such as the Threat Simulation Theory (TST) and the Social Simulation Theory (SST), as we argued in our target article. We agree with Dresler that these two functions may not be the only functions of dreaming, but we still have grounds to believe that they are the strongest contenders. In our reply we first clarify why the functions of sleep should be considered separately from the functions of dreaming. Second, we outline what a good scientific theory of dreaming should be like and what it should be capable of. Furthermore, we evaluate the current state of simulation theories within this context. To conclude, we propose that instead of a general multifunctional theory of sleep and dreaming, where no hypothesis is excluded, the future progress of dream science will benefit more from opposing, competing and mutually exclusive theories about the specific functions of dreaming. This, however, demands that the opposing theories and their predictions must be risky, clearly formulated, and empirically testable.

Keywords
Avatars | Dream | Dreaming | Multifunctionality | Simulation | Sleep | Social simulation | Threat simulation | Virtual reality

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1 Introduction

We are grateful to Martin Dresler (this collection) for his thorough and insightful commentary on our target article (Revonsuo et al. this collection). Dresler's commentary places the proposed simulation functions of dreaming into the wider context of other functions for sleep and dreaming, demonstrating that these phenomena may have multiple different and partly overlapping functions. He also suggests the threat simulation and social simulation functions are unique. They can neatly be connected to evolutionary theory and only they explain why the suppression of reality testing and the lack of lucidity are necessary features of these simulation functions of dreaming (i.e., they require an "oblivious avatar"). While we agree with many of the points presented in Dresler's analysis, we believe that it is possible to regard the different proposed functions of dreaming as representing different (preliminary) scientific theories of dreaming. When viewed from this theory-driven perspective, it is also possible to present more definitive evaluations as to which of them are more plausible theoretical explanations than others.

2 Function of sleep vs. function of dreaming

Many of the findings Dresler (this collection) mentions in his commentary are not about dreaming, but rather about sleep, its different stages, and their potential correlates, effects, and functions. While it is encouraging that there is much evidence about the functions of sleep that relates to memory and learning, and that emotionally significant information seems to hold a special place, most of those studies have very little or nothing to do with dreaming as a subjective experience. In most of the sleep studies, whether or not the sleeping participants have been dreaming or not, and what their dream contents have been, is irrelevant for the hypotheses being tested (e.g., whether a certain stage of sleep enhances memory consolidation of particular types of stimuli) and usually remains unknown. In sleep studies purely objective neurophysiological and behavioural phenomena are investigated with objective measures. In contrast, in dream studies purely subjective phenomena are explored by collecting subjective introspective reports describing the contents of phenomenal consciousness. Modern theories of the functions of sleep are undoubtedly quite strong as scientific theories of sleep and its relationship to some neurocognitive mechanisms of memory and learning, but they are not in any direct sense theories of dreaming. Of course, any proposed theory of dreaming should be at the very least *consistent* with the leading theories of sleep, because the phenomenal level of organization supervenes on the lower, neurophysiological level. However, the opposite is not necessarily true. As Dresler (this collection) points out, lower-level functions can be carried out independently of the higher, phenomenal level of organization. Thus, we would like to strongly emphasize that the merits and the predictions of theories of dreaming primarily have to be tested by using data that reflects subjective dream contents, not the objective features of sleep.

3 What is it like to be a strong scientific theory of dreaming?

Any theory of a phenomenon should include a precise definition and description of its target phenomenon (or *explanandum*), as well as clear demarcation of conceptually and empirically different phenomena. Theories of dreaming should clearly state i) in what way dreaming is a different type of phenomenon from sleep (or any particular stage of sleep), and ii) in what way dreaming is a special form of mental activity occurring during sleep. In our approach the starting points are that while sleep and its different stages can be defined by objective behavioural and neurophysiological criteria, dreaming is a subjective phenomenon; a special, complex altered state of consciousness that can be differentiated from simple sleep mentation. Quite independently from any functional considerations, the general, universal *form* of dreaming, as most dream researchers currently agree, is a complex,

multi-modal *simulation* of the sensory perceptual world, inhabited by a simulated self or a self-model (Hobson 2009; Metzinger 2003, 2013; Nielsen 2010; Windt 2010). A fruitful idea in biology is that *form suggests function*; thus the form that dreaming takes, a world-simulation, most likely suggests that the major functions of dreaming have something to do with world-simulation. The most frequent dream contents are therefore the most likely candidates for reflecting the specific function(s) of dreaming: how, when, under what circumstances, and what contents to simulate. Thus, to state that dreaming is an internal world-simulation is to describe the general form that this phenomenon universally takes, but not necessarily its function. The function(s) of the simulation, according to our view, are mainly related to the specific contents selected for simulation.[1]

