The threat simulation theory in light of recent empirical evidence: A review

KATJA VALLI and ANTTI REVONSUO
University of Turku

The recently proposed threat simulation theory (TST) states that dreaming about threatening events has a biological function. In the past few years, the TST has led to several dream content analysis studies that empirically test the theory. The predictions of the TST have been investigated mainly with a new content analysis system, the Dream Threat Scale (DTS), a method developed for identifying and classifying threatening events in dreams. In this article we review the studies that have tested the TST with the DTS. We summarize and reevaluate the results based on the dreams of Finnish and Swedish university students, traumatized and nontraumatized Kurdish, Palestinian, and Finnish children, and special dream samples, namely recurrent dreams and nightmares collected from Canadian participants. We sum up other recent research that has relevance for the TST and discuss the extent to which empirical evidence supports or conflicts with the TST. New evidence and new direct tests of the predictions of the TST yield strong support for the theory, and the TST's strengths seem to outweigh its weaknesses.

The threat simulation theory (TST) (Revonsuo, 2000a, 2000b) claims that dreaming originally evolved as an offline simulation of the real perceptual world and that its function in the ancestral human environment was to repeatedly produce simulations of the real threatening events that had been encountered during waking hours and had left a mark in emotional memory. The function of threat simulation in dreams was the repeated nocturnal rehearsal of the neurocognitive mechanisms that are essential for threat recognition and avoidance behaviors while awake. In the environment of evolutionary adaptedness (EEA), recurring threat simulations during dreaming increased the survival and reproductive success of the individuals possessing an efficient threat simulation system. Gradually, as the neural mechanisms underlying dream consciousness were genetically transmitted from generation to generation, the system propagated its own existence in the EEA. Thus, modern humans still possess this ancient defense mechanism, although the threat simulation system probably cannot fulfill its original biological function in the present environment because the modern environment is remarkably different from the one where the system evolved.

The TST states that dreaming fulfills a threat simulation function, and this statement can be tested directly by investigating whether dreaming shows fea-

tures that we would predict a threat simulation mechanism to have. In contrast, when the TST postulates an evolutionary origin for the threat simulation function of dreaming—that is, infers a historical causal relationship between the present form of dreaming and the origin of dreaming—this is not a directly testable statement. Regardless, historical causal claims about evolved psychological mechanisms can be investigated indirectly by study of the traces the proposed function has left in the psychological architecture of currently living humans (Tooby & Cosmides, 1992, 1995). Consequently, the decision whether the mechanism is an evolved adaptation is based on a probability estimate (Tooby & Cosmides, 1992). In sum, we can empirically directly test whether dreaming shows the features needed for a threat simulation function, but we can only indirectly estimate whether threat simulation during dreaming is an adaptation.

Although the TST was published quite recently (Revonsuo, 2000b), within a few years empirical evidence relevant to the TST has been accumulating rapidly. The aim of this article is to bring together all available findings and evaluate the TST in light of the newly acquired information. First, we briefly review the TST and its predictions. Second, we present the method with which the TST is usually tested: the Dream Threat Scale (DTS). Third, we review and summarize the findings of dream studies that have used the DTS, and fourth, based on these results, we offer estimates for annual threat simulation rates in healthy young adults. Fifth, we survey a variety of other recent research, draw together all the currently available evidence, and discuss the propositions of the TST in light of the recent evidence.

The TST
The TST was originally presented in the form of six propositions, each leading to several empirically testable predictions (Revonsuo, 2000b). Consequently, the central claims of the theory are open to supporting or falsifying evidence. The first proposition of the TST is that dream consciousness is an organized and selective simulation of the perceptual world. To begin with, the TST accepts, based on previous empirical evidence, that the form of dream experience is organized along the same lines as perceptual waking consciousness (Foulkes, 1985; Rechtschaffen & Buchignani, 1992; Strauch & Meier, 1996) and that

the coherent dream world functions as a credible multimodal world analog (Foulkes, 1985) that is experienced, during dreaming, as real life (Revonsuo, 2000b, 2006). Consequently, the TST claims that the dream experience is functionally constructed to resemble waking experiences and therefore shows clear design features for a world simulation function. Moreover, the TST assumes, also based on currently available evidence, that dream consciousness is selective in a sense that certain types of contents (e.g., social interactions and emotions) (Domhoff, 1996; Strauch & Meier, 1996) are regularly simulated in dreams, whereas some others are not (e.g., reading, writing, using a computer, and many other activities often practiced during waking hours) (Hartmann, 2000; Schredl & Hofmann, 2003).

Second, the TST claims that dream consciousness is specialized in the simulation of threatening events, that is, dream content selectively represents negative situations. Thus, the TST predicts that threatening events should occur in dreams more frequently than in waking life and that the content of dream threats should reflect the original function of dream consciousness as a threat simulator. Therefore, threatening events in dreams should focus on simulating dangerous events critical for the future survival of the individual, and the threats should mainly endanger the well-being of the dream self and people significant for the self (close kin and allies). The threats should be realistic portrayals of real threatening events. The dream self should be able to participate in the course of the threatening events and defend itself with appropriate and reasonable actions that would be relevant in a comparable waking situation.

Third, the TST predicts that only real threatening events can fully activate the threat simulation system. Encounters with real threats in the environment are stored in "hot" emotional memory, and when asleep, the dream production system automatically selects the memory traces with the highest salience for dream construction. Consequently, memory representations containing the highest negative emotional charge, encoding fearful and threatening events, should be selected over and over again for simulation. Thus, real-life threat experiences activate the threat simulation system by offering raw materials to it. Moreover, the activation of the threat simulation system after exposure to life-threatening

events should be a universal phenomenon, not dependent on any specific culture, and the intensity of the simulations (frequency and persistence) should be directly related to the degree of personal threat experienced in the original situation.

The fourth proposition of the TST states that threat simulations are perceptually and behaviorally realistic rehearsals of real threatening events. During dreaming, the offline world simulation engages the same brain mechanisms as perceptual consciousness and seems real to us because we are unaware that it is nothing but a hallucination (except very rarely in lucid dreams). Similarly, the sleeping brain is capable of simulating the planning and execution of motor commands, but muscular atonia during rapid eye movement (REM) sleep prevents our bodies from carrying out the planned behaviors. If the muscular atonia during REM sleep is removed, we should observe that the body of the dreamer carries out isomorphic behaviors while they happen in the dream.

Fifth, the TST assumes that perceptually and behaviorally realistic simulation and rehearsal of any skills (in this case threat recognition, avoidance, and coping skills) should improve performance, regardless of whether the training episodes are explicitly remembered. Simulation training and mental training have been shown to improve performance; that is, implicit procedural learning occurs when behaviors are repeatedly practiced in nonreal situations (Lejune, Decker, & Sanchez, 1994; Yaguez et al., 1998). Furthermore, procedural learning occurs also in amnesiacs, showing that performance enhancement can be attained without explicit memory of training episodes (Schacter, 1996).

Finally, the sixth proposition of the TST states that the original human EEA included frequent dangerous events, which imposed severe selection pressures on ancestral populations, and that the ecologically valid threat cues in the environment fully activated the threat simulation system. Thus, we can predict that children old enough to implement threat recognition and avoidance skills during wakefulness should be capable of simulating threatening events in their dreams, especially when exposed to ecologically valid threat cues. Moreover, ontogenetically early exposure to real threat cues should lead to earlier, more frequent, and more intensive threat simulation dreams, whereas lack of exposure should lead to slower development of the

dream production system and less frequent and milder threat simulation dreams. (The latter may often be the case in modern Western world.)

The DTS

Because the TST makes claims about the content of dreams, dream content analysis can be used in the direct testing of the TST. Content analysis is a method of transforming verbal material into numbers, that is, a tool that allows objective quantification of qualitative data (Hall & Van de Castle, 1966). The aim is to describe qualitative material in terms of frequencies and rates, so that statistically significant features can be revealed from large samples of individual cases.

