The Avatars in the Machine

Dreaming as a Simulation of Social Reality

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The idea that dreaming is a simulation of the waking world is currently becoming a far more widely shared and accepted view among dream researchers. Several philosophers, psychologists, and neuroscientists have recently characterized dreaming in terms of virtual reality, immersive spatiotemporal simulation, or realistic and useful world simulation. Thus, the conception of dreaming as a simulated world now unifies definitions of the basic nature of dreaming within dream and consciousness research. This novel concept of dreaming has consequently led to the idea that social interactions in dreams, known to be a universal and abundant feature of human dream content, can best be characterized as a simulation of human social reality, simulating the social skills, bonds, interactions, and networks that we engage in during our waking lives. Yet this tempting idea has never before been formulated into a clear and empirically testable theory of dreaming. Here we show that a testable Social Simulation Theory (SST) of dreaming can be formulated, from which empirical predictions can be derived. Some of the predictions can gain initial support by relying on already existing data in the literature, but many more remain to be tested by further research. We argue that the SST should be tested by directly contrasting its predictions with the major competing theories on the nature and function of dreaming, such as the Continuity Hypothesis (CH) and the Threat Simulation Theory (TST). These three major theories of dreaming make differing predictions as to the quality and the quantity of social simulations in dreams. We will outline the first steps towards a theory-and-hypothesis-driven research program in dream research that treats dreaming as a simulated world in general and as a social simulation in particular. By following this research program it will be possible to find out whether dreaming is a relatively unselective and thus probably non-functional simulation of the waking world (CH), a simulation primarily specialized in the simulation of dangerous and threatening events that present important challenges for our survival and prosperity (TST), or whether it is a simulation primarily specialized in training the social skills and bonds most important for us humans as a social species (SST). Whatever the evidence for or against the specific theories turn out to be, in any case the conception of dreaming as a simulated world has already proved to be a fruitful theoretical approach to understanding the nature of dreaming and consciousness.

Keywords
Altered state of consciousness | Avatar | Consciousness | Continuity hypothesis | Dreaming | Evolutionary psychology | Inclusive fitness | Kin selection theory | Need to belong | Practise and preparation hypothesis | Reciprocal altruism theory | Simulation | Social brain hypothesis | Social mapping hypothesis | Social simulation theory | Sociometer theory | Strengthening hypothesis | The dream self | The inclusive fitness theory | Threat simulation theory | Virtual reality | Virtual reality metaphor

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1 Introduction

There may be no Cartesian ghosts residing within the machinery of the brain, but still, something rather peculiar is going on in there, especially during the darkest hours of the night. As we sleep and our bodies cease to interact behaviourally with the surrounding physical world, our conscious experiences do not entirely disappear. On the contrary, during sleep we often find ourselves embodied and immersed in an experiential reality, an altered state of consciousness called dreaming. The Dream Self—the character with which we identify ourselves in the dream world, and from whose embodied perspective the dream world is experienced—is who *I* am in the dream world (Revonsuo 2005).

But we are not alone in this alternative reality—there are other apparently living, intelligent beings present, who seem to share this reality with us. We see and interact with realistic human characters in our dreams. Their behaviour and their very existence in the dream world seem to be autonomous. The dream people who I encounter within the dream seem to go about their own business: I cannot predict or control what they will say or do. Yet, they, too, are somehow produced by my own dreaming brain.

On the one hand, dreaming is a solipsistic experience: when we dream, we dream alone, and outsiders have no way of participating in our dream. Yet on the other hand, dreaming is an intensely *social* experience, even if the social contacts and interactions in the dream world are merely virtual. In this paper, we will explore the idea that dreaming is a *simulated* world, but not only a simulation of the *physical* world. It is equally or perhaps even more importantly a simulation of the *social* world. We will proceed in the following way:

First, we will argue that a remarkable convergence has gradually emerged in theories about the nature of dreaming. The field used to be a disunified battleground of directly opposing views on what dreams are, how exactly the concept of "dreaming" should be defined, and on the proper level of description and explanation for dreaming. Recently, the field has converged towards a more unified understanding of the basic nature of dreams. A widely shared conceptualization of dreaming now depicts it as the *simulation* of waking reality. We will briefly describe how this theoretical shift has taken place and where we currently are in the theoretical definition of dreaming. This theoretical development has paved the way for understanding the *social* nature of dreams in terms of social simulation.

Second, we will explore the nature of social dream simulation in more detail. In what sense can dreaming be taken as a simulation of our human *social* reality? How much and what types of social perception and interaction occur in dreams? This question can be broken down into a number of more detailed questions. We will try to answer some of these questions based on the already existing knowledge and empirical evidence about the social nature of dreams. Furthermore, we will try to formulate more clearly the questions that cannot yet be answered empirically due to the lack of appropriate data.

Third, we will review hypotheses that already address the question of the social nature of dreams or assign a social simulation function for dreams. Finally, we will outline some basic ideas of a Social Simulation Theory (SST) of dreaming that might offer some explanations for the social nature of dreams, or at least might produce well-defined, testable research questions concerning the possible *functions* of social dream simulations.

To describe and explain the social nature of dreams as social simulation, concepts borrowed from virtual reality technology may be applied, in this case to the social aspects of dreaming. One of these concepts is the notion of "avatar": *A simulated virtual human character* who plays the role of a corresponding real human within a virtual reality. If dreams are virtual realities in the brain (Revonsuo 1995), then we ourselves within the dream world are avatars, and we interact with other avatars inside the simulated reality. Somehow, the dreaming brain is capable of creating credible, autonomous human simulations out of neural

activities in the sleeping brain. A theory of dreaming as a social simulation should predict what kind of avatars are represented in our dreams, what types of interactions we engage in with them, and in particular, *why* it would be useful to simulate such avatars and interactions in our dreams—what functions, if any, do they serve for us.

2 Consciousness as reality-modeling and world-simulation

Dreaming is the most universal and most regularly occurring, as well as a perfectly natural and physiological (as opposed to pathological), altered state of consciousness. Thus, any plausible (empirical or philosophical) theory of consciousness should also describe and explain dreaming as a major state of consciousness. Most theories of consciousness, however, do not consider dreaming at all or at least do not discuss the results of dream research in any detail (Revonsuo 2006).

Dreaming presents a particularly difficult challenge for externalist, embodied, and enactive types of theories of consciousness.[1] They all anchor the existence and nature of consciousness to something in the world external to the brain, or to some kind of brain-world relations that, at least partly, reside outside the brain. By contrast, the empirical evidence from dream research shows that full-blown, complex subjective experiences similar with or identical to experiences during wakefulness (e.g., Rechtschaffen & Buchignani 1992), regularly and universally happen during rapid eye movement (REM) sleep. The conscious experiences we have during dreaming are isolated from behavioural and perceptual interactions with the environment, which refutes any theory that states that organism-environment interaction or other external relationships are constitutive of the existence of consciousness (Revonsuo 2006).

A few theories of consciousness have, however, taken dreaming as a central starting point in their conceptualization and explanation of consciousness. When dreaming is taken seriously, ideas about the nature of consciousness tend to converge on internalist theories of consciousness that take consciousness and dreaming to be varieties of the same internal phenomenon, whose main function is to simulate reality.

One of the earliest attempts to conceptualize both waking consciousness and dreaming as the expressions of the same internally-activated neural mechanism, only differently stimulated, was put forward by Llinás & Paré in 1991:

> [C]onsciousness is an intrinsic property arising from the expression of existing dispositions of the brain to be active in certain ways. It is a close kin to dreaming, where sensory input by constraining the intrinsic functional states specifies, rather than informs, the brain of those properties of external reality that are important for survival. [...] That consciousness is generated intrinsically is not difficult to understand when one considers the completeness of the sensory representations in our dreams. (1991, p. 531)

The argument by Llinás & Paré (1991) was mostly based on considerations of the shared neurophysiological mechanisms (in the thalamocortical system) that could act as the final common path for both dreaming and waking consciousness. Binding information together within this system intrinsically generates consciousness ("It binds, therefore I am", Llinás 2001, p. 261); but only during wakefulness is consciousness modulated by sensory-perceptual information—in this model, wakefulness can be seen as a dream-like state (Llinás & Ribary 1994).

Although the idea that dreaming *simulates* waking consciousness was implicit in this neuroscientific theory, Llinás & Paré (1991) did not consider the phenomenology of dreaming and consciousness in any detail. Theoretical approaches characterizing the nature of dreaming as simulation, based on a combination of philosophical arguments and empirical facts about dreaming, started to emerge during the 1990s. In Revonsuo (1995) the idea was put forward

1 The same criticism may to some extent also apply to representationalist theories of consciousness and dreaming, depending on which externalist or internalist version of representationalism the theory is committed to.

that consciousness in general and dreaming in particular may best be characterized as a virtual reality in the brain, or a model of the world that places a (virtual) self in the centre of a (virtual) world. All experiences are virtual in the sense that they are world-models rather than the external physical world somehow directly apprehended. While the causal chains that modulate the virtual reality are different during wakefulness and dreaming, the virtual world is ontologically the same biological phenomenon: the *phenomenal level of organization* in the brain (Revonsuo 1995). All experiences are, according to this view, in their intrinsic phenomenal character, no different from dreams.

Metzinger (2003) took this line of thought further and analysed dreams as complex, multimodal, sequentially organized models of the world that satisfy several important constraints of consciousness. Dreams activate a *global* model of the world (globality), they integrate this model into a *window of presence* (presentationality), and this model is *transparent* to the experiencing subject, who takes it to be a real world and not a mere model of the world (transparency) (see also Windt & Metzinger 2007).