Furthermore, a proper theory of dreaming should be *simple yet covering*, so that the same general principles apply to many types of dreams, including the pathologies of dreaming, animal dreaming, and other special cases; the theory should be *fruitful*, so that it leads to new ideas, hypotheses, and new directions for active research; it should be *empirically testable*, so that it leads to risky predictions whose accuracy can be objectively checked. It should have both predictive and explanatory power.

Of course, these virtues are desirable in any scientific theory of any phenomenon. When there are rival theories of the same phenomenon, they should be compared with regard to their overall strengths and weaknesses as scientific theories. If they are consistent with each other, perhaps they can be combined into a single, more covering theory. If they are inconsistent with each other, their differing predictions should be empirically tested. After their relative strengths and weaknesses are compared, it should be possible to say which ones are stronger than others.

1 Further, Dresler (this collection) raises the question of whether the frequency of specific dream contents can be regarded as evidence for the importance of its underlying functions. If we consider the function of dreaming more broadly to be that of a training ground for essential and adaptive behaviors, it becomes rather clear that the observed frequency of these behaviors can be viewed as a valid measure of their importance. This, however, is evident only when comparing the contents within the phenomenal level of explanation.

4 Simulation theories of dreaming

According to the simulation view, dreaming is a special case of phenomenal consciousness, or the phenomenal level of organization being activated in the brain. Waking consciousness and dreaming are manifestations of the same natural biological phenomenon in the brain, but they occur in different contexts and under different conditions. The simulation theory of dreaming is anchored to a more general theory of consciousness, which in turn is anchored philosophically to weak emergent materialism and multi-level explanation (Bechtel 2008, 2011; Craver 2007; Revonsuo 2006, 2010). In a multi-level explanation of a mental phenomenon, several different explanatory dimensions surround the target phenomenon: the *downward-looking* explanation specifies its neural correlates and mechanisms; the *backward-looking* mechanisms specify what has causally brought about or modulated the phenomenon (e.g., day residues or traumatic experiences that directly influenced specific contents of dreaming; the ontogeny of dreaming—how dreaming came about during individual development; phylogeny—how dreaming emerged and might have been selected for during evolutionary history[2]); and the *upward-looking* (functional) explanation—how does dreaming guide or change consequent mental states or external behaviours? Only after all these explanatory dimensions can be accounted for may we be said to have a comprehensive theory of dreaming, including its function(s) (see also Revonsuo 2006, 2010; Valli 2011).

So far, one general and three separate, more specific simulation theories have been proposed. From a more general perspective, some versions of the Continuity Hypothesis (CH) can be regarded as a simulation theory, as some proponents of it consider the world-simulation itself to be a functional *form* of dreaming (e.g., Foulkes 1985, pp. 201–202). Three other, more specific simulation theories have been proposed:

2 We should, however, also keep in mind the option that dreaming does not serve any function at all and was not selected for, but is merely epiphenomenal, as suggested, for example, by Flanagan (2001), and implied by the Continuity Hypothesis (CH). This notion should be the null hypothesis against which the proposed functions of dreaming are to be pitted.