In order to test the predictions of the TST, Revonsuo and Valli (2000) devised a content analysis system to specifically measure the frequency and quality of threatening events in dreams, the DTS.[1] The aim was to develop a method that would help in extracting all the information in dream reports that describe threatening situations and to further categorize them according to the specific content. The threat identification criteria used in the DTS include objective threats, that is, events in which the physical or mental well-being of any person, or the physical resources or territory of any person, is endangered, and subjective threats, that is, events that are interpreted or emotionally experienced by the dreamer to be somehow dangerous or threatening, even if no objective threat is reported to accompany this feeling.[2] In contrast, situations that are experienced as fictional in the context of the dream (e.g., the dreamer reports watching a movie or playing a computer game that includes threats) are not considered as threatening events, nor are situations in which the dream self is deliberately trying to harm himself or herself.

As to coding the specific quality of dream threats, the DTS accounts for the nature of threats (escapes or pursuits, accidents or misfortunes, failures, catastrophes, disease or illness, nonphysical aggression, and direct physical aggression), the targets of threats (self, significant others or resources, insignificant people or resources), the severity of threat to self (life-threatening, physically dangerous, nonphysically severe, minor), the participation of self in the event (does participate, does not or cannot participate), the reaction of self to the event (relevant or adequate, physically

impossible, irrelevant, no reaction or reaction not possible), the resolution of threat (resolved, realized, resolution unclear due to discontinuity, resolution not reported), the consequences of threat to self (no losses, minor losses, severe losses, consequences not reported), and the realism of threat (realistic, realistic but unlikely, fictitious). In sum, the DTS takes into account all types of harmful events that either directly or indirectly had a significant effect on the survival and reproductive success of an individual in EEA. Including all kinds of threatening events in the DTS and separately investigating their specific quality allows us to test hypotheses about the activity level of the threat simulation system in different populations, as the TST predicts that waking life experiences have a significant effect on the frequency and quality of threats in dreams.

Studies conducted using the DTS

After the development of the DTS, the next goal in testing the TST was to collect dream samples from various participant populations, with varying exposure levels to real threatening events, from different cultures, and from children as well as adults. It was assumed that if the TST correctly predicts the frequency and content of threatening events in many different dream samples, the theory would receive support, whereas if the predictions proved to be false, the theory should be rejected or at least thoroughly modified. Consequently, all the studies using the DTS were designed to test a specific hypothesis or hypotheses of the TST, and the participant populations varied accordingly.

UNIVERSITY STUDENT SAMPLES.

In the very first study conducted to test the TST (Revonsuo & Valli, 2000, Study I), the aim was to test the predictions derived from the second proposition of the TST, that is, that threatening events should be frequent in dreams, targeted against the dream self, severe, and realistic and should enable the dreamer to participate in and react to the situation. The participants were 52 Finnish university students who kept systematic dream diaries for 4 weeks. Detailed instructions on how to report dreams were provided, and altogether, the participants produced 592 dream reports. The data were collected in 1995, well before the TST existed. Thus, the participants and the re-

searchers involved in the data collection were blind to the predictions of the TST. The second study undertaken to test the TST (Study II) was a replication of the original Study I in a sample of 248 dreams collected from 50 Swedish university students (Valli, Lenasdotter, MacGregor, & Revonsuo, 2007). The purpose of the study was to investigate whether the findings of the original Revonsuo and Valli (2000) study would be replicated in an independent but comparable participant sample, collected in different language area, and analyzed by different judges.

Study III (Valli, Strandholm, Sillanmäki, & Revonsuo, 2008) tested the hypotheses of the TST that dream threats are more frequently experienced than comparable real-life threats and that in threat simulations the severity of threats is exaggerated. Although the frequency and quality of dream threats were described in Studies I and II, there was no baseline of the frequency and quality of real-life threat experiences to compare the frequency and quality of dream threats to. The participants were 39 Finnish university students who wrote down their dreams (N = 419) and simultaneously recorded their real-life experiences in daily logs (N = 490). The participants were also interviewed about all the threatening events they had ever experienced and could recall from their long-term autobiographical memory (N = 714). Then, the frequency and quality of dream threats, most recent threats, and threats encoded into long-term episodic memory were compared.

SPECIAL POPULATIONS.

Study IV and Study V were designed to test the third proposition of the TST, that exposure to real threatening events fully activates the threat simulation system. If this is the case, the frequency and quality of threat simulation dreams should vary significantly between participants who have been and participants who have not been exposed to real life-threatening events. In Study IV, the participants were 64 severely traumatized and 53 less traumatized Kurdish children and 70 nontraumatized Finnish children (Valli et al., 2005). Altogether, 763 dreams were acquired, 331 from severely traumatized children and 216 from both less traumatized and nontraumatized children. Comparably, in Study V the participants were 235 traumatized and 121 nontraumatized Palestinian children, who reported 986 and 362 dreams, respectively

(Valli, Revonsuo, Pälkäs, & Punamäki, 2006). In both studies dreams were collected on 7 consecutive nights using a semistructured dream and sleep diary. The data were collected for different purposes and before the publication of the TST, and consequently the participants and the researchers who collected the data were unaware of the TST.

SPECIAL DREAM SAMPLES.

Zadra, Desjardins, and Marcotte (2006) (Study VI) used the DTS in a Canadian sample to explore threatening events in recurrent dreams. They aimed to clarify whether recurrent dreams could be seen as exemplary cases of threat simulation dreams, as suggested by Revonsuo (2000a). The data were collected with a retrospective questionnaire from 212 participants recruited to studies on dreams and personality. One dream report was selected from each participant, although some of them reported more than one recurrent dream. In another study, Desjardins and Zadra (2004) used the DTS to explore the extent to which nightmares could be interpreted as extreme threat simulation dreams (Study VII). The participants were 118 healthy Canadian adults. The data were collected using a 2- to 4-week dream diary, and from the diaries, a maximum of two nightmares per participant were randomly selected ($N = 174$). The data for Studies VI and VII were not originally collected to test the TST, and therefore experimental demands did not bias the samples.

RELIABILITY OF THE DTS.

In Study I, the dreams were content analyzed by three independent raters, two of whom had devised the DTS. The agreement levels between raters varied from fair to strong, rendering the results reliable, and were highest between the two developers. In Study II, two raters new to the DTS content analyzed the data, reaching strong interrater agreement levels. This indicates that the DTS can be used reliably by researchers other than the developers of the scale. Again, in Study III two raters analyzed the data; one judge was new to the DTS, and the other was a developer. They reached strong interrater agreement levels in analyzing dream reports, daily log descriptions, and interview transcripts, indicating that the DTS can be used reliably not only in analyzing dream reports but also in investigating other verbal material.

In Studies IV and V two judges identified and classified the threats, and one of the two had previous experience with the DTS, whereas the other was newly trained. In addition, the analyzed material differed significantly from that in previous studies; it was composed of children's dreams that were translated from two Kurdish dialects (Study IV) and Arabic (Study V) into English. The agreement levels ranged from good to strong, indicating that the DTS can be used reliably in analyzing children's dream content and in samples consisting of participants with different cultural backgrounds. In Studies VI and VII, two judges who had not participated in the development of the scale coded the data. In Study VI, they reached a level of agreement ranging from fair to strong. Information on the agreement levels in Study VII was not available.

To summarize, the DTS has been used in several studies, and in all these studies the DTS has proven to be a reliable tool for identifying and classifying threatening events in written reports, independent of data collection method (questionnaire vs. dream diary), source of data (dreams vs. real-life experiences), age of participants (children vs. adults), life experiences of participants (traumatized vs. nontraumatized), and cultural background of participants (Finnish, Swedish, Canadian, Kurdish, or Palestinian). We therefore recommend the use of the DTS in future studies on threatening dream events or empirical tests of the TST.

Results of the reviewed studies

In this section we review the main results of the aforementioned studies. We start by presenting the findings on the frequency of threats in dreams and then review the more detailed content of these threats.

FREQUENCY OF THREATENING EVENTS.

In Study I, Revonsuo and Valli (2000) found that threatening events are common in the dreams of ordinary young adults. A total of 672 threatening events were identified in 592 dream reports, amounting to 1.2 threats per report. Two thirds of all dream reports (66.4%) included a description of a threat, and many dreams included several threatening events. There were no participants whose dream reports did not include threatening events, even though the frequency of threats per dream report varied widely between

participants (0.23–3.75). In the written reports, 34% of total recall count (TRC; Antrobus, 1983) was used for describing threatening events, whereas two thirds of words described other types of events.