In *Inner Presence* Revonsuo (2006) presented a lengthy analysis and defence of the idea that dreams are internal virtual realities, or *world-simulations*, and argued that consciousness in general would be best described and explained by treating dreaming as a paradigmatic model system for consciousness. The world-simulation contains the *virtual self* and its *sense of presence* in the centre of the simulation. The virtual self is perceptually surrounded by the *virtual place*; the virtual place in turn contains multiple perceptual contents in the form of animate and inanimate *virtual objects*, including human characters. The virtual objects are bound together from phenomenal features like color, shape, and motion, but this binding in dreams does not always work coherently, thereby resulting in bizarre feature combinations and incongruous or discontinuous objects and persons in dreams (Revonsuo 2006).

Recently, Windt (2010) has formulated a definition of dreams that stems from similar basic ideas. Windt's definition aims to capture the minimal set of phenomenological features that an experience during sleep should have in order to count as a "dream" (as opposed to other types of sleep mentation). This definition, although not explicitly applying the concept of "simulation", is consistent with the world-simulation model of dreaming. According to Windt, dreams are Immersive Spatiotemporal Hallucinations (ISTH): there is a sense of spatial and temporal presence in dreams; there is a hallucinatory scene organized around a first-person perspective, and there is a sense of "now", along with temporal duration. The core feature of a dream experience is, in Windt's ISTH, *the sense of immersion or presence in a spatiotemporal frame of reference*. Thus, Windt's ISTH, as well as Metzinger and Revonsuo's earlier definitions, all involve similar ideas of dreams as involving an immersive presence of a virtual self in a virtual, spatiotemporally organized world-model or simulation.

3 Dreaming as simulation: Converging definitions from dream research

Within empirical dream research, definitions of dreaming have been highly variable and often motivated by underlying theoretical background assumptions held by the theorist. Thus, the pure description of the *explanandum*, which should come first in any scientific inquiry, has perhaps been biased by a pre-existing theory as to what might count as the *explanans*—the entities, processes, and concepts that are supposed to explain the phenomenon. We will only briefly mention three approaches to defining (and explaining) dreams in the recent history of dream research, where the definition and description of the data seem to have been theoretically motivated.

The field of dream research was, in the 1970–1990s, a theoretically disunified field. The deep disagreements over finding a definition of "dreaming" that would be acceptable across the field were noted by Nielsen (2000, p. 853)

> [T]here is currently no widely accepted or standardized definition of dreaming.

as well as by Hobson et al. (2000, p. 1019):

> [...T]here is no clearly agreed upon definition of what a dream is [...] and we are not even close to agreement.

Hobson's (1988, 1997, 2001) own definition of dreaming is (or at least was in his earlier writings) a list of some features of dream experience. According to him, a dream is mentation during sleep that has most of the following features: *hallucination, delusion, narrative structure, hyperemotionality, and bizarreness*. This definition may be (and was) criticized as including only paradigmatic late-night REM dreams that are spontaneously remembered and on which our everyday stereotype of what dreams are like is based. This bias in the definition towards REM dreams might be seen to reflect the underlying theoretical idea or commitment, obvious in Hobson's earlier theories, that dream phenomenology should be (reductively) explained by referring to the features of REM neurophysiology.

The opposing, cognitive–psychological view of the 1980s and 1990s conceptualized dreaming as a cognitive process that should be explained at the cognitive–psychological level (Foulkes 1985). References to the neurophysiological level were unnecessary. In that time and in the spirit of functionalism and classical cognitive science, the cognitive levels of description and explanation were in general seen to be completely independent of implementation levels, such as neurophysiology. Furthermore, dreaming was thought to occur in every stage of sleep, not only REM sleep, and rather than being full of bizarreness was mostly a credible replica of the waking world. Thus, according to the cognitive approach, an explanation of dreaming cannot be based on neurophysiological mechanisms in general, or for REM sleep on neurophysiology in particular. The explanation should be given at cognitive levels rather than neurobiological ones. Interestingly, it was probably Foulkes (1985) who first characterized dreams in terms of the idea and the concept of simulation. In 1985 he described dreams as *credible world analogs*, an organized form of consciousness that *simulates* what life is like in a nearly perfect manner.

A third theoretical definition of dreaming came from clinical dream research, and reflected the long and widespread idea in clinical psychology that dreams restore our emotional balance and have a psychotherapeutic function. Hartmann formulated this definition of dreaming most clearly, when he said that "Dreaming, like therapy, is the making of connections in a safe place" (1996, p. 13).

During recent years in dream research, the concept of simulation has become a widely accepted way of characterizing and defining dreaming, as well as a way of formulating theoretical ideas about the potential functions of dreaming. Thus, the idea that *dreaming is a multimodal, complex, dynamic world-simulation in consciousness during sleep*, may be a type of conception and definition of dreaming that many if not most dream researchers are ready to accept (Nielsen 2010). The various contents of dreams—their events and objects and characters—can be taken to be simulations of their real-world counterparts.

Taking Foulkes's idea of dreams as credible world analogs and as the simulation of what life is like as a starting point for defining dreaming, Revonsuo (1995) formulated the Virtual Reality metaphor and later the TST (Threat Simulation Theory) of the evolutionary function of dreaming. This theory is built on two background assumptions, the first of which is precisely the definition of dreaming as "an organized simulation of the perceptual world" (Revonsuo 2000, p. 883). An additional, more specific assumption of this theory is that dream experience is *specialized* in particular in the simulation of *threatening* events: it tends to select and include various types of dangerous enemies and events and then simulates what it is like to perceive and recognize them (simulation of threat perception) as well as how to react and behaviourally respond to them (simulation of threat avoidance behaviours and strategies). Threat simulations appear in a paradigmatic and powerful form especially in nightmares, bad dreams, and post-traumatic dreams, but are also abundant in many other types of dreams

such as everyday dreams, recurrent dreams, and in various parasomnias such as RBD (REM-Sleep Behaviour Disorder).

Domhoff (2007), who represents a similar psychological and content-analysis approach to dream research as Foulkes (1985), also characterizes dreams as mostly realistic and reasonable *simulations* of waking life. By emphasizing that, according to convincing empirical data from content-analysis studies of dreams, dream simulations are mostly *realistic* rather than overly bizarre and hyperemotional, Domhoff argues against the Hobsonian definition of dreaming as being full of bizarre contents.

Still, despite their disagreements, both camps now seem to accept the notion of *simulation* as a valid description of the core nature of dreaming. Hobson, in his new *protoconsciousness* theory of dreaming and REM sleep (2009), uses the concept of simulation to characterize the root phenomenon, protoconsciousness, from which both our waking and dreaming consciousness arise. According to Hobson, protoconsciousness is the simulated experiential reality or a virtual reality model of the world that the developing brain turns on during REM sleep even before birth, to prepare the conscious brain to simulate the external reality that it will encounter through the senses after birth. This model of the world is genetic, innate, and a human universal. Protoconsciousness acts as the template on which both waking and dreaming consciousness are built after birth. Thus, according to this theory, protoconscious dream consciousness—a very basic form of an internally simulated world—comes into being prior to waking consciousness, and is causally necessary for waking consciousness. As Hobson (2011, p. 30) puts it: "I REM, therefore I will be". According to Hobson & Friston (2012), *predictive coding* is an underlying mechanism in the brain that produces predictive simulations of the world. Therefore, dreaming may also function as a preparatory simulation of the waking world; thus their idea is closely related to the other simulation-theories of dreaming (Hobson & Friston 2012).

In conclusion, while there still are disagreements about many details of dream content and function, there seems to be relatively widespread agreement that the definition of dreaming includes the idea of "simulation" of the waking world. The use of the concept of "simulation" to characterize dreaming has recently gained wide acceptance in the field. The simulation is variously characterized as the simulation of waking life, of waking reality, or of waking consciousness, and variously called by different authors a realistic world-simulation, a virtual reality, an immersive spatiotemporal model of the world, and so on—but despite the somewhat varying terminology, the different terms seem to describe the same basic idea. This conceptual unification is a significant step forward in the theoretical description and explanation of dreams. It paves the way for a more unified theory of dreaming.

4 The simulation of social reality in dreams

Dreaming not only places us into an immersive (virtual) physical reality, but also immerses us into a (virtual) *social* reality: in dreams we are surrounded by close friends and family members, schoolmates, teachers and students, spouses, romantic partners, old crushes, colleagues and bosses, celebrities, politicians, acquaintances, strangers, and mobs as well as monsters and other fictitious characters from movies and video games. All are there in dream simulation with us as simulated characters—avatars—and we interact with these avatars in multiple ways: we perceive, recognize, and semantically classify them, we communicate and talk with them, we collaborate with them, help them, criticize them, fight them, escape them, fear them, and love them. At least intuitively, there is no doubt that in our dreams, we live rich and colourful social lives, even if only simulated ones.

If dreaming in general can be defined as a simulated world, the question arises whether the concept of "simulation" can also be usefully applied to describe the social reality of dreams. The first task for a theory that takes the concept of simulation seriously is to simply *describe* the social contents of dreams as simula-

tions of human social reality. The descriptive questions can be formulated in more detail along the following lines:

1. What kind of social perception, social interaction, and social behaviours are simulated in dreams?
2. How frequently are different kinds of social perception, interaction, and behaviour simulated in dreams? How much variation is there in the frequency of different social simulations as a function of gender, age, culture, and as a function of the quality and quantity of social interactions during waking life?