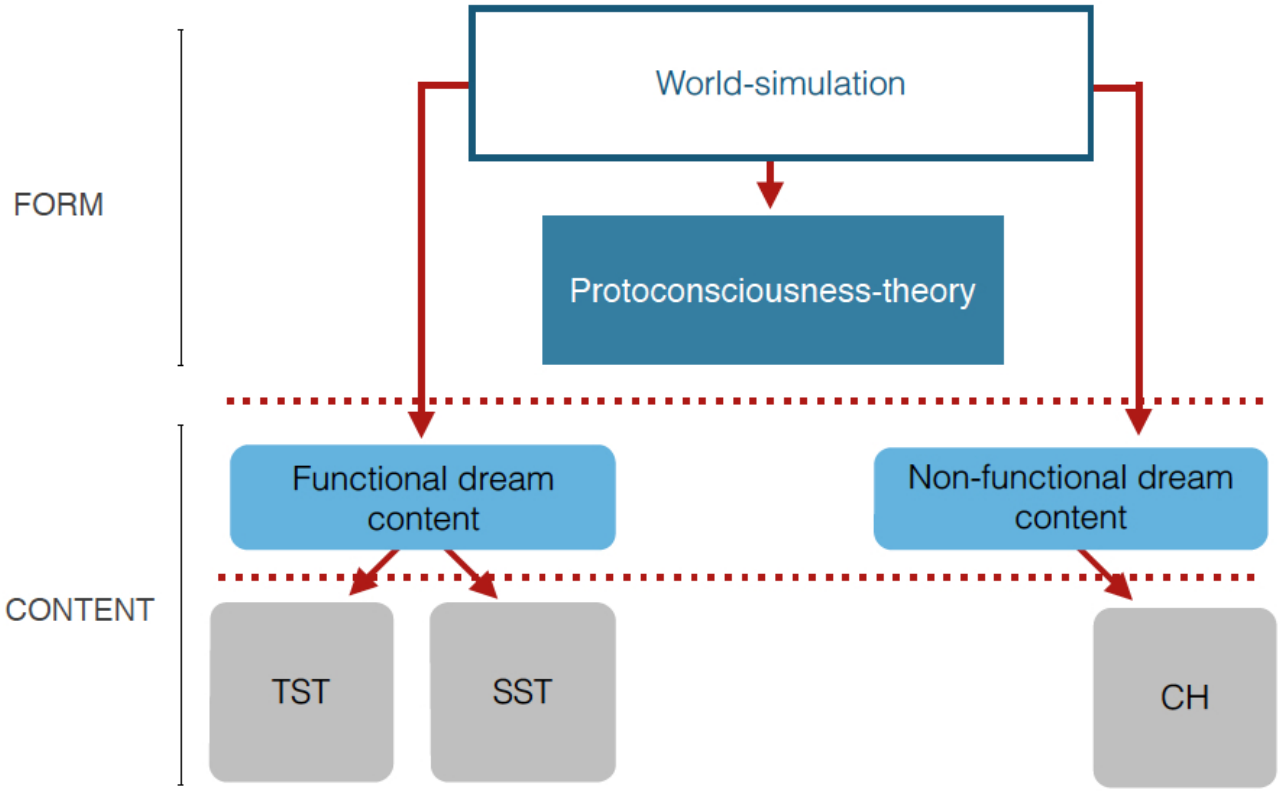

Figure 1: Simulation theories of dreaming. All simulation theories assume that dreaming can be defined as a world-simulation, the form of which is functional. The protoconsciousness-theory is more focused on explaining the form of dreams instead of their specific contents. Threat simulation and Social simulation theories try to explain the content of dreams as having a specific function, while the Continuity Hypothesis assumes the content of the simulation to be evolutionarily non-functional.

the protoconsciousness theory (Hobson 2009), which covers the role of dreaming in ontogeny; the Threat-Simulation Theory (TST), which covers the negative contents of dreaming and provides an evolutionary account for them; and the Social Simulation Theory (SST), which covers the social contents of dreaming, including the positively charged ones. Taken together, these theories are at the same time both covering and economical: the simple principle of "internally activated world-simulation" underlies all of them (see figure 1). The proto-consciousness theory accounts for how and why the basic form of the virtual-reality generator comes about in the developing brain, and how during early brain maturation both dreaming and waking consciousness emerge together in interaction. It is, however, the most speculative of the three simulation theories, as we cannot hope to test it with data about subjective experiences describing the postulated fetal dream experience: what is it like to be a proto-conscious dreaming fetus? Thus, its weakness is that dream reports or any other direct evidence of the existence of subjective dream-like states cannot conceivably be empirically collected to test the validity of the theory.