In a comparable Swedish university student sample (Study II), threatening events were slightly more common. Altogether, 381 threatening events were identified in 248 dreams, for an average of 1.6 threats per dream. More than three quarters (77%) of all dream reports contained at least one threatening event, and all participants, even those who reported only one dream, had threatening events in their dreams.

In Study III, the threat simulation frequency results were highly similar to those in other student samples: 581 threatening events were found in 419 dreams, amounting to 1.4 threats per report. The threat description percentage of TRC was 37.1%. Nevertheless, Study III was specifically designed not only to measure threat frequency in dreams but also to investigate whether threatening events are more frequent in dreams than in waking life. Of the students' dream reports, 72.8% included threatening events, compared with only 15% of daily logs. In the interviews the students recalled, on average, 18 real threats from their lives, whereas during the 2-week diary period they had experienced, on average, 15 dream threat simulations. Thus, the results indicate that dream threats are far more common than the most recent threats experienced during the preceding days or the past real threats retrievable from autobiographical memory. Also, the quality of threats varied in these three samples, with dream threats the most severe.

Special populations. In nontraumatized children's dreams (Studies IV and V) the average threat simulation frequency was lower than in nontraumatized adults' dreams. By far the lowest threat frequency of any sample was found in the dreams of Finnish children (Study IV), who had lived all their lives in the most peaceful and stable environment of all the studied children. Threat simulations occurred in one third of their dream reports (38%: 81 threats in 216 dreams), but almost half of the participants' reports included no threats at all. The average number of threats per dream report was 0.38, and the threat description percentage of TRC was 20.1%. Nontraumatized Palestinian children (Study V) who

had also led safe lives but must have heard about the dangerous situation in other parts of the state had an average threat simulation frequency of 0.64 per dream report, as 233 threatening events were identified in 362 dreams. About half (47.8%) of their dream reports included threatening events, but almost a third of participants (28.9%) had no threats in their reports. In this nontraumatized sample, the TRC threat description percentage was 38.0%.

In contrast, exposure to traumatic events increased the frequency of threat simulations in dreams. The more severe the trauma, the more dreams included threat simulations, equaling or even surpassing the threat simulation frequencies of ordinary young adults. Of the severely traumatized Kurdish children's dreams ($N = 331$), 79.5% included threatening events, the highest of any sample of children or adult dreams. Similarly, the percentage of TRC used for describing threats exceeded the values seen in any other sample (61.1%). On average, there were 1.2 threatening events per dream report, and all participants reported at least one threat in their dreams.

In the less severely traumatized Kurdish (Study IV) and traumatized Palestinian children's dreams (Study V), the results formed a continuum with those of the severely traumatized and nontraumatized children. In the traumatized Palestinian sample, 948 threats were found in 986 dreams, or 0.96 threats per dream. The threat description percentage of TRC was 45.7%, and 58.7% of all dream reports included threatening events. In the less traumatized Kurdish children's dreams ($N = 216$), 144 threatening events were identified, amounting to 0.67 threats per dream report. Of the reports, 55.6% included threatening events, and the TRC threat description percentage was 42.1%.

Special dreams. In 212 recurrent dreams, 147 threatening events were identified, for a mean threat frequency of 0.69 per report. Of recurrent dreams, 65.6% included a threatening event or two. No comparable information was available from the nightmare study, except that 63% of reports included one or more threatening events. These results indicate that recurrent dreams and nightmares simulate threatening events as often as normative dreams, not more frequently (but the quality of the threats in special dreams differs from that in normative dreams).

Although the distribution of specific types of threatening events varies to some degree from study to study, certain regularities clearly emerge from the results. In this section, the statistically systematically appearing features of dream threats are summarized.

Nature of threatening events. Threats including aggressive components (i.e., escape and pursuit situations, nonphysical and direct physical aggression) are the most prominent type of threatening event. In university student samples, 41–42% of all threats include aggression. Studies IV and V on dreams of traumatized and nontraumatized children show that aggression is even more prevalent in children's dreams, ranging from 53% of all threats in Finnish children's dreams to 76% in traumatized Palestinian children's dreams. These results are consistent with previous findings on the levels of aggression in children's dreams (Hall & Domhoff, 1963). In addition, the traumatized children had significantly more aggressive threats in their dreams than the nontraumatized children or ordinary young adults. Threatening events including aggressive components are also prominent in recurrent dreams (45%) and nightmares (64%). In sum, the threat simulation system of the traumatized children seems to be more active in constructing threat simulations including aggressive components than that of the nontraumatized children or adults, and nightmares seem to simulate especially primitive and severe types of threats.

Failures and accidents and misfortunes are also common types of threats. In university students' dreams, failures constituted 26–27%, and accidents and misfortunes constituted 21–22% of threats in the Finnish samples compared with 36% failures and 17% accidents and misfortunes in the Swedish sample. In contrast, failures and accidents or misfortunes were less common in children's dreams, with failures accounting for 8% to 18% and accidents or misfortunes accounting for 9% to 16% of threats. Accidents and misfortunes were prominent types of threats in recurrent dreams (20%) and less common in nightmares (12%). Failures were uncommon in both recurrent dreams (7%) and nightmares (4%). Catastrophic events (3–6%) and disease or illness (0–11%) were uncommon in all dream samples, and in special dreams, disease or illness was never simulated.

The results of Study III revealed that dream threats much more closely resemble the autobiographical threats than the most recent real threats. Failures were most frequently reported in the daily logs, whereas aggressive events and accidents and misfortunes were prevailing types of dream threats and autobiographical real threats. Thus, the themes of dream threats seem to be constructed mostly from the old memory traces of the most threatening events ever encountered rather than from the new traces reflecting minor threats experienced in the preceding days. This indicates that the negative emotional charge of the memory trace is a more prominent determining factor in the automatic selection process of memory traces for simulation than the recency of encoding of the memory.

Targets of threatening events. In all studies, the threatening events were targeted mainly against the dream self (69–94%), followed by people significant for the future success of the dream self ($M = 30.5\%$), that is close kin, friends, and allies. Significant others were more often threatened in children's ($M = 38.4\%$, range = 29–47%) than in adults' ($M = 22.6\%$, range = 4–30%) dreams, possibly reflecting the fact that young children are dependent on caretakers. In addition, in all samples the threats were more people centered than resource centered. Insignificant people were less frequently threatened than self and significant others but more often than resources significant for the dream self, such as physical property or territory, or insignificant resources, such as property of insignificant strangers. Furthermore, distribution of the targets of dream threats was similar to that of the targets in the most salient threats ever encountered in real life (i.e., threats encoded into and retrievable from long-term autobiographical memory; Study III).

The pattern of results makes sense from an evolutionary perspective. The simulation serves as an efficient rehearsal of the dreamer's threat perception and avoidance skills only when the survival or reproductive success of the self or significant people is directly threatened. Conversely, threats targeted against insignificant people or resources do not require that the dream self react to the threats in any way. Still, the dreamer may learn how to deal with threats by witnessing other people's threat avoidance behaviors. New evidence from cognitive neuroscience supports the view that when we observe

another person performing an action, our own brain perceives this action by mirroring it, activating the same brain mechanisms as if we were carrying out those acts ourselves (Rizzolatti & Graighero, 2004). The mirror neurons are assumed to be the neural basis of action in understanding and imitation learning. Thus, observation of threat avoidance behaviors may be functional and enhance a kind of vicarious learning, although it may not be as efficient as being the target of the threat oneself.

Severity of threatening events. In the dreams of ordinary young adults (Studies I, II, III), 18–22% of all threatening situations were life-threatening to the dreamer. In these studies, 17–50% of threats simulated physically and nonphysically severe situations in which the physical or psychological well-being of the self or the social or financial resources of the dreamer were acutely threatened. Thus, about 40–70% of dream threats are severe enough that they would have endangered the survival or reproductive success (i.e., fitness) of the person in the EEA. The rest of the threatening events, 32–61%, represented minor everyday mishaps that did not threaten the future survival of the self but nevertheless presented the dreamer with situations that required attention and actions aimed at dealing with the event.