It is possible to find answers to many of the above descriptive questions from the already-existing dream research literature where various aspects of the social contents of dreams have been reported, even if they have not been conceptualized as social simulations. In what follows, we will first briefly review some of the major findings in the literature that describe the quality and the quantity of social simulation in dreams. Once we have detailed empirical descriptions of the quality and quantity of social simulations in dreams, we may seek explanatory theories and testable hypotheses that could account for why we have social simulation in dreams.

4.1 Evidence for simulation of social perception in dreams

From the already existing literature, it is possible to find statistics that describe the quality and quantity of social simulations in dreams. However, the theoretical concept of "social simulation" is rarely used in dream research literature for interpreting the descriptive results. Here, we will briefly summarize only some of the major findings.

The minimal criterion for a dream to count as a social simulation is that the Dream Self is not alone in the dream but in the presence of at least some other animate character or characters. In less than 5% of dreams is the dreamer alone (Domhoff 1996); thus, on this minimal criterion, dreaming seems to consistently simulate social reality. The other animate characters simulated in dreams are predominantly human (normative finding in adults is about 95% human, 5% animal), but the proportion of animal characters varies in different cultures and age groups, being highest (up to 30–40%) in young children and in adults in hunter-gatherer societies (Domhoff 1996; Revonsuo 2000). As human characters are reported in almost all dreams, and typically there are two to four non-self characters in a dream (Nielsen & Lara-Carrasco 2007), the presence of simulated human characters must be perceptually detected and registered in the dream by the dreamer. Thus, during dreaming, *our neurocognitive mechanisms constantly simulate social perception.*

The minimal form of social perception is to *detect or register the presence* of some human character. A more sophisticated form is the perceptual *recognition* and *identification* of the human characters who are present, first in terms of some basic perceptual and semantic categories (male/female; familiar/stranger), and then in terms of more detailed semantic and autobiographical information about the precise identity and name of the person. According to the Hall and Van de Castle norms, about 90% of simulated human characters have sufficiently definite characteristics to be semantically categorized, for example as male or female, or as familiar or unfamiliar (Domhoff 1996). Thus, social recognition and identification mechanisms are highly engaged in almost all cases of social perception in dreams. The dreamer knows, both during the dream and afterwards when reporting it, whether the simulated characters present in the dream are (or were) male or female, familiar or strange, friend or family; and in most cases, the familiar characters are identified as particular persons from real life.

Typically, a slight majority of dream characters are avatars for familiar persons, although there are well-established gender differences (Domhoff 1996) that might, however, partly depend on the gender distribution encountered in the real-world social environment (Paul & Schredl 2012). In a sample of five hundred REM dreams (Strauch & Meier 1996) familiar people

(friends, acquaintances, and relatives) were simulated most frequently (44% of all characters), strangers represented about 25% of dream characters, and undefined people about 19%. In most dreams, both familiar and unfamiliar people were simulated, but in 30% only strangers and in 20% only familiar people appeared. The mixture of familiar and unfamiliar people was true also at the individual level—there were no participants who would have simulated only strangers or only familiar people in their dreams.

For the most part, the human avatars in the dream world are quite *realistic* simulations of their waking counterparts. The degree of realism, however, is difficult to express with accuracy by any single measure or quantity, as there are several features of human characters that may independently vary along the dimension of realism (Revonsuo & Tarkko 2002). The opposite pole for realism is called *bizarreness,* which in dream research refers to deviation from the corresponding entity in waking life.

If any kind and degree of deviation from a waking counterpart is counted as a bizarre feature of a simulated person, then over half of the simulated humans in dreams (over 60% according to Kahn et al. 2002; 53% according to Revonsuo & Tarkko 2002) are not perfectly realistic simulations. In contrast to other dream characters the Dream Self is rarely distorted in any way (Revonsuo & Salmivalli 1995). Revonsuo & Tarkko (2002) also found that in the vast majority of cases (around 90% of dream characters), non-self dream characters are *perceptually* entirely realistic—they *look* the same as their counterparts look in real life. Where they deviate from their counterparts is most often their verbal and nonverbal behaviour. Thus, although the perceptual simulation of human characters is nearly flawless in dreams, the simulation of expected or predicted *behaviours* deviate from waking norms relatively often, though still at least a slight majority of behaviours by dream characters are no different from waking life.

Dream characters are also spatially and temporally quite stable and continuous within the dream, although transformations and discontinuities sometimes do happen (Nielsen & Lara-Carrasco 2007). A simulated person sometimes appears from nowhere, is magically transformed into someone else, or suddenly disappears without a trace. But these kind of discontinuous features account for less than 5% of dream character features (Revonsuo & Salmivalli 1995; see also Revonsuo & Tarkko 2002).

By contrast, the behaviours expressed by dream characters are relatively often to some extent odd or unpredictable. Thus, the simulated social reality in dreams is *less predictable* than the corresponding social reality during wakefulness. However, it is unclear how this unpredictability should be interpreted: does it simply reflect the difficulty (and consequently failure) of simulating complex human behaviours and interactions realistically by the dreaming brain, or is there some other more functional explanation as to why the avatars in our dreams tend to behave in more erratic ways compared to their waking-life counterparts? We will come back to this question when we consider the possible functions of social simulation in dreams.

4.2 Evidence for simulation of social interactions in dreams

The Dream Self and other dream characters are simulated in almost all dreams, but how often are they engaged in mutual social interactions? According to Strauch & Meier's (1996) data (140 REM dreams in which a Dream Self was present and had an active role), in nearly 50% of these dreams the Dream Self and characters interacted, in an additional 20% they acted together, and in 20% they acted independently of each other. In the rest, the Dream Self acted alone. Thus, social interaction or acting together is typically simulated in dreams where the Dream Self is present together with some other dream characters. When social interaction takes place, there is almost always verbal communication or conversation between the Dream Self and the other characters, which tends to be focused on concrete topics (Strauch & Meier 1996), and it is understandable and something that would be sayable in waking life (Heynick 1993).

The more detailed nature of social interactions has typically been categorized in terms of "friendly" and "aggressive" interactions. Friendly interactions are on average found in about 40% of dreams, whereas aggressive interactions are somewhat more common, and occur in about 45% of dreams in a normative sample (Domhoff 1996). Strauch and Meier, however, point out that in their sample, neutral interactions were also common, and only about half of the social interactions in their sample could be classified as particularly friendly or aggressive. The third category of social interactions that has typically been quantified in dream reports is sexual interactions, but they occur at a very low frequency—in Strauch & Meier's (1996) laboratory data, in less than 1% of REM dreams, and in the normative Hall and Van de Castle (Domhoff 1996) data, in 4% of women's and in 12% of men's dreams collected in a home setting.

In sum, the simulation of dream characters occurs very frequently, the characters are perceived and recognized by the Dream Self, and the Dream Self actively participates in communication, social interaction, and joint actions with the characters. The simulated characters are also for the most part realistic, stable, and represent a variety of different kinds of people. Their behaviours, however, may sometimes be unusual or inappropriate, and not exactly what we would have expected from their counterparts in real life. The tone of the interactions may be neutral, friendly, or aggressive.

When this evidence is taken together, we may conclude that dreaming simulates a rich, variable, realistic, and concrete, but somewhat unpredictable social reality, inhabited by a mixture of familiar, unfamiliar, and undefined people. Therefore, we have solid grounds to state that dreaming *is*, among other things, definitely a social simulation. If this is a universal and ubiquitous feature of dreaming, what kind of theory could explain it? *Why* does dreaming simulate social reality at all? It is by no means self-evident that this should be the case. Dreaming could as well be only a simulation of some basic features of the physical world: space, time, objects, events, and the perception of and bodily interaction with the physical world. Or it could be a simulation of thought processes, a thinking-through of our problems, or of our emotional states and concerns. Moreover, simulation of physical objects and their behaviour, or a replay of thinking and emotions, would probably be a simpler task for the brain than the simulation of a complex social world. Simulation of human bodies and faces and interactive behaviours such as conversations seems to require a lot of energy and computing power—these are very complex phenomena to simulate realistically. Thus, *why* does the sleeping brain simulate social situations in such an intense and invariant manner? Is there any convincing theoretical answer to be found to this question?

5 The continuity hypothesis and social simulation theories of dreaming

There are, of course, countless theories of dreaming. Some have explicitly considered the role of social interactions in dreams, while others make more general statements about dream content. One of the latter is the Continuity Hypothesis (CH), which states that dreams *reflect* waking life experiences (Schredl & Hofmann 2003) or, more specifically, that our waking concerns, thoughts, and experiences have a *causal influence* on subsequent dream content. Thus, if certain types of social contacts or interactions become more frequent (or less frequent) in waking life, their simulation in dreams becomes correspondingly more (or less) frequent.

This general principle seems to hold in many cases. For example, in hunter-gatherer societies, where people perceive and interact with wild animals on a daily basis, the proportion of animal characters remains high (as it is in children's dreams across cultures), whereas in highly industrialized societies, the animal percentage decreases dramatically from childhood to adulthood. But the CH merely restates this empirical relationship; it cannot answer the theoretical question of *why* in young children's dreams the proportion of animal characters *is high to begin with*. TST (Revonsuo 2000) has attempted to answer this question by referring not to personal experiences in waking life, but to a universal bias that is built into the default

values of dream content during human evolutionary history.