The TST and SST, as we have explicated in our target article (Revonsuo et al. this collection) and in earlier publications elsewhere (Revonsuo 2000, 2006; Valli & Revonsuo 2009) are testable as they issue specific predictions concerning the frequency and quality of dream contents under different circumstances. They are also covering, TST potentially accounts for normal dreaming as well as several special types of dreams, where negative dream contents are particularly abundant and dominate (bad

dreams, recurrent dreams, nightmares, post-traumatic dreams, children's earliest dreams, dreams in parasomnias such as RBD, night terrors, and so on). Together TST and SST potentially cover a very large proportion of the statistically most frequent dream contents, and the predictions derived from these theories have specific empirically testable consequences as to the quantity and quality of these types of dream contents. As Dresler (this collection) points out, simulation theories also have the advantage of being highly consistent with the peculiar behavioural, neurophysiological, and phenomenal features of dreaming such as isolation from sensory input, motor activity, cognitive reflection, and reality testing. These features are necessary preconditions for running powerful, phenomenologically realistic but behaviorally isolated virtual reality simulations in the sleeping brain. The simulation theories thus have a lot of explanatory power. The concept of world-simulation unifies numerous separate phenomena related to dreaming and makes sense of them under a single concept. In this the simulation theories of dreaming fulfil the requirements of simplicity, coverage, and economy as well as having predictive and explanatory power. Compared to some of the other ideas Dresler presents in his commentary, it appears that currently the simulation theories are amongst the strongest frameworks for the form and function of dreaming.

5 Rival paradigms in dream science

Of the theories that are directly applicable to dreaming, we have already addressed the Continuity Hypothesis (CH) in our target article (Revonsuo et al. this collection). As we say there, it has never been formulated in a sufficiently precise manner such that risky, testable predictions can be derived from it. The CH, largely because of its vagueness, might actually be consistent with simulation theories. The particular contents of dreams are neither selected through an active process, nor do they reflect any function(s); they are selected through a passive and more or less random mirroring of the experiences that have been lived through. Further, CH does not consider how to deal with potential anomalies for the theory: the relatively frequent cases where either something very alien to our waking world (and thus entirely discontinuous with it) appears, or where something very common in our waking life fails to appear in our dream contents. Can the theory be regarded as falsified when evidence of such blatantly discontinuous dream contents appear over and over again in dream data? One version of the CH, presented by Foulkes (1985) states that the mnemonic sources of dream contents are random and unpredictable; thus dream contents are unselective random samples of our memories; but the general form of dreams as world simulations as such is highly predictable —thus the function of dreaming would be more related to the general form than to the specific contents of dreams. However, as we have argued, dream contents are *not* random, but selective, and in particular they select threatening and social events into dreams. Thus, the basic assumption behind Foulkes's version of CH has turned out to be empirically false. The CH thus does not look very promising. But, as we argued in our target article (Revonsuo et al. this collection), some testable predictions can and should be derived from CH, to render its predictions as the null hypothesis "no selectivity, no functionality", and thereby directly test its predictions against those derived from TST and SST.

Another major functional theory of dreaming, the Emotion Regulation Theory (ERT; also reviewed by Dresler this collection), also seems relatively weak as a scientific theory. It has been presented by many different authors in many different formulations (e.g., Cartwright et al. 2006; Hartmann 1996; Kramer 1991). There seems to be no standard, detailed, or shared version of this theory among its supporters; thus it also suffers from a vagueness similar to that of CH. The shared core in all of the different versions appears to be the idea that dreaming works with and processes difficult, unpleasant emotions and events, and through this dream processing makes us get over them and feel and function better in our lives. An often-used analogy compares dreaming with psychotherapy (Hartmann 1995; Walker & van der Helm 2009).

Again, when looking at the evidence it is important to separate sleep from dreaming. When it comes to emotional processing during sleep, the analogy to psychotherapy gains some support (Walker & van der Helm 2009). But when applied specifically to dreaming and dream contents, the idea runs into difficulties. Its theoretical roots appear to originate predominantly from the clinical tradition, and more specifically from the idea that the function of dreaming is to protect sleep from strong surges of emotion and to solve emotional problems. The negative contents of dreams originate from interpersonal conflicts and current concerns, thus being consistent with the continuity between dreaming and waking, in fact so much so that the CH coupled with the ERT could perhaps be seen to form one specific paradigm of dream theorizing. Perhaps one of the core differences between the ERT+CH paradigm and the simulation paradigm is their relationship to biological explanations. The ERT+CH favours psychological-level explanations and emphasizes recent individual experiences (learning, nurture) as proximate explanations of dreaming. The simulation paradigm emphasizes biological explanations of the form and contents of dreaming, and links dream consciousness to both the underlying neurophysiological levels as well as the ontogenetic and phylogenetic, ultimate biological history of dreaming as explanations of the form and contents of dreaming. A further core difference between these paradigms is that the psychological paradigm sees the function of dreaming as contributing to our psychological well-being and psychological adaptation to our lives, whereas the biological paradigm sees the origin of dreaming in its ability to increase fitness in all mammals and in humans during their evolutionary history; but dreaming need not *necessarily* contribute to our psychological well-being in order to fulfill its original biological function.