Personal exposure to life-threatening events activated the threat simulation system, as predicted by the TST. Traumatized children simulated life-threatening (M = 30.7%, range = 26–35%) and physically and nonphysically severe threats (M = 34.3%, range = 29–40%) more often in their dreams than did nontraumatized children (life-threatening M = 26%, range = 24–28%; physically or nonphysically severe M = 31.5%, range = 30–33%) or nontraumatized young adults (Studies I–III). Because the overall threat simulation frequency for traumatized children was much higher to begin with (1.2 vs. 0.4), percentages of occurrences alone do not accurately reflect the state of affairs. In fact, when mean threat simulation frequency is accounted for, life-threatening and physically and nonphysically severe threats were experienced by severely traumatized Kurdish children twice as often as by less traumatized Kurdish children and six times more frequently than by nontraumatized Finnish children.

Recurrent dreams and nightmares specifically concentrated on simulating life-threatening situations rather than minor and trivial mishaps (Studies VI and VII). Sixty-five percent of all threats in recurrent dreams and 72% in nightmares were life-threatening to the dream self, whereas minor mishaps occurred much more rarely (22.0% and 6.0%, respectively).

Compared with the most recent and the most salient real-life threats (Study III), dream threats were significantly more severe. Whereas the most recent threats consisted mainly of minor everyday mishaps and concerns (93%) (no life-threatening events were reported in the daily logs), almost half of the dream threats simulated life-threatening and physically and nonphysically severe events. Although less than half of the participants (15 of 39) could recall having experienced a life-threatening event in reality, in their dreams they were forced to face life-endangering situations on a weekly basis. Thus, in our dreams we more frequently undergo life-threatening and other severe incidents than in our waking lives, and our dreams exaggerate the dangerousness of the threatening events we have experienced during the waking hours.

Participation of the dream self in threatening events. In adults' dreams, the dreamer could and did actively participate in the course of the threatening events in 46–60% of cases (Studies I, II, and III). In contrast, in 40–54% of threatening events the dreamer could not or did not actively partake in the events. Participation rates were lower in children's dreams (26–40%), and the degree of trauma did not have any effect on participation rates. Nevertheless, because threat simulation rates were as much as three times higher in severely traumatized than nontraumatized children's dreams (1.2 vs. 0.4), the traumatized children got much more practice in dealing with threatening events than the nontraumatized children. In addition, participation rates were higher in recurrent dreams (78%) and nightmares (77%) than in normative dreams (Studies VI and VII).

The effect of the severity of the threatening event on the dreamer's activity is unclear. In Study I, $\chi^2(1, n = 643) = 18.58, p < .001$, and Study III, $\chi^2(9, n = 581) = 18.37, p < .05$, the dreamer was more likely to respond to life-threatening events than to other, less severe events. Similarly, in Study V, traumatized children showed this connection, $\chi^2(1, n = 948) = 42.81, p < .001$, but not the nontraumatized children. In contrast, no significant connection between the severity

of threats and the participation of the dream self was observed in Studies II and IV. We could not explore the issue in recurrent dreams or nightmares.

The main reason participation rates remain low seems to be that participation cannot be coded for because of lack of information in the dream report, mainly because of disruption or discontinuity within the dream: Studies I–III; $M = 24\%$, range = 14–37%; Studies IV and V, $M = 22\%$, range = 14–27%. In Study VI on recurrent dreams, Zadra et al. (2006) investigated the factors behind the inactivity of the dreamer. In 21% of threats the participation could not be coded for because of missing information, in 15% the dreamer did not participate because it was impossible (dreamer was not present in the situation, or the threat had already taken place), in 5% of cases someone prevented the dream self from participating, and in 2% of cases the dreamer was passive or indifferent to the situation. In sum, discontinuity within and disruption of the dream report are major reasons why participation in the event remains unclear, but when participation can be coded for, inactivity of the dreamer most often results from external factors that prevent participation, not from passivity on behalf of the dreamer. Nevertheless, in all adults' dreams participation in the threatening events was possible in more than half of the cases, and the dreamer actively took advantage of this possibility. Thus, frequent rehearsal of threat avoidance behaviors does seem to take place in dreams.

Reaction of the dream self to threatening events. Although reaction to the threat is not always possible in dreams, when reactions occur, they are almost without exception relevant, reasonable, and appropriate to the dreamed situation, both in normative dreams ($M = 93.5\%$, range = 93–94%) and in special dream samples ($M = 73.5\%$, range = 58–89%). Only rarely does the dreamer engage in actions that are impossible in the physical realm but efficient in the dream ($M = 2.3\%$) (e.g., flying away from an attacking animal) or physically possible but inappropriate in a comparable waking situation ($M = 4.7\%$) (e.g., jumping off a cliff to escape an attacking animal). As to more specific types of reactions, in recurrent dreams the dreamer actively fought the threat in 34% of cases, fled from the event in 39%, or did both in 5%. Similarly, in nightmares 58% of threatening events were met by fighting or fleeing the situation.

Resolution and consequences of threatening events. The threatening events more often became fully realized ($M = 42.8\%$, range = 37–54%) than dissolved ($M = 23.5\%$, range = 17–32%). As mentioned earlier, discontinuity within the dream and disruption of the dream were also quite common. Interestingly, in all studies in which the statistics could be gathered, threatening events were significantly more often resolved (i.e., the situation had a happy ending) than realized when the dream self actively participated in the course of the events: Study I, $\chi^2(3, n = 638) = 54.69$, $p < .001$; Study II, $\chi^2(3, N = 389) = 27.94$, $p < .001$; Study III, $\chi^2(12, N = 581) = 46.15$, $p < .001$; Study VI, $\chi^2(1, n = 60) = 14.89$, $p < .001$. Thus, the activity of the dream self positively affected the outcome of the situation.

As to consequences of threats, they often go unreported in normative dreams ($M = 25.3\%$, range = 18–30%), and especially in children's dreams ($M = 43.2\%$, range = 39–46%). In many cases there were no consequences at all: normative dreams, $M = 30.7\%$; children's dreams, $M = 17.6\%$; recurrent dreams, 73%. When the threats resulted in losses, the consequences were usually minor, not severely affecting the future success of the individual: normative dreams, $M = 34\%$; children's dreams, 21.4%. On the other hand, severe consequences were very rarely experienced (2–9%), although they were more common in the dreams of traumatized children ($M = 7.3\%$) than nontraumatized children ($M = 4.0\%$) or adults ($M = 2.7\%$). The threat simulation mechanisms therefore does not seem to be interested in simulating what happens after the threat has been recognized and encountered and appropriate actions have been taken to avert the threat.

Source of threatening events. A majority of threats in the student samples ($M = 63.7\%$, range = 63–68%) were based on information about events that are realistic and possible in the living environment of the participant. That is, the person has possibly been in contact with somebody who has experienced such a threat or might even have personally been exposed to such an event in his or her life. Threats that are realistic in some parts of the world but are highly unlikely to happen to Finnish or Swedish university students in their normal environment constituted on average 29.0% (range = 21–33%) of all threats. These types of threats usually come to our knowledge through the mass media and include elements such as exotic

animals, war, or natural catastrophes. In contrast, threatening events based on fantasy, fiction, or folklore were rare in student samples, ranging from 4% to 8% of all threats.

In recurrent dreams, however, the reverse seems to be true. Completely realistic threats accounted for only one quarter of all threats (26%), unlikely but possible threats accounted for one third (34%), and fictitious threats were in majority (40%). Recurrent dreams thus seem to include more unrealistic and bizarre threat simulations than normative dreams. Nightmares fall somewhere between normative dreams and recurrent dreams, as more than half of the threats in nightmares were realistic (52%), a quarter realistic but unlikely (25%), and a quarter fantasy or fiction based (23%).

In Studies IV and V, the realism of the threats was not addressed, partially because of cultural differences between the participants and the judges, which complicated the scoring procedure. However, Punamäki (1997) and Punamäki, Ali, Ismahil, and Nuutinen (2005) analyzed the same dream samples and found that the more traumatized the children are, the less bizarre, the more negatively toned, and the more realistic the dream content is. Exposure to real-life threats thus seems to lead to more realistic threat simulations.