The CH, even if on the right track in many cases, is too vague and general as a theoretical explanation of the details of dream content. It does not predict in any detail how and why the causal relationship between waking and dreaming works. It also does not specify in any detail what counts as a "continuity" and what would count as a "discontinuity" between waking life experiences and dream simulations of the same. If something happens in waking life *how closely similar* will the dream simulation be to its waking origin, *when* will the same (or a similar) content appear in dreams, *how frequently and for how long* will it be incorporated into dreams, and so on? These questions have been studied under the concepts of day residue (Freud 1950) and the dream lag effect (Nielsen & Powell 1989). The CH takes almost any similarity between waking life and dream life as a confirmation of the continuity hypothesis. But "similarity" as a relationship between two phenomena is undefined, ambiguous, and vague. Something that in one respect is similar to its waking counterpart is in another respect dissimilar from it; thus it can be interpreted as either continuous or as discontinuous with waking life. Obviously, if the very same evidence could be counted as either supporting or disconfirming a theory, there is something wrong with how the theory is formulated.[2]

As long as the CH remains vaguely formulated, almost anything can be counted as its support. If the hypothesis does not specify in any detail the potential empirical observations after which its predictions would be falsified, it is not an empirically testable theory. Unless it is formulated in a much more specific manner, so that risky, exact predictions can be derived from it, its explanatory power remains correspondingly weak. In one study where more precise predictions from CH were derived, the CH was found not to be valid as a general rule concerning how often different everyday activities are reflected in dreams (Schredl & Hofmann 2003).

2 For a recent exchange, see Hobson & Schredl (2011) and related commentaries in the International Journal of Dream Research (2011, vol. 4).

Perhaps a more precise prediction that could be derived from CH can be formulated in the following way: according to CH, dreams represent a random sample of recent waking experiences (or a random sample of their memory representations). The quantities of different types of contents in dreams will therefore passively reflect the proportion of their occurrence in waking life in the recent past (or the memory representations of waking life). If CH is formulated in this manner, as a prediction of random sampling and passive mirroring of recent waking life, then any systematic deviation from a random sample of waking contents (or memories thereof) would count as evidence against the CH. A deviation from passive mirroring of waking life would suggest that some kind of *selective* mechanism is at work. An *active selection* bias of particular contents to be either included in dreams or to be left out would be expected to result in a disproportionately exaggerated or diminished frequency of that content in dreams as compared with waking life. This kind of formulation of the predictions of CH makes it a testable theory.

Some more specific suggestions about dreaming as social simulation have been put forward in the literature. Brereton's (2000) Social Mapping Hypothesis suggests that dreaming simulates, among other things, the awareness of other persons (social perception) and their internal mental states (mentalizing or theory of mind-abilities). This theory proceeds from an evolutionary standpoint, and considers dreaming as a rehearsal ground for emotional and perceptual abilities related to the mapping of the body image of the self into an emotionally-salient social space. Others have also hypothesized that our mindreading abilities could potentially be a target of simulated social perception in dreams (Kahn & Hobson 2005; McNamara et al. 2007). Moreover, Nielsen & Germain (2000) have suggested that dreaming might simulate attachment relationships and interpersonal bonds in ways that would maintain their adaptive significance even today, and Humphrey (2000) has compared the social functions of dreaming to those of play. The possibility that dreaming simulates pro-social and ag-

gressive social interactions in distinct sleep stages, and that these simulations might exert a regulatory influence on our waking social lives, was put forward by McNamara et al. (2005). Last, Franklin & Zyphur (2005) have considered how the simulation function of dreams might be expanded to cover social cognition and complex socio-cultural situations.[3]

The problem with the above social simulation theories of dreaming is that either they are not detailed enough to be testable, or that few, if any, have ever been directly tested against competing theories. They are interesting general ideas, but not strictly formulated theories that could be directly tested, or from which detailed predictions and potential explanations for the social contents of dreaming could be derived. Thus, these theoretical ideas have not led to a strong empirical, hypothesis-driven research program that would be able to systematically test the plausibility of these theories.

Whenever we formulate theories of dreaming, or of the functions of dreaming, they should be formulated in such detail that *empirically testable predictions* can be derived from them. Statements that are too vague or too general (e.g., "dreams are continuous with waking life"; "dreams are social simulations") are difficult to test as such. The predictions derived from general statements are too unspecific. Thus, the theories remain uninformative but of course consistent with almost anything we might realistically expect to find in dream content. If a theory makes no detailed, risky predictions about what should or should not be found in dream content (under some specific circumstances or in specific populations) it doesn't have much explanatory power, either. So far there is no detailed, convincing, testable theory of the nature and the function(s) of social simulations during dreaming. There is also a lack of data on the detailed quantity and quality of simulated social interactions in dreams, and how they relate to real social interactions in the waking life of the same person. In the rest of this paper, we will try to outline ideas for the theoretical basis of a social simulation theory of dreaming and to formulate some empirically-testable hypotheses directly derived from the theory.

6 Towards a testable social simulation theory of dreaming

The relatively loose idea or the general observation that dreams are social simulations needs to be turned into a theory from which testable predictions can be derived. There are several ways in which this could be done. In the rest of this paper, we will formulate some suggestions towards that end. The basic assumptions that we adopt are based on the earlier work on the definition of dreaming (and consciousness) as an internal world-simulation in general (Revonsuo 2006). Any plausible theory of social simulation should also take into consideration, and draw from, concepts and advances in the fields of social psychology and evolutionary biology, in order to create a credible theoretical context into which social simulations in dreams can be placed. We will therefore connect the idea that dreaming may function as a platform for simulating social perception and interactions to some influential evolutionary biological and social psychological theories, as well as to the earlier simulation theory of the original evolutionary function of dreaming, the TST (Revonsuo 2000).

The two generally-accepted theories in evolutionary biology that seem to be relevant for the formulation of an evolutionary SST of dreaming are the Inclusive Fitness and Kin Selection Theory (Hamilton 1964) and Reciprocal Altruism Theory (Trivers 1971). Both are general evolutionary biological theories that apply not only to humans, but to multiple other species as well. Further, both have received ample empirical support from animal and human stud-

3 Another popular theory of dreaming postulates that the realistic simulation of character–self interactions serves the function of *emotion regulation* during dreaming (Nielsen & Lara-Carrasco 2007). In this group of theories, the function of dreaming is proposed to be the calming down of emotional surges, such as we see in psychotherapy (Hartmann 1995, 1996, 1998), or as reflecting the extinguishing of fear memories (Nielsen & Levin 2007). It is increasingly apparent that sleep plays a role in the consolidation of emotional memories, but whether sleep also *regulates* the emotional charge and valence of memories is not yet entirely clear (for a recent review, see Deliens et al. 2014). Thus, whether the emotional regulation theory has specific implications or predictions for social simulations in dreaming is not evident.

ies, and could thus serve as solid ground in guiding our thinking about social behaviours in evolutionary biological terms.

The Inclusive Fitness Theory (Hamilton 1964) postulates that an individual's genetic reproductive success is the sum of that individual's direct reproduction and the reproduction of the individuals carrying identical gene alleles. An individual can improve its overall genetic success by engaging in altruistic social behaviour that is directed towards individuals carrying identical alleles. The Kin Selection Theory is a more specific form of the inclusive fitness theory, which requires that the shared alleles are identical by descent. Thus, Kin Selection Theory postulates that an individual can increase its inclusive fitness by directing acts of altruism specifically towards genetic relatives, whereas inclusive fitness as such is not limited only to cases where kin are involved. Both, however, predict that acts of altruism should more often be directed towards individuals who share identical alleles.

Reciprocal Altruism (Trivers 1971) is defined as behaviour whereby an individual acts in such a way that temporarily reduces its fitness while increasing another individual's fitness. However, individuals engage in altruistic behaviour with the expectation that the recipient of the altruistic act will act in a similar manner at a later time. A strategy of mutual cooperation may be favoured when there are repeated encounters between the same individuals. Although cheating might be more beneficial for the individual in terms of immediate rewards, co-operation might provide net gain compared to short-term benefits.

Since selection pressures act on the typical conditions present in the history of any species, consideration of the demographics of the typical evolutionary environment of humans is crucial for understanding the evolution of social behaviours in our species. Recently, Hill et al. (2011) analyzed co-residence patterns among thirty-two present-day foraging societies, assuming that these might reflect an ancestral human group structure. They found that primary and distant kin of an adult individual accounted for approximately 25% of the co-resident adult members of a band, i.e., about 25% of adult members in the group were directly genetically related, whereas about half of the adults were related through spouse or siblings' spouses, and the other 25% of adults were genetically unrelated.

If we accept the assumption that this observed distribution of relatedness approximates the degree of relatedness in ancestral human bands, there have been ample opportunities for ancestral humans to be subjected to selection pressures that could be explained using strategies postulated by the inclusive fitness and Kin Selection Theory, as well as Reciprocal Altruism Theory. There is ample evidence that people are more likely to help their relatives than genetically unrelated individuals (e.g., Burnstein et al. 1994), and that lethal violence is more frequently directed towards genetically-unrelated individuals than relatives (Daly & Wilson 1988). People also tend to be more altruistic towards other people in single round prisoner's dilemma game than could be expected (Frank et al. 1993) in order to protect their reputations. This seems to be a reasonable course of action, given that the faces of individuals labelled as untrustworthy cheaters are better recalled than those labelled as cooperative (Mealey et al. 1996). There are also rather large interindividual differences in altruistic behaviour, depending on factors such as age, sex, tendency to empathize, and circumstantial conditions.