As these approaches represent different paradigms with differing core ideas, it might not be possible to integrate them, in the manner that Dresler (this collection) suggests, into one overall multifunctional theory of dreaming. Some of the core assumptions of ERT are inconsistent with TST, especially when it comes to the function(s) of dreaming and to the explanation of nightmares and bad dreams. According to TST, post-traumatic dreams, recurrent dreams, nightmares, bad dreams, and the earliest dreams in childhood are the best and strongest manifestations of the function of dreaming, when the function is fully at work and typically activated by ecologically valid threat cues and dangerous events observed in the environment, often displaying universal threat scripts consistent with evolutionarily relevant threats. In parasomnias the threat-simulation system can be overactivated, or activated in an inappropriate context and therefore seen as psychologically dysfunctional, so that it might in actuality either decrease the well-being of the individual or hamper with other functions of sleep and dreaming, even though it at the same time carries out its original biological function perfectly. By contrast, according to ERT, such highly negative dreams are malfunctions and failures of the core function of dreaming itself, because such dreams disturb sleep and make us feel negative emotions. Nightmares cause psychological suffering and sleep disturbances, thus they are like a failed psychotherapy session that increases the individual's psychological distress, instead of calming the individual down. As such, very large and important categories of dreams (and their functionality) are explained in squarely opposing ways by the two paradigms.

6 Concluding remarks

Consequently, it is not only possible but theoretically necessary to separate the basic assumptions, the predictions, and the hypotheses of the simulation theories from those of ERT and others. We can have multiple *theories* of dream functions, but dreaming as a specific phenomenon cannot have multiple *conflicting functions*! If one theory says that recurrent dreams, nightmares, and bad dreams are types of dreams that most strongly carry out the TST functions and thus were selected for in human evolutionary history, and another theory says that such dreams are, from the functional point

of view, total failures of dream function, it becomes impossible to construct from those mutually opposing ingredients a "multifunctional" theory.[3] A theory that combines TST and ERT would have to say that on the one hand the function of dreaming is to have many threatening events in dreams, bad dreams, nightmares, and recurrent negative dreams, in order to rehearse threat perception and avoidance, but on the other hand the function of dreaming is also to calm down or suppress exactly those types of dreams to make the dreamer feel better. What is the dream production system supposed to do: increase or decrease the number and impact of these kinds of dreams? The multifunctional theory cannot derive coherent testable predictions about the quantity and quality of these types of dreams.

This situation, however, is far from a scientific catastrophe; in fact, it is highly *desirable*. The problem is not that there is a lack of different theories, hypotheses, ideas, or suggestions about the nature and functions of dreaming, but rather that there are too many. Consequently, it is not only possible, but theoretically necessary to separate the basic assumptions, predictions, and hypotheses of the simulation theories from those of ERT, CH, and others. We can have multiple independent *theories* of dream functions, but dreaming as a specific phenomenon cannot have multiple *mutually inconsistent functions*. We hope that the simulation theories of dreaming, whether they turn out to be correct or not, will at least push dream science forward. The progress of any science is best served by the directly opposing predictions issued by rival, clearly stated, empirically testable hypotheses. Thus it is, from the scientific point of view, much more desirable to have many squarely opposing testable hypotheses than one all-inclusive theory that is unfalsifiable or too vague to be tested. When the opposing theories have been well-formulated and put through fair but strict empirical tests several times, we will know which ones to adopt for the time being and which ones to leave behind for good, in order to keep dream science a progressive branch of science.

3 The multifunctionality of dreaming might be possible in different populations, so that in a population that lives in a very threat-filled environment a strong threat simulation system would be selected for, whereas in a population living in more peaceful conditions the psychotherapeutic function and taming of threat simulations dreams would be more likely candidates for selection. However, one and the same population cannot manifest both functions at the same time. Just as in some species of moths, in one environment individuals are selected for towards being white because white provides the best camouflage, while in another environment the color of individuals in the same moth species is selected for towards being dark gray or black, because in that environment all the white individuals are too easily detected by predators.

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