Repetitive training and threat simulation rates

As in the learning or maintenance of any skill, repetition is the key to improved performance. Repetitive training is used by many professionals, such as artists, athletes, airline pilots, firefighters, and doctors, to enhance performance in subsequent situations. In many cases, practicing the needed modes of behavior in real situations would be costly or include high risks for physical well-being, so simulation training is used. Furthermore, mental training (i.e., within-mind simulation) has been shown to improve both motor performance (Lejune et al., 1994) and learning of new motor skills (Yaguez et al., 1998). In fact, mental training seems to lead to similar reorganization of the motor cortex as actual training (Pascual-Leone et al., 1995), indicating that the physical structure and function of the brain can be altered by mere mental images of performance. Moreover, learning various behavioral skills is based on procedural memory that operates on automatic

and noncognitive level, and this type of learning is efficient regardless of whether the training episodes are remembered (Schacter, 1996). Thus, even though most dreams and therefore most threat simulations are forgotten, rehearsal of threat avoidance skills in the virtual reality of dreams could lead to an improved performance in real situations.

THREAT SIMULATION RATES.

If repetition is essential in improving performance, then this must also be the case in threat simulation. But how much practice in dealing with threatening situations do we actually get? Based on the data from Studies I, II, and III, we calculated nightly, weekly (7 days), monthly (30 days), and annual (365 days) threat simulation rates (Table 1). Our aim here is to explicate how often threat simulations occur in nontraumatized young adults, on average, and what types of threatening events they frequently deal with in their dreams.

Based on averaging of the results of Studies I, II, and III, the participants recalled 3.57 dreams per week, $SD = 1.6$, range = 2.50–5.35 (Table 1). Of these, 72.1%, $SD = 5.3$, range = 66.4–77.0%, or 2.57 dreams included at least one threatening event, and the average threat simulation frequency per dream was 1.43, $SD = 0.25$, range = 1.2–1.7. Consequently, in the dreams of young adults, threat simulations occur, on average, 5.1 times per week.

However, the rates presented in Table 1 are based only on spontaneously recalled dreams. Indirect evidence suggests that we experience several dreams per night but are usually unable to recall all of them. Therefore, we also estimated nightly, weekly, monthly, and annual threat simulation frequencies based on what is currently known about the frequency of dreaming (Table 1). In this calculation, we took into account the average amount of sleep per night (The National Sleep Foundation, 2002; Kronholm, Härmä, Hublin, Aro, & Partonen, 2006), the average amount of REM sleep per night (Roffwarg, Muzio, & Dement, 1966), and the high correlation between REM sleep and dreaming (mean dream recall rate in REM awakenings is 81.9% according to a review by Nielsen, 2000). We also assumed that we have one dream per each REM period and that threat simulation rates remain constant throughout the night.

In sum, based directly on the reported dreams,

TABLE 1. Mean estimated dreaming and threat repetition rates in young adults				
	Nightly	**Weekly**	**Monthly**	**Annually**
	University student samples[a]			
Spontaneous dream recall rate	0.51	3.57	15.3	186.2
Dreams including at least 1 threatening event	0.37	2.57	11.1	135.1
Threat repetition rate	0.73	5.10	21.9	266.5
	Estimated threat repetition rate in REM dreams[b]			
REM dreaming rate	3.28	22.96	98.4	1,197.2
REM dreams including at least 1 threatening event	2.36	16.55	70.9	863.2
REM dream threat repetition rate	4.69	32.83	140.7	1,712.0

[a]Figures based on results of Studies I, II, and III: On average, 72.1% of dreams include at least 1 threatening event, and on average there are 1.43 threatening events per dream.
[b]Figures based on estimation that on average people have 3.28 REM dreams per night, of which 72.1% include at least 1 threatening event, and on average there are 1.43 threatening events per dream.

the estimate we offer for annual threat simulation frequency is approximately 250. Based on the total amount of REM sleep dreaming, we suggest that the rate is six to seven times higher. And if non-REM dreaming (average recall rate 43%; Nielsen, 2000) is also considered relevant to threat simulation, we end up with more than 1,700 threat simulations per year, according to the average amount of REM and non-REM dreaming. How much threat recognition and avoidance rehearsal would be sufficient to have a survival-enhancing effect on performance in comparable real situations? This issue will be discussed after we take a closer look at how often specific types of threatening situations are simulated in dreams and what kinds of contributions to the study of the TST are offered by related research.

RATES OF SPECIFIC TYPES OF THREAT SIMULATIONS.
The threat simulation frequency estimates and information about the specific quality of threatening events allow us to calculate how often young adults are exposed to particular types of threat simulations in their dreams. Based on the threat simulation frequency estimates (Table 1) and the specific quality of threatening events in Studies I, II, and III, we calculated weekly, monthly, and annual exposure rates for specific types of threatening events. Similarly, based on estimated threat repetition rates in REM dreams, we reckoned the weekly, monthly, and annual fre-

quencies of specific types of threat simulations. The specific threat repetition rates are listed in Table 2.

Rehearsal of threats including aggression (escape situations, nonphysical and direct physical aggression) is the most prominent type of threat practice (41.7% of all threats), averaging to a conservative estimate of 111 annual simulations (based on a threat simulation total of 266 per year). The estimated liberal repetition rate of aggressive threats in REM dreams amounts to 714 annual simulations (based on 1,712 per year). Failures to achieve a set goal are the second most common topic of threat simulations (29.7%), averaging to a conservative estimate of 80 per year and to a liberal estimate of more than 500 REM dream simulations per year. Dealing with accidents is also frequently practiced (20.0%), amounting to more than 300 per year in a liberal estimation. The threats are targeted mostly against the dream self, the self being the target of the threat about 200 (conservative estimate) or 1,200 (liberal estimate) times per year.

Threats endangering the future reproductive success of the self (life-threatening events, situations compromising the physical well-being of the self, and nonphysically severe threats) are slightly more common than minor mishaps (annual conservative estimate 142 vs. 124; annual liberal estimate 914 vs. 800). According to a conservative estimate, relevant reactions to the threats are practiced 250 times per