The social environment has afflicted strong selection pressures on human cognitive faculties, and there are several theories that consider our essentially social nature. Dunbar (1992, 2008) has forwarded the Social Brain Hypothesis, which states that the main factor in the increase of our neocortical volume has been the cognitive demand bestowed on us by the increase in hominid group size. Sutcliffe et al. (2012) propose the idea that the costs and benefits of social interactions have been a critical driver for cognitive evolution. While our most intimate relationships are a source of social support, they are also the most costly as the quality of these relationships is dependent on the time invested in creating and maintaining them

over time. Forming weaker and less time-consuming ties with acquaintances can provide benefits such as information exchange and access to resources without exhausting an individual's resources that are allocated for social interaction. Our individual social worlds thus consist of hierarchically-layered sets of relationships defined by relationship intimacy, and different relationship types are designed to have different kinds of functions.

Turning our attention to the potentially relevant literature in social psychology, some further concepts and measures might be considered useful for dream theory. When it comes to the simulation of social interaction, one of the most relevant concepts is the social "Need to Belong" (Baumeister & Leary 1995). This fundamental motive towards interpersonal attachment and close, supportive social bonds pervades and influences our actions, emotions, and cognitions, and is fulfilled only by social affiliation and acceptance. To help us navigate the complex social world, and attune us to socially relevant information, two further advancements have been hypothesized in the form of the Sociometer Theory (Leary et al. 1995) and the social monitoring system (Gardner et al. 2000). Sociometer Theory proposes an internal monitoring device that feeds forward information about our level of social inclusion in the form of self-esteem or self-worth (Leary et al. 1998), whereas the social monitoring system is purported to guide the processing of social information whenever people's needs to belong are not being met (Pickett et al. 2004). In sum, the concept of "Need to Belong" in general, and the suggested social monitoring systems in particular, might prove useful in postulating testable hypotheses for the functions of social simulation in dreams. The Sociometer, for example, might act in a similar fashion to the threat cues postulated in TST, and prompt dreams to simulate relevant social skills or interactions.

An interesting developmental suggestion about the interplay between simulation mechanisms and social deficits has recently been put forward by Oberman & Ramachandran (2007), who propose that in typically developing individuals the abilities of Theory-of-Mind (ToM), empathy, perceptual recognition, and motor mimicry might be mediated by an internal simulation mechanism or mechanisms. By taking into consideration a condition—autism—where all these abilities appear to be impaired, they make the case for a possible link between deficient simulation mechanisms and behavioural and social deficits. The exact implications of this idea for the hypothesis that dreams serve a social simulation function requires further consideration. One possibility is to test whether individuals with Autism Spectrum Disorders (ASD) dream less of social interactions, or whether their dreams of social interactions are different in content from those of other people. Thus far this line of research has not been explored in depth. Daoust et al. (2008) have looked into the dream contents of people with ASD, and found that they report significantly less dream-characters and social interactions than the control group. They note, however, possible error sources in the testing procedure, such as, for example, how the reporting of dreams itself might be affected by ASD.

There has been some research linking the effects of attachment relationships to dreaming. If, as attachment theory proposes, we use our early experiences with primary caregivers and other attachment figures as model states for future social interactions and the way we view and attune to our social world, it could be assumed that this would also affect our simulations of this world. Early attachment and bonding are, after all, quintessential for our species, and according to Fonagy & Target (1997) might also work as the basis for our abilities to mentalize or to create a ToM. McNamara (1996) has developed the idea that REM sleep is the mechanism that activates and maintains early attachment relations, as well as pair-bonding in later life. Selterman & Drigotas (2009) have found that attachment style is correlated to dream emotions when dreaming about romantic partners, so that those with anxious or avoidant attachment styles reported more stress, conflict, and negative emotions.

In an exploratory study on the dream contents of those suffering from Complicated Grief

(CG) after the loss of an attachment figure, Germain et al. (2013) found the dreams containing family members to become significantly more frequent, while there was no marked increase in the occurrence of deceased characters. Males suffering from CG also reported more familiar persons in their dreams than the control group. Both male and female CG patients also exhibited fewer negative emotions and fewer instances of aggression in their dreams, and females also had decreased amounts of positive emotions and friendliness.

We can thus conclude that the inherently social nature of our species is deeply ingrained, and has likely been as important for our survival in the ancestral environment as threat perception and avoidance skills. SST can therefore be formulated in an analogous manner to TST, but in addition to the evolutionary background theory, also taking into consideration important social functions such as the need to belong, social bonding, social networking, and social support as essential ingredients.

TST (Revonsuo 2000) places the contents and the function of dreaming in an evolutionary-psychological context and proposes that dreams were selected for their ability and propensity to simulate threatening events in a safe way, thus preparing the individual to survive real-life dangers. The hypotheses and predictions of the TST, especially concerning the inclusion of threat simulations in dream content, have gained support from several independent sources, such as studies on the content of nightmares and bad dreams (e.g., Robert & Zadra 2014), recurrent dreams (Valli & Revonsuo 2006; Zadra et al. 2006), post-traumatic dreams in children and adults (Bulkeley & Kahan 2008; Valli et al. 2006), dreams anticipating a stressful experience (Arnulf et al. 2014), children's earliest dreams (Bulkeley et al. 2005), dreams and mental contents in parasomnias (Uguccioni et al. 2013), the dreams and nightmares of new mothers (which mostly depict the infant in peril and trigger protective behaviours, Lara-Carrasco et al. 2013, 2014; Nielsen & Lara-Carrasco 2007), as well as dreams of the general population (for a review, Valli & Revonsuo 2009).

Thus, when it comes to emotionally negatively-charged dream contents that simulate some sort of dangerous situation or unfortunate event, the TST seems able to quite well predict and explain many features of the quantity and the quality of the threat simulations found in the data. Therefore, a similar theoretical approach might also prove fruitful in the case of social simulation theory. The SST, however, needs to be formulated in such a manner that its predictions can be clearly distinguished from those of the TST.

As negative and threatening events commonly occur in dreams, the TST alone already covers a fairly large proportion of dream content. But it also ignores a relatively large proportion of dream content, as it does not offer any explanation of non-threatening dreams or for the simulation of neutral and positive events in dreams. This raises the question: do types of dream events other than those that are threatening have some evolutionarily-based simulation function, independent of the threat-simulation function of dreaming? Are there events that are equally important targets for simulation as the negative, threatening situations simulated in threat simulation dreams?

TST covers threatening events in dreams, whether social in nature or not. Many threatening events of course do involve social interaction (such as verbal or physical aggression), but are explained by the TST as primarily simulations of specific types of threat, and therefore as rehearsals of threat perception and threat-avoidance behaviours, rather than as simulations of social interactions as such. A social simulation theory that explains dreams that TST does not cover should thus focus on social simulations that are largely independent of the threat-simulation function. In some dreams these two types of simulation may, however, be difficult to tease apart. For example, a social simulation theory might account for some social interactions that happen during a threatening event in a dream, such as how the Dream Self interacts with others and collaborates with them during a threatening situation. Furthermore, these two simulation theories may not be mutually exclusive but instead complement each other. Some specific

types of simulations of negative social interactions are better accounted for by the TST while other, positively toned simulations can be explained by the SST. For example, from an evolutionary perspective it might make sense to simulate different kinds of interactions, friendly or aggressive, with people belonging to different layers of our social hierarchy.

We are open to the possibility that social simulation is an original evolutionary function of dreams alongside the threat-simulation function of dreaming. We believe that social simulation theories hold much promise. But before this belief can be empirically justified, a testable version of the social simulation theory needs to be formulated. Such a theory should independently cover the social simulations in dreams that fall outside the scope of the TST.

Furthermore, also the predictions of the CH must be distinguished and separated from those of the SST. Therefore, the question becomes: What aspects of human social reality might dreams be specialized in simulating in such a way that these social simulations have significant consequences for cognition and behaviour during the waking state, and in virtue of which social simulations during dreaming have fulfilled important functions in the evolutionary history of the human species? What kind of social-cognitive processes and behavioural social skills might have been both critical enough both for an individual's survival and successful reproduction, as well as occurring frequently and universally enough in the human ancestral environment, to be selected for as a universal feature of human dreaming? Moreover, those processes and skills would have to be something that in fact *can* be regularly simulated by the dreaming brain, and they have to be contents that actually *are* being simulated frequently and universally in human dreaming, according to the evidence from content analysis studies of dreaming.

To sum up, a credible version of the SST should have predictions and explanations that are clearly different from both the TST and the CH. To be different from TST, the SST should predict and explain the social simulations that happen outside threatening events in dreams, and to be different from the CH, the SST should predict that some types of social stimuli, social cognition, or social behaviours are simulated actively and selectively, so that they are overrepresented in dreams as compared to waking life.

We will first consider some basic cognitive processes that might fulfil these roles and will then proceed to more complex social behaviours and interactions. We admit that many of these ideas are at this stage speculative. But if it is possible to formulate them in an empirically testable manner, then we can figure out later on which ideas remain mere empirically unsupported speculations, and which ones might actually predict and explain central aspects of our dream content.

6.1 The simulation of social perception as a function of dreaming

Overall, there are good reasons to support the view that fast and errorless social perception abilities were universally important skills for humans during their evolutionary history, and, therefore, rehearsing them through dream simulations would have served to maintain and enhance their speed and accuracy during wakefulness. In the ancestral environment, fast and efficient social perception and recognition mechanisms were essential for telling friends and allies apart from potential enemies. Thus, detecting the presence of other human beings in the same spatiotemporal context where oneself is located, immediately classifying them in terms of familiarity, identity, and history of past interactions with them, and predicting the nature of future encounters with them must have been an important survival skill. Perhaps it was important enough that rehearsal of these social-cognitive functions through social simulations during dreaming would have increased an individual's inclusive fitness.

The social perception system needs to quickly estimate answers to the following questions: *am I alone in here or are there other humans present? Are the other humans around me familiar to me or are they strangers?* Thus, the first stage of social perception is to detect other humans in the vicinity and to classify them in

terms of unfamiliar people (strangers) vs. familiar people. As Diamond (2012) explains in "The World Until Yesterday", in most traditional societies during human evolutionary history, to encounter strangers was unusual and typically considered potentially dangerous, because the social interaction that followed might not necessarily have been peaceful in nature.

The second stage of social perception deals in more detail with the familiar people that are detected. If the people in my presence are familiar to me, who exactly are they? What is my relationship with them? What have my past interactions with them been like? What should I expect the interaction between us to be like this time around? To answer these questions, familiar people need to be quickly identified. Based on semantic and autobiographical memory information that we have about people familiar to us, we quickly activate expectations and strategies as to how we should interact with the people around us in the most constructive way.

But so far this idea is mere speculation. What kind of *testable hypotheses and predictions* could be derived from this theory? How could we derive predictions that clearly distinguish the SST from the CH? The CH does not attribute any evolutionary simulation functions to dream content; according to CH, dreaming simply and passively *mirrors* whatever experiences have recently been encountered in the dreamer's waking life (and thus impressed on long-term memory). Obviously, therefore, it would not lend sufficient (or specific) support to the SST to predict that social perception should be found in dreams in the same proportions as in waking life, because the CH predicts and explains exactly the same observation and, moreover, does it more parsimoniously, without postulating any just-so-story of evolutionary *functions* to social dream content.

The SST must thus go beyond the CH and make the risky prediction that, if social perception is the original evolutionary function of dreaming and it is therefore still expressed in our dream contents, then dreams are *specialized* in simulating social perception. If dreams are specialized in simulating social perception, then perceptual contents, cognitive processes, and behaviours relating to social perception skills should occur (as simulations) in a selective or *exaggerated* form in our dreams. The testable prediction derived from this is that during dreaming, social perception occurs *more frequently* than in waking life (shows quantitatively an increased frequency) and/or qualitatively in a more difficult or challenging form than in waking life.

Quantitatively, dream simulations could exaggerate the proportion of the types of stimuli that were most important to recognize quickly and accurately during evolutionary history (e.g., strangers vs. familiar people; enemies vs. friends). It is important to process this information quickly because the information had high survival value in ancestral environments. Furthermore, dream simulations could present qualitatively challenging stimuli for the social perception system; for example, more variety of different kinds of stimuli (different kinds of familiar and unfamiliar simulated people), or ambiguous stimuli that are more difficult to perceive or interpret than real life stimuli (vague or unstable simulations of people).

Conversely, if the social stimuli in dreams simply mirror the social stimuli during wakefulness (and memory representations of them), quantitatively and qualitatively, then the CH gains support: dream experiences merely *copy* the patterns and rates of social stimulation encountered during wakefulness, but do not *selectively* and *actively* simulate them in ways and proportions that would reflect some original evolutionary functions and would therefore have supported important survival skills in ancestral environments.

To test these two opposing theories, SST and CH, against each other empirically, we need detailed information not only about the quantity and quality of social perception in dreams, but also about the quantity and quality of social perception during wakefulness in the same subjects' lives during the same period of their lives. Some studies already exist that provide us with this kind of data, but most of the hypotheses remain to be tested in future studies that should be explicitly designed to test the opposing hypotheses and predictions of the two theories.

McNamara et al. (2005) conducted an interesting study that can be interpreted as testing the SST prediction that social perception is quantitatively exaggerated in dreams as compared to waking life. They conducted experience sampling from fifteen individuals over two weeks across waking, REM sleep, and Non-Rapid Eye-Movement (NREM) sleep states. The participants recorded verbal reports of their perceptual and other experiences when paged at random intervals during sleep or wakefulness.

The results showed that *more characters appeared in dreams than in wake reports*. Unfortunately McNamara et al. (2005) do not report the exact descriptive statistics of this finding, so we do not know how large this difference exactly was. In any case, this finding is better in accordance with the predictions of the SST than CH: Stimuli requiring social perception (human characters) are present at higher frequencies during dreaming than during wakefulness, when experiences from both states are sampled and reported in a similar manner.

This important finding suggests that the basic processes and skills required in social perception are more engaged during dreaming than during an equal stretch of time in wakefulness. This lends support to the hypothesis that *dreaming is specialized in the simulation and rehearsal of social perception*, which may thus be one of the original evolutionary functions of dreaming. It has to be added, however, that McNamara et al. (2005) is the only study so far that provides us with this kind of data, where the frequencies of the social contents of dreaming and waking experiences have been directly compared with each other. Replications are obviously required in different populations and in larger samples of dreams and waking experiences. But so far, so good for SST.

The same study can be taken to test the additional prediction of SST, namely that dream simulations of human characters should exaggerate the proportion of the particular types of stimuli that were, during evolutionary history, most important to recognize quickly. Meeting strangers posed a threat in the original evolutionary context; thus, the SST predicts that *strangers or unfamiliar people should be overrepresented in dreams as compared to waking life*, to simulate and rehearse the type of perceptual categorization (familiar vs. unfamiliar) that was most important in the evolutionary context. McNamara et al. (2005) report that the proportion of strangers (or unfamiliar people) encountered in dreams is indeed significantly higher than in waking life. Only 25% of people present in the waking episodes were unfamiliar, whereas about 50% of the (simulated) people in dreams were unfamiliar. Again, this discrepant pattern is well predicted by and accounted for by the SST, but goes against the predictions of the CH.

The recognition and identification of familiar people as who exactly they are could also potentially be a target of useful simulation in dreams. It might be argued from SST that quick and correct recognition of familiar people enhances the quick selection of the appropriate social strategies and behaviours when we interact with them. As about 50% of simulated people in dreams are familiar, there are still plenty of opportunities to rehearse these recognition skills. There are, however, no studies that would have directly and quantitatively compared the frequency of face recognition during dreaming and wakefulness. But still, there are some studies that question whether face recognition is engaged during dreaming and to what extent.

Kahn et al. (2002) report, in a character recognition study, that about 45% of familiar dream characters were recognized through their appearance (including facial features), and an additional 12% by their observable behaviour. Thus, nearly 60% of dream characters are recognized perceptually. However, about another 12% of dream characters are recognized intuitively, by "just knowing" who they are, which suggests that in those cases, the "recognition" happens in a top-down manner and is therefore independent of the perceptual and facial features of the dream character.

If familiar persons are *not* overrepresented in dreams to begin with (as the McNamara et al. 2005 study suggests), and only well *under 50% of the familiar people simulated in dreams*

are recognized through their facial features, this pattern of data does *not* particularly support the idea that dreams are specialized in rehearsing familiar face recognition. However, we still lack knowledge about the frequency of face recognition in waking vs. dreaming, and only a study directly making that comparison could properly test this idea. So, the case remains open, but the expectations are not particularly high that this prediction of the SST will gain strong support in the future.

6.2 The simulation of mindreading as a function of dreaming

In addition to the processing of familiarity and identity, another aspect of social perception is called Theory-of-Mind (ToM) or "mindreading". This refers to the interpretations we automatically make about the internal mental states of the people around us. We not only categorize the people around us as familiar and unfamiliar, and assign an identity to familiar persons, we also attribute thoughts, beliefs, motives, and emotions to them. As mindreading is crucial for our ability to predict and explain other people's behaviours, our mindreading abilities could potentially have been a target of simulation during simulated social perception in dreams (Kahn & Hobson 2005; McNamara et al. 2007).

The study by Kahn & Hobson (2005) quantifies the frequency of mindreading activities in dreams. In one sample of thirty-five participants and about nine dream reports per participant, about four dream characters per report were observed on average. In over 80% of these dreams, the participants reported having had engaged in mindreading (at least one of) the other dream characters' internal mental states. In another sample, 24 subjects reported on average six dreams per participant. Each dream was divided into separate dream events (on average four events per report were found), and the participants were asked to report, concerning each event, whether or not they were engaged in mindreading the other dream characters. In 50% of the episodes, mindreading was reported to have occurred. Thus, on the basis of these results, we may say that mindreading frequently occurs during dreaming. Kahn & Hobson (2005) in fact suggest that this may be evidence for a specific simulation function being at work:

> The two studies undertaken here support the idea that dreaming may provide a simulation of waking life as suggested by Revonsuo (2000), though not restricted to only threatening events. Instead, the data of these studies suggest that if dreaming is a simulation process, it is a simulation that provides a way of knowing and dealing with the intentions of others, both positive and negative. (p. 56)

The above studies show that mindreading is well represented in dreams, but they cannot tell us whether mindreading is *overrepresented* in dreams, as its frequency of occurrence cannot be directly compared to waking life. However, McNamara et al. (2007) have conducted a direct comparison of the frequency of mindreading between waking experiences, REM dreams, and NREM dreams of the same subjects. This is what they found:

> REM reports were three times as likely to contain instances of mind-reading as were wake reports and 1.3 times as likely as NREM reports. Of 100 reports per state, there were 39 instances of mind-reading in REM reports, 29 in NREM reports, and 12 in wake reports. (McNamara et al. 2007, p. 211)

In conclusion, from looking at these studies, we may say that mindreading activities frequently occur in dreams, and that their frequency of occurrence is significantly greater during dreaming than during wakefulness: Mindreading is overrepresented or exaggerated during dreaming. Thus, this data *supports the* SST *prediction that dreaming specifically simulates mindreading* in order to maintain and rehearse our mindreading abilities, rather than the CH prediction that dreaming simply reflects the amount of mindreading we engage in during wake experiences.