TABLE 2. Frequencies of exposure to specific threat content in young adults

Threat content category	Mean % of threats (*SD*, range)	University student samples[a]			Estimated threat repetition rate in REM dreams[b]		
		Weekly *n*	Monthly *n*	Annually *n*	Weekly *n*	Monthly *n*	Annually *n*
Nature of threat							
Escapes	9.7 (2.3, 7–11)	0.49	2.12	25.85	3.18	13.65	166.06
Accidents	20.0 (2.6, 17–22)	1.02	4.38	53.30	6.57	28.14	342.40
Failures	29.7 (5.5, 26–36)	1.51	6.5	79.15	9.75	41.79	508.46
Catastrophes	3.0 (0.0, 3)	0.15	0.66	7.80	0.98	4.22	51.36
Disease	4.7 (2.9, 3–8)	0.24	1.03	12.52	1.54	6.61	80.46
Aggression	32.0 (1.7, 31–34)	1.63	7.01	85.28	10.51	45.02	547.84
Target of threat							
Self	73.3 (6.5, 67–80)	3,74	16.05	195.34	24.06	103.13	1,254.90
Significant others	28.0 (1.7, 27–30)	1.43	6.13	74.62	9.19	39.40	479.36
Significant resources	11.7 (1.5, 10-13)	0.60	2.56	31.18	3.84	16.46	200.30
Insignificant people and resources	30.0 (11.8, 20-43)	1.53	6.57	79.95	9.85	42.21	513.60
Severity of threat							
Life-threatening	20.7 (2.3, 18–22)	1.06	4.53	55.17	6.80	29.12	354.38
Physically severe	9.0 (0, 9)	0.46	1.97	23.99	0.42	12.66	154.08
Nonphysically severe	29.7 (17.79, 17–50)	1.51	6.50	79.15	9.75	41.79	508.46
Minor	46.7 (14.5, 32–61)	2.38	10.23	124.46	15.33	65.71	799.50
Participation							
Active	54.0 (7.2, 46–60)	2.75	11.83	143.91	17.73	75.78	924.48
Does not or cannot actively participate	46.0 (7.2, 40-54)	2.35	10.07	122.59	15.10	64.72	787.52
Reaction[c]							
Relevant action	93.5 (0.7, 93–94)	4.77	20.48	249.18	30.70	131.55	1,600.72
Impossible action	1.5 (0.7, 1–2)	0.08	0.33	4.00	0.49	2.11	25.68
Irrelevant action	3.5 (0.7, 3–4)	0.18	0.77	9.33	1.15	4.92	59.92
No reaction, not possible or reported	36.7 (11.4, 24–46)	1.87	8.04	97.81	12.05	51.64	628.30
Resolution							
Threat resolved	25.7 (5.5, 22–32)	1.31	5.63	68.49	8.44	36.16	439.98
Threat realized	43.7 (9.1, 37–54)	2.23	9.57	116.46	14.35	61.49	748.14
Discontinuity	13.0 (6.6, 6–19)	0.66	2.85	34.65	4.27	18.29	222.56
Disrupted	14.3 (5.5, 8–18)	0.73	3.13	38.11	4.69	20.12	244.82
Consequences							
No losses	30.7 (6.0, 25–37)	1.57	6.72	81.82	10.08	43.19	525.58
Minor losses	34.0 (13.7, 22–49)	1.73	7.45	90.61	11.16	47.84	582.08
Severe losses	2.7 (0.6, 2–3)	0.14	0.59	7.20	0.89	3.80	46.22
Not reported	25.3 (6.4, 18–30)	1.29	5.54	67.42	8.31	35.60	433.14
Source of threat							
Realistic threat	63.7 (4.0, 60-68)	3.25	13.95	169.76	20.91	89.63	1,090.54
Unlikely threat	29.0 (6.9, 21–33)	1.48	6.35	77.29	9.52	40.80	496.48
Fictitious threat	6.3 (2.1, 4–8)	0.32	1.38	16.79	2.07	8.86	107.86
Not classifiable	1.7 (2.1, 0-4)	0.09	0.37	4.53	0.56	2.39	29.10

[a]Based on weekly, monthly, and annual threat frequency estimates (Table 1) and percentages of specific content of threatening events in Studies I, II, and III.
[b]Based on weekly, monthly, and annual REM dream threat repetition rate (Table 1) and percentages of specific content of threatening events in Studies I, II, and III.
[c]Type of reaction (relevant, impossible, irrelevant action) calculated only from cases in which a reaction was reported.
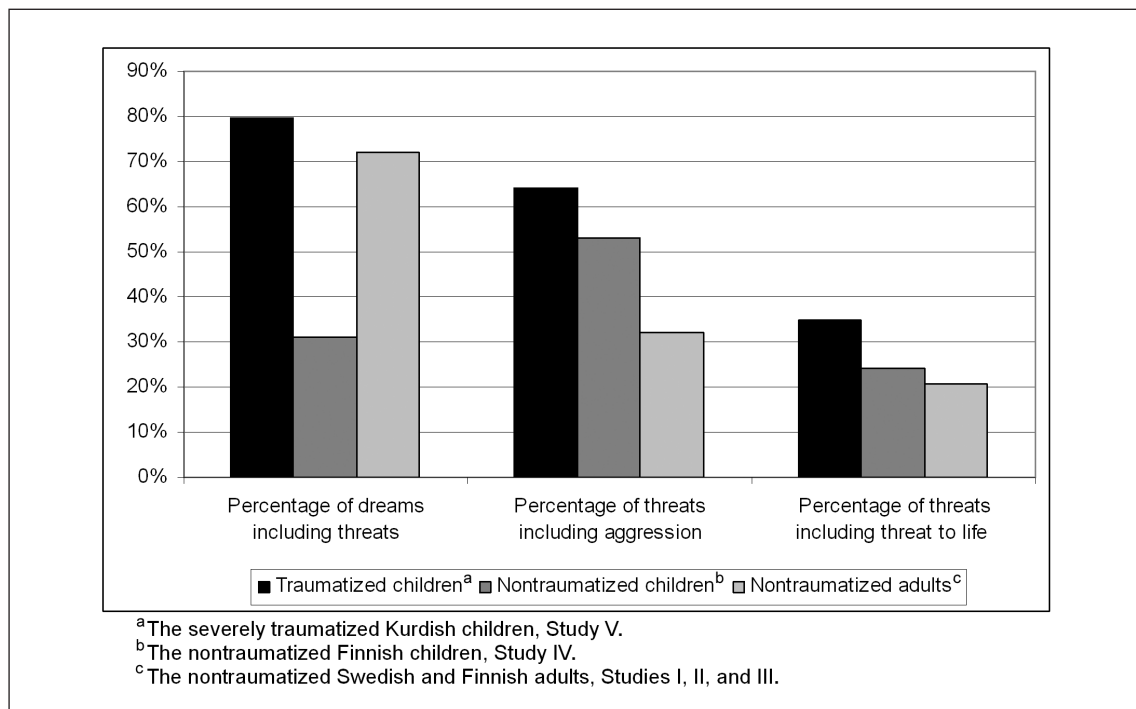
year, and to a liberal estimate, 1,600 times per year. Similarly, realistic and realistic but unlikely threats are simulated about 250 times per year (conservative estimate) or almost 1,600 times per year (liberal estimate). In contrast, only 6 or 7 threats out of 100 are based on fantastic or fictitious sources, and according to our liberal estimate, these unrealistic threats are simulated approximately 100 times per year in nontraumatized participants who have not been exposed to severe threatening events in reality.

To put it briefly, an average young adult faces at least 250 threat simulations per year and probably as many as 1,700 (or more than that if non-REM simulation rates also could be calculated). Thus, threat scenarios are encountered several times per night, although we remember only a small proportion of them. Even though about half of the REM dream threat simulations in nontraumatized participants deal with minor current concerns, the other half (i.e., almost 1,000 simulations) focus on events that would endanger the future reproductive success of the individual if experienced during waking hours.

Furthermore, exposure to real threatening events probably would increase the estimated threat repetition rates and render the threat simulations more severe, as indicated by the data from traumatized children. Because the TST predicts that lifelong exposure to ecologically valid real threatening events increases the frequency and severity of threat simulations to its highest level, traumatized people come closest to an ideal model population for testing the TST. If we rank the dream content studies exploring threatening events in dreams, the proportion of dreams containing threatening events is highest in the sample of severely traumatized Kurdish children, intermediate in nontraumatized adults, and lowest in nontraumatized Finnish children (Revonsuo & Valli, 2000; Valli et al., 2005; Valli, Lenasdotter, et al., 2007; Valli, Strandholm, et al., 2008) (Figure 1), as would be expected by the TST. The severely traumatized children's dreams also contain aggressive encounters and more severe threats more often than the nontraumatized children's or adults' dreams, as predicted by the TST.

To summarize, our results are in harmony with the predictions of the TST that only ecologically valid threat cues in the environment fully activate the threat simulation system and that ontogenetically early and lifelong exposure to real threats leads to more frequent and more intense threat simulations. In contrast, in

a The severely traumatized Kurdish children, Study V.
b The nontraumatized Finnish children, Study IV.
c The nontraumatized Swedish and Finnish adults, Studies I, II, and III.

FIGURE 1. Frequency and severity of threatening events in dreams of traumatized and nontraumatized children and nontraumatized adults

people not exposed to ecologically valid threat cues, the threat simulation system develops and matures more slowly, and consequently the threat simulation dreams remain less frequent and milder, exactly as was predicted by the TST (see Revonsuo, 2000b, Note 5, p. 899). Even in adulthood, nontraumatized people do not reach the threat simulation levels present in traumatized children.[3] If we assume that the frequency and content of threat simulations in the dreams of traumatized children would accurately model those of ancestral humans (who were probably frequently exposed to severe and ecologically valid threats), our ancestors could have been simulating threatening events thousands of times per year in their dreams.

Discussion

Thus far, we have presented only results based on studies that were designed to test the TST directly. In addition, other studies relevant to the TST have also been conducted recently. Now we return to the six propositions of the TST and summarize what kind of new evidence has accumulated for or against the central propositions of the TST.