Another finding that might indirectly lend support to the SST-mindreading idea is that the behaviours and communications of dream characters are often bizarre (Kahn et al. 2002; Revonsuo & Salmivalli 1995; Revonsuo & Tarkko 2002); that is, they are unusual, unexpected, and thus unpredictable on the basis of our waking expectations. Studies on intentional social interactions between the Dream Self and other avatars in lucid dreaming suggest that dream characters are largely independent of the dreamer and behave autonomously (Stumbrys et al. 2011; Tholey 1989). Unusual and unpredictable behaviours could be interpreted simply as failures of the dream simulation to produce credible sequences of real-life behaviour. But they could also be interpreted as particularly engaging and activating social stimuli that serve to challenge our mindreading skills. That is, bizarreness in this case could be functional in the sense that it makes the simulation more challenging. Perception of unexpected behaviours may trigger a reconsideration of what is going on in the character's mind in order to produce such unexpected behaviour, and thus present a frequent need to engage in mindreading as we interact with unpredictable characters in our dreams. This idea could be empirically tested by studying whether bizarre behaviours on the part of dream characters tend to trigger mindreading in the Dream Self, and whether this feature of dreams might partially explain the apparently frequent engagement in mindreading in dreams.

6.3 The simulation of social interactions as a function of dreaming

Humans are an essentially social species and an individual's survival in the ancestral environment was most likely entirely dependent on the individual's ability to form long-lasting positive social bonds with close kin and other group members who offered protection, access to nutrition and other crucial resources for survival, collaboration, friendship, social support, mating opportunities, and opportunities to gain a better social status within the group.

Social interaction in dreams is a more complex affair than simple social perception. There need to be some behaviours that link dream characters and the Dream Self, where the intentional behaviour of one character (or the Dream Self) is directed at another character (or at the Dream Self), and the recipient somehow registers it or reacts to it. Traditionally, in the Hall & Van de Castle (1966) content analysis system, social interactions have been classified into three different categories: aggression, friendliness, and sexual interactions. It may be, however, that these three categories are too broad, and do not cover or identify all theoretically-interesting types of social interaction.

When it comes to the simulation of social interactions, the predictions of the SST should, again, be contrasted with the predictions derived from competing theories. In this case the SST needs to be distinguished from two other theories: CH and the TST. The TST is a simulation theory that describes and explains the simulation of aggressive behaviours in dreams, by including them under the category of "threatening events". The function of dreaming, according to TST, is not to specialize in the simulation of social interactions *per se*, but in threatening events; thus, any social interactions are simulated in dreams not because they are social events but because they are threatening events. No independent social simulation theory is required to explain the simulation of social interactions involving a threat; and aggressive behaviours between dream characters are, obviously, social interactions where the wellbeing of the Dream Self or some other dream character is potentially threatened.

Compared to CH or SST, the TST can account for the overrepresentation of threatening events and aggressive interactions in dreams (as compared to waking life, McNamara et al. 2005; Valli et al. 2008). The TST, however, gives no description or functional explanation for neutral and positive types of social interactions (unless they occur as parts of a threatening event). The TST assumes that neutral and positive events in dreams are either parts of a threat simulation (e.g., responding to a threat by helping others who are targets of a threat) or that they repres-

ent some kind of superfluous, non-functional dreaming that simply goes on automatically even if the threat simulation mechanisms are not activated. Thus, when it comes to social interactions, the SST should in particular predict and explain the neutral and friendly types of social interactions, and show that some of them are actively selected as targets of dream simulation. In contrast, the CH predicts that neutral and positive types of social interactions should only occur in the same proportions as they occur in real life, passively reflecting their waking-life frequencies.

If, according to SST, the simulation of neutral and positive social interactions in dreams serve to represent and strengthen important social connections and to rehearse prosocial behaviours in relation to those connections, then these types of interactions should frequently occur in dreams. This would serve the function of maintaining, rehearsing, or strengthening our waking life social bonds and networks, and would satisfy our social need to belong to groups that enhance our survival. After dreaming about prosocial behaviours, our social bonds during wakefulness would automatically be experienced as stronger and we would be more likely to engage in behaviours that further strengthen those bonds. Some tentative steps towards examining how the affects and contents of social dreams predict subsequent waking behaviour have been taken by Selterman et al. (2014). They discovered that an increased frequency of dreams involving significant others was associated with higher levels of intimacy and interaction the following day, whereas dream infidelity predicted less intimacy. Reported arguments in dreams were also found to be correlated with subsequent conflict in waking life. They leave open the question whether this is due to the conscious reflection of the reporting procedure, a more implicit association, or a mixture of the two.

Again, there are no detailed content analysis studies that have investigated the exact nature of social interaction in dreams by taking into account the social context of the interaction; that is, by studying who is engaged in what type of interaction and with whom. From previous studies based on home dream diaries we know that dreamer-involved aggression, adjusted to take into account all social interactions except sexual interactions, is present in 60% of male dreams and half (51%) of female dreams (Domhoff 1996). When male strangers appear in a dream, the likelihood that physical aggression will occur in that dream far exceeds what would be expected on the basis of chance. Basically this means that male strangers signal physical aggression. The dreamer, however, is an aggressor in 40% of male dreams and a third of all female dreams (Domhoff 1996).

Yet, as the Hall and Van de Castle norms indicate, there are friendly interactions in dreams—slightly more often in female (42%) than male (38%) dreams (Domhoff 1996). Females also dream more often of familiar people (58%) than of strangers (42%) while the opposite is true for males (45% vs 55%, respectively); which might suggest that when there are more familiar people in dreams, there is also more friendliness. The dreamer participates in the majority of interactions that involve friendliness (84% for females, 90% for males), and the befriender proportion is 50% for males and 47% for females. Thus, both sexes initiate friendly interactions in their dreams approximately as often as they are befriended. Helping and protecting is the most frequent type of friendly behaviour in both sexes, followed by friendly remarks and compliments, and giving gifts or granting loans. Surprisingly, however, there is very little mutual or reciprocal friendliness, so although friendly interactions are initiated in dreams by the Dream Self or other characters, in less than 10% of friendly interactions the act is reciprocated immediately. This observation goes against any social simulation theory that predicts reciprocal friendliness should be highly represented in dreams: this does not seem to be the case.

McNamara et al. (2005) investigated whether types of social interaction are different in REM than in NREM dreams compared to wakefulness, and noticed that aggressive interactions were more often simulated in REM dreams, whereas friendly interactions were more often simulated in NREM dreams. Furthermore,

dreamer initiated friendliness was more typical for NREM than REM dreams. What is most interesting in this study, however, is that they also found that social interactions in general are more often depicted in both REM and NREM dreams than in wake reports. While aggression was more often simulated in dreams than encountered in waking life, the number of reports with at least one occurrence of friendliness did not differ significantly across sleep–wake states. Thus, these observations imply that dreams do not seem to overrepresent friendly interactions as compared to waking experiences.

In sum, aggressive interactions seem to be more prominent in dreams than neutral or friendly interactions, which would lend more support to the TST than to SST, and friendly interactions are not more prominent in dreams than in waking life, which would lend support to CH and the TST. Nevertheless, if simulations are biologically functional, and if these two types of simulation functions are not mutually exclusive, might there be enough room in the dream content for simulation of neutral and positive interactions, in such a way that it could have contributed to the inclusive fitness of our dreaming ancestors?

6.4 Some testable ideas derived from SST

Let us see how this general approach to social simulation in dreams could be translated into some directly testable hypotheses. Now, a general thesis derived from the SST could be formulated as follows:

Dreams are *specialized* in simulating *the most important social connections and networks* of the dreamer to give an additional selective advantage and to enhance the survival of the dreamer in waking life. The simulations of particular people (the frequency of their presence in a person's dream life), and the simulations of positive interactions with particular people, should focus on the people closest to us in waking life and on the social bonds most important for our inclusive fitness in the real world.

This thesis could be directly tested by deriving some empirical predictions from it, telling us what kind of simulations of social interactions and to what extent they should appear in dreams. If dreams are specialized in the way predicted by SST, then the most important social networks and the people in them *should appear more frequently in dream life than in a corresponding stretch of waking life*. That is, their frequency of occurrence should be targets of active selection and inclusion into dreams, and hence over-represented and exaggerated in dreams.

This empirical prediction could be tested by identifying a person's most important social networks in waking life, and by quantifying the frequency of interactions of the dreamer with those people during dreaming vs. during wakefulness. In the already existing literature, there are some data relevant to the hypothesis, but data that directly compares waking social life and dream life in the manner required to test the hypothesis seems to be lacking.

The data scattered in the literature describes the relative frequency of dreams in which a certain type of close person appears on average in the dreams of the general (or the student) population. For example, romantic partners occur in 20% of dreams and this frequency correlates with the time spent together in wakefulness (Schredl 2011; Schredl & Hofmann 2003). Core family members occur in 10%–30% of dreams; parents in about 8%–20% of dreams, and siblings from 2%–7.5% of dreams (see Schredl 2013). Friends occur in about 20% of dreams (Roll & Millen 1979), but during long-term isolation from social contacts with friends in one case (Merei 1994) this declined to 10%. In studies of long dream series from a single person, a close family member or spouse has been found to be the person most often dreamed about. In a sample of over two hundred dream reports, reported by a married woman (Arlie) with four grown-up children, the most frequently occurring character is her husband; whereas in a sample of over three hundred dreams from an unmarried woman in her thirties (Merri), the most frequently occurring character is her sister, who was no longer alive at the time when the dream reports were collected (Schweickert 2007).

In Schredl's studies, interesting analyses of a long dream series from a single dreamer were conducted, revealing the proportions of schoolmates (2012) and family members (2013) simulated in dreams across a period stretching over twenty years. Old school mates continued to appear in about 5% of dreams over the years when the dreamer had nothing to do with them any more in real life. Similarly, family members, even when the participant was not living with them anymore, still retained a strong if somewhat reduced presence in the same dream series, being present in approximately 15–20% of the dreams over a twenty-year period.

These results show that the probability of occurrence of a character in dreams is to some extent related to the amount of real life contact with that person and to the closeness of the relationship in real life, thus supporting the CH. However, people who have at some point in life been close and important *do not seem to disappear totally* from the dream simulations even though they have long ago totally disappeared from the real life of the dreamer. This feature of the already-existing data suggests that simulations of social contact might serve the function of maintaining or strengthening close relationships over time. When the frequency of a previously close and important social contact falls to zero in waking life, and the person is no longer encountered in waking life (like old school mates after leaving school, or after the death of a family member), the simulation of such a person seems never to totally disappear from dream life, even if the frequency of dream simulations of that person to some extent diminishes. Social simulations in dreams thus seem to maintain an active storage and rehearsal of the most important and closest social relationships of our entire lives, even when those relationships are broken or discontinued for good, or are temporarily on hold in our waking lives.

What happens if a relationship that has disappeared from waking life is reactivated after years of disconnection? In Schredl's (2012) study, old schoolmates met for a reunion twenty years after going their separate ways. Interestingly, when the same relationships are re-activated in real life for just one day, the dream simulation of those social relationships is increased significantly and for a long period of time (compared to the time of actually meeting). The mechanism that reactivates old targets of simulation might be analogous to that proposed in TST for the re-activation of old threats. The frequency with which the most important real threats are simulated (e.g., in post-traumatic nightmares) increases when, during wakefulness, new cues are encountered that are associated with the old threat possibly reoccurring in real life.

These considerations suggest a more precise function of social dream simulations that could be formulated along the following lines. We may call it the Strengthening Hypothesis: *the function of social simulations in dreams is to maintain and strengthen the dreamer's most important social bonds from waking life.* Consequently, a prediction derived from the Strengthening Hypothesis can be formulated as follows: if strengthening important social bonds is a function of social dream simulations, then dreaming should include with high frequency social interactions in which the (current or past) most important social bonds are strengthened through various types of simulated positive social interactions and prosocial behaviours. Thus, the frequency of prosocial, positive interactions (bond-strengthening) with the most important persons should clearly surpass the frequency of negative (bond-weakening) interactions within dreams, and also be more frequent in dreams than in a corresponding stretch of waking life.

Schredl's (2012, 2013) findings are to some extent consistent with both the CH and the SST, but do not allow any firm conclusions about which theory better predicts the occurrence of the most important social connections in dreams. Studies that collect data from both waking life and dream life during the same period of life from the same people, as well as from the life history of these individuals, are necessarily required to test whether the representation of the most important connections is exaggerated in dreams, or if they just reflect the waking frequency. In practice, this prediction could be tested by identifying all the interactions between the dreamer and the people in his

or her most important social networks, in both dream and waking reports. Then the interactions could be classified according to whether they tend to strengthen or weaken the relationship with that particular person. If the frequency with which dreaming simulates positive interactions surpasses the frequency of those interactions in real life, then the SST would gain credence over the CH.

Another potential simulation function to consider can be called the Practise and Preparation Hypothesis. According to this hypothesis, the function of social simulations in dreams is to force the dreamer *to practise important social bonding skills*, such as how to give social support to others. The prediction derived from this hypothesis states that if practising social bonding skills is a function of dreaming, then the dreamer should frequently offer various types of social support to other dream characters, for example emotional, instrumental, or informational support. Furthermore, the types of social support offered should be dependent on the degree of relationship intimacy, i.e., the distance between the self and the recipient in the hierarchy of the social world of the individual. If the Practise and Preparation Hypothesis is correct, then the frequency of simulating social support should be higher than comparable behaviours in real life.

These ideas are testable, but dream content studies are to be carefully designed with the specific aim of testing them. In the literature already published, friendliness percentages in different dream samples and descriptive statistics concerning who initiates friendliness in dreams might shed some light on these questions. However, without any data about the frequency of occurrence of these same behaviours in the waking state of the same person, the purely descriptive findings from dreaming alone will not be able to separate CH predictions from SST predictions. The comparable waking data is crucial as a baseline against which the dream data can be evaluated and in relation to which the CH predictions can be contrasted with the SST predictions.

In an ideal setting the hypotheses for the SST and its proposed functions would also be tested cross-culturally and in particular, as the theory makes bold evolutionary claims, in traditional small-scale human societies. As Henrich et al. (2010) have pointed out, the concentration of behavioural research into the so-called Western, Educated, Industrialized, Rich, and Democratic (WEIRD) societies are highly unrepresentative of the species, and might pose problems for the generalizability of the results. Furthermore, by contrasting, for example, the differences between the social simulations of small-scale and Western societies, we might uncover useful information about the plasticity and ontogenetic mechanisms of the social simulation function.

7 Conclusions

The concept of "simulation" is a useful theoretical concept for dream research. It unifies definitions and descriptions of the basic nature of dreaming, and helps to formulate testable theories of the function of dreaming. Applying this concept to the social reality of dreams means that we start to describe the persons and social interactions in dreams as simulations of their counterparts in real life. Consequently, we can ask: How does the simulated social reality relate to the actual social reality in the same person's waking life? Is it plausible to hypothesize that the avatars in the dreaming brain might in fact be there in order to force us to maintain and practise various evolutionarily important functions of social perception and social bonding?

In this paper we made an attempt to clarify what it means to put forward the theoretical statement that "dreaming is a social simulation", especially when this claim is offered as an expression of a theory of the *function* of dreaming. The SST can be formulated in a testable manner, and a number of testable predictions can be derived from it. Some of those predictions, concerning basic social perception and mindreading abilities, already receive rather strong support from the published literature. Many more hypotheses remain to be tested. To achieve theoretically-informative results and to directly contrast the predictions of different theories, future studies have to be designed in a

strictly theory-driven and hypothesis driven manner—which, unfortunately, is not a common approach in dream research.

If the SST, or some parts of it, prove successful, we have to be able to show that the SST predicts the nature and the occurrence of social simulations in dreams more accurately than its main competitors, the CH and the TST. To fare better than the CH, the data would have to show that the most important social contents are actively selected for incorporation in dreams as social simulations, and therefore rehearsed in an exaggerated quantity or form in dreams. To show that the CH is on the right track, the data would have to show that dream simulations merely reflect, both quantitatively and qualitatively, whatever experiences waking life has recently presented to the same person. To go beyond what the TST predicts and explains, the data supporting the SST would have to show that dreaming over-represents and actively runs positive or neutral social simulations in dreams that strengthen the skills of social perception and bonding, but that have nothing specifically to do with threat-perception and avoidance.

At this point, we are not yet sure how strong the empirical case for SST is going to be, and whether the evidence will mostly turn out to be for or against it. We shall wait for the kind of studies that directly test SST and set it against other theories' predictions. However, what we are confident about is that SST *is* an empirically testable theory, and that dream research would in general gain much if dream content studies were rigorously designed to test the predictions derived from opposing theories, and if dream data were in general collected and analysed in a manner that provides us with strong tests of different theoretical hypotheses rather than just producing more and more purely descriptive data of dream content (and then presenting vague, post-hoc theoretical interpretations of them). In that way, dream research would be able to find and test new, promising theoretical ideas, perhaps derived from cognitive and social neuroscience and from evolutionary psychological considerations. New theoretically-guided studies would help leave behind old ideas if they did not generate any clear and testable predictions or if such predictions did not gain sufficient empirical support.

Even if we will at some point be able to explain some of the functions of social simulation in our dreams, we might not be able to explain the *underlying mechanisms that generate* the simulations. The fundamental metaphysical nature of the simulated persons inhabiting our dreaming brain might after all be almost equally mysterious as the immaterial nature of a Cartesian ghost, because, like everything we experience in our dreams, the avatars in our dreams are built out of features that have no objective, physically observable, or measurable substance. Instead, they consist of subjectively-experienced phenomenal features, and at least at the present state of consciousness science, the only way for us to get any empirically-based data about them is through the introspective reports carefully collected from the dreamers. How the sleeping brain produces vivid, dynamic, complex phenomenality and organizes it into subjective spatiotemporal hallucinations, inhabited by avatars and social simulations, still remains beyond any current theoretical explanations of dreaming and consciousness. Any plausible explanation of the actual brain mechanisms that do the trick would have to solve the hard problem of consciousness (Chalmers 1996) and cross the explanatory gap (Levine 1983) between the objective neural mechanisms in the brain and the subjective experiential realities going on in subjective consciousness. We are not quite there yet.

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