PROPOSITION 1. DREAM CONSCIOUSNESS IS AN ORGANIZED AND SELECTIVE OFFLINE SIMULATION OF THE REAL PERCEPTUAL WORLD.

As far as we are aware, no recent publications would offer any new information about the organized and selective nature of dream consciousness. Therefore, we will not discuss this proposition further; for a detailed review, see Revonsuo (2000b).

PROPOSITION 2. DREAM CONSCIOUSNESS IS SPECIALIZED IN SIMULATING THREATENING EVENTS.

We have established in the present review that threat simulations frequently occur in dreams, much more frequently than real threatening events are encountered in the waking realm, and that threat simulations are severe, realistic, and efficient rehearsals of real situations for the dream self. However, Revonsuo and Valli (2000) were not the first ones to explore threatening events in dreams. In the early 1960s, Framo, Osterweil, and Boszormenyi-Nagy (1962)[4] studied the incidence of threats in dreams of psychotic patients, guided by the psychoanalytic paradigm. Of the 98 patients enrolled in the study, 92 reported at least one dream in an interview, and all but 5 patients reported a threatening dream. The self was the target

in 60% of dreams including threats, and other people were targets in the remaining 40%. Although psychotic patients are not an ideal sample for studying threatening events in dreams, because nightmares and the reported distress associated with the nightmare experience are related to psychological disturbance (Claridge, Clark, & Davis, 1997; Levin & Fireman, 2002), the findings of Framo et al. (1962) are consistent with results presented in this review.

Malcolm-Smith and Solms (2004) recently studied the effect of threatening real-life events on dream content. They collected 401 most recent dreams (MRDs), one dream per participant, from South African university students, of whom 44.6% reported an exposure to a real life-threatening event. Approximately every fifth MRD (21.2%) included an event threatening the dreamer's physical well-being, of which about one third were life threatening (8.5% of dreams). Successful threat avoidance responses took place in half of the threats (13 of 21.2; 2.7% of all dreams). Malcolm-Smith and Solms interpreted their results that almost 80% of MRDs did not include threats to physical well-being, and that in only half of the threatening situations the dreamer managed to successfully avoid a realistic threat, as falsifying evidence for the predictions of TST. They regarded that the TST is incorrect in predicting that threatening events are more frequently experienced in dreams than in waking life and that exposure to real ecologically valid threat cues fully activates the threat simulation system.

Malcolm-Smith and Solms's (2004) interpretation is open to some criticism. First, they measured the incidence of dream threats and threats encountered in waking life by collecting a single MRD, that is, a report that covered only a few minutes of the participant's dream life; and an autobiographical, lifelong threat incidence history, that is, a report that covered the participant's entire lifetime (median age was 20 years). Thus, the two sample ranges are inherently incomparable. Second, to test the third prediction of TST that only real ecologically valid threat cues in the environment fully activate the threat simulation system, Malcolm-Smith and Solms should have compared systematic dream diaries from participants who were personally exposed to real life-threatening event with diaries from those who were not, to establish whether traumatized people more often simulated threatening events in their

dreams. Consequently, Malcolm-Smith and Solms's study is not a valid test for the predictions of TST that threatening events are overrepresented in dreams during any given time period compared with waking life and that real threat experiences more fully activate the threat simulation system.

Furthermore, if we assume that the South African students in Malcolm-Smith and Solms's (2004) study have 3.3 REM dreams per night (as estimated for Scandinavian university students) and that 12.7% of dreams include a threat to physical well-being and 8.5% of dreams a life-threatening event, the annual frequency estimation of simulated life-threatening and physically dangerous events will add up to, on average, 153 physical threats and 102 life-threatening dream events per year. The annual frequency estimation of simulated threatening events based on Malcolm-Smith and Solms's data is actually much higher than our conservative estimate based on Studies I, II, and III (153 vs. 24 physically dangerous threats and 102 vs. 55 life-threatening events) (Table 2). In fact, the annual threat simulation frequencies for situations endangering the physical well-being of the dreamer calculated from South African data are much closer to our liberal than to our conservative threat simulation estimates (153 vs. 154; Table 2). Moreover, the number is also much higher than the incidence of threatening events in Finnish and Swedish students' real life (Study III) and thus probably also higher than what South African university students are expected to encounter in their waking lives. To summarize, when the perspective of threat repetition rates is taken, Malcolm-Smith and Solms's data seem to support the predictions of the TST.

In addition, Malcolm-Smith and Solms (2004) used a very narrow definition for a threatening event, including only events that pose a threat for the physical well-being of the dream self. In student samples, these threats account for less than one third of all threats. Other types of threats, just as significant for the reproductive success of the self (at least in the EEA), were overlooked (i.e., nonphysically severe threats, such as loss of significant other, social status, or valuable resource). Similarly, all threats may not be targeted directly against the dream self, as defined by Malcolm-Smith and Solms, but might still have a severe effect on the reproductive success of the dream self (e.g., death or injury of a parent, spouse, own child, relative, or close friend). Thus, Malcolm-Smith and Solms might have underestimated the incidence of dream threats because of the sampling method and the content analysis scale used. We recommend the use of the DTS so that results over different studies would be directly comparable.

Indirect evidence of the prominence of threat themes in dreams is offered also by retrospective surveys conducted in different cultures. These surveys reveal that the most typical dream theme around the world is that of the dream self being chased or attacked (Domhoff, 1996; Garfield, 2001; Hartmann, 1984; Nielsen et al., 2003; Robbins & Houshi, 1983; Schredl, Ciric, Götz, & Wittmann, 2004; Zadra & Nielsen, 1997). Other universal dream themes consist mainly of negatively toned events, such as falling or being on the verge of falling; drowning; being lost or trapped; being naked or inappropriately dressed in public; being accidentally injured, ill, or dying; being in a human-made or natural disaster; having trouble taking a test or other poor performance; and having trouble with a car or other transport (Garfield, 2001; Nielsen et al., 2003). These types of findings offer support for the proposition of the TST that dreams are specialized in the simulation of threatening events. Nevertheless, people also universally dream of positive themes, such as sexual experiences, flying through the air, or finding money, but much less frequently than they dream of threats.

PROPOSITION 3. REAL THREAT EXPERIENCES TRIGGER THE ACTIVATION OF THE THREAT SIMULATION SYSTEM, AND THE MATERIAL FOR DREAM SIMULATIONS IS DERIVED FROM EPISODIC LONG-TERM MEMORY.

The threat simulation system functions more actively in traumatized than in nontraumatized people, producing more frequent and more severe threat simulation dreams (Valli et al., 2005, 2006). Real trauma experiences render the subsequent dream content more negative, more realistic, and less bizarre (Punamäki, 1997; Punamäki et al., 2005). Posttraumatic nightmares are systematically reported by both children (Nader, 1996; Nader, Pynoos, Fairbanks, & Frederick, 1990; Pynoos et al., 1987; Pynoos & Nader, 1988; Terr, 1979, 1983) and adults (Barrett, 1996; Hartmann, 1984, 1996; Lavie, 1996; Wilmer, 1996) who have been exposed to life-threatening events.

The TST claims that the triggering and construction of threat simulations are systematically modulated by the negative emotional charge attached to the episodic memory traces in the amygdala-centered "hot" emotional memory systems. The evidence from both dream content and brain imaging studies seems support these predictions, although more direct tests are needed. First, in different participants and across several studies, the same brain areas are found to be activated or deactivated during REM sleep (Maquet, 2000), and the functions performed by these activated or deactivated brain areas during wakefulness correlate with the central dream content features (Schwartz & Maquet, 2002). Second, the amygdaloid complexes and the brain areas receiving abundant amygdalar efferents are highly active during REM sleep and dreaming. This indicates that episodic memories paired with emotional stimuli, especially aversive and threatening stimuli, are activated and processed during dreaming, probably contributing to negatively biased dream content (Hamann, Ely, Grafton, & Kilts, 1999; Maquet, 2000; Schwartz & Maquet, 2002).

Furthermore, participants with relative limbic hyperfunction, scoring high in the Limbic System Checklist (LSCL-33), report more threatening dream content than participants scoring low in LSCL-33, measured by recollection of MRD (Peterson, Henke, & Hayes, 2002). In contrast, participants scoring low in limbic system function report more pleasant dream content. A similar pattern is found in the recurrent dreams reported by these groups.

In sum, real ecologically valid threat cues in the environment truly seem to modulate dream content, and the material for threat simulations is activated from autobiographical long-term memory. However, there might be innate differences in the sensitivity to produce threat simulation dreams, as indicated by Peterson et al's. (2002) limbic hyperfunction study and by the fact that a certain proportion of the population is prone to chronic nightmares without exposure to real threatening events. In fact, an evolutionary hypothesis readily accepts, even demands, innate variation in the population in the sensitivity of the dream production and threat simulation systems, and thus the findings that some people have high dream recall and threat simulation rates whereas other report never having dreamed (Pagel, 2003) are compatible with an evolutionary approach to dreaming.

PROPOSITION 4. THREAT SIMULATIONS ARE BEHAVIORALLY AND PERCEPTUALLY REALISTIC.

As far as the brain mechanisms responsible for the planning and execution of motor commands are concerned, mentally simulated actions are equivalent to real actions (Decety, 1996; Jeannerod, 1995). During REM sleep, motor commands are created at the cortical level, but their execution is inhibited by the brain stem mechanisms producing muscular atonia. The TST predicts that if the muscular atonia during REM sleep is removed, we should be able to observe, in the physical realm, behaviors that the dreamer is simultaneously performing within the dream.

When the brain stem areas responsible for REM sleep atonia have been surgically lesioned in cats, complex behaviors have been observed during REM sleep. REM sleep without muscle tone leads to species-specific behaviors, inducing postures and motions typical for visual exploration, orienting, searching, stalking, running, hunting, predatory aggression, and attacking but also for fear, defense, and rage (Jouvet, 1999; Morrison, 1983). However, we do not know whether these oneiric behaviors are related to dreaming because animals are unable to give introspective reports of their subjective experiences.

Anecdotal evidence concerning whether the movements performed in the dream context are isomorphic to real movements carried out simultaneously in the physical realm is available from REM sleep behavior disorder (RBD) patients. According to Schenck (1993), there is a very close link between the actions performed within the dream experience and the observed enacting behaviors. In the very first RBD study by Schenck, Bundlie, Ettiger, and Mahowald (1986), three of the five studied patients directly linked dreaming with sleep behaviors, and the relationship was inferred by the spouses of the two other patients. Similar cases have also been reported by Boeve et al. (1998), Comella, Nardine, Diedrich, and Stebbins (1998), and Dyken, Lin-Dyken, Seaba, and Yamada (1995). Upon awakening after manifested movements, 87% of the RBD patients explained their actions as defense against attack (Olson, Boeve, & Silber, 2000). Thus, dreamed actions seem to isomorphically correspond to real actions, and dream enactment behaviors seem to be elicited especially by threatening dream content.

Thus far, only a few systematic studies have been

conducted on the dream content of RBD patients. In an interview study, Fantini, Corona, Clerici, and Ferini-Strambi (2005) compared the dream content of RBD patients with the dream content of age- and sex-matched controls, simultaneously accounting for levels of daytime aggressiveness. They found that RBD patients' dream content is characterized by an increase in aggressive contents, without any increase in the levels of daytime aggressiveness. In a comparable sleep laboratory study, Santamaria et al. (2004) found that dreams with violent or highly anxious content were reported only by RBD patients but not by healthy controls. In the same study, they compared dream recall frequency and dream content of RBD patients with the intensity of their nocturnal movements and discovered that dream recall increased with intensity of movements but that severe movements were not always linked to dream recall or to violent or highly anxious dream content. Thus, the relationship between nocturnal enactment behaviors and dream content remains unclear. The currently available evidence suggests that dream content and nocturnal movements are at least sometimes related to each other, although they may also occur independently.

PROPOSITION 5. REPEATED REHEARSAL LEADS TO IMPROVED PERFORMANCE, EVEN IN THE ABSENCE OF RECALL OF THE TRAINING EPISODES.

REM sleep deprivation should have a detrimental effect on performance requiring implicit, but not explicit, memory. In fact, Smith (1995) found in humans that memory for implicit procedural tasks is impaired by REM sleep deprivation, whereas the memory for explicit tasks is not. Interestingly, Martinez-Gonzalez et al. (2004) studied, in rats, the effects of REM deprivation on defensive and coping behaviors elicited by threatening stimuli. They found that REM sleep–deprived rats spent more time on open fields, had decreased freezing time, and exhibited less defensive burying behavior; that is, the species-typical threat avoidance and coping behaviors were widely affected by REM deprivation. Even the administration of amphetamine to compensate for sleep loss did not reverse the harmful effects of REM deprivation, and in some cases the deficits were even exacerbated. Thus, we can hypothesize that REM deprivation (and loss of dreaming) might result in weakened threat avoidance responses in humans.

PROPOSITION 6. ECOLOGICALLY VALID THREAT CUES IN THE ANCESTRAL ENVIRONMENT FULLY ACTIVATED THE THREAT SIMULATION SYSTEM, AND AN ACTIVE THREAT SIMULATION MECHANISM LED TO ENHANCED REPRODUCTIVE SUCCESS.

The threat simulation system develops and matures from early childhood on, as soon as the child is capable of perceiving and recognizing threats in his or her environment, and as soon as the child is able to construct offline dream simulations. In the ancestral environment, real ecologically valid threat cues were ever present and fully activated the threat simulation mechanism. Nightmares (i.e., unpleasant nocturnal simulations) have been reported by children as young as 2 years old and are prominent in 3- to 6-year-olds (Hartmann, 1998). The themes are often about being chased or hurt (Hartmann, 1998). Thus, under ideal ecologically valid conditions (an ancestral environment full of threat cues), the threat simulation system probably was activated by the age of 6.

Early activation of the simulation system is essential if the person is to be able to respond efficiently to environmental demands from the start. Because the mean life expectancy in Pleistocene humans was well below 25 years (Meindl, 1992), the critical period when an active threat simulation system would have yielded survival benefits would have been after the child started to explore the world independently and before his or her offspring were old enough to survive independent of parental care. Thus, in the ancestral environment the greatest benefits offered by an active threat simulation system would have been approximately between ages 6 and 20. Altogether, a person who lived long enough to produce offspring and raise them to the age when they were able to provide for themselves would have been simulating threats in his or her dreams for about 15 years. If our liberal estimation of the annual REM dream threat repetition rate is anywhere close to accurate, 15 years of dreaming amounts to more than 25,000 threat simulations during one's life span. And because the threat simulation system is fully activated only after lifelong exposure to real ecologically valid threat cues, our ancestors probably had much higher threat simulation rates than the nontraumatized young adults on whose dreams our threat simulation frequency estimates are based.

But what types of threatening events did our ancestors have to survive in order to reproduce? In the Pleistocene environment, major causes of death

included infectious diseases, parasites and poor living conditions, exposure to natural elements, risky activities in food acquisition, predation by large carnivores, and aggressive encounters with conspecifics (Dobson, 1992; Landers, 1992; Meindl, 1992). Of these, infections probably were the hardest to avoid, and a small cut or an infected wisdom tooth that allowed microscopic pathogens to enter the bloodstream might have been fatal. In addition, infections were difficult to cure in the absence of medication. Thus, simulating infectious illnesses and how to deal with them would have been futile. As we now know, disease is seldom simulated in dreams, a finding compatible with the cost–benefit analysis of such simulations.

Although threats posed by the natural elements, such as cold, drought, and storms, were probably common in the evolutionary environment, large-scale catastrophes were rare. Thus, simulations of how to deal with ordinary and systematically occurring natural forces would have been valuable rehearsals, but because devastating natural disasters were not stable and recurrent selection pressures in the EEA, simulating such threats would not have been cost effective. Moreover, when faced with a natural catastrophe (e.g., a major volcanic eruption or earthquake), one can do very little to avoid such peril. The DTS reveals that natural and human-made catastrophes are rare in dreams, but accidents (all events in the environment that the dream self has no control over, including natural forces) are quite common. Similarly, Nielsen et al. (2003) found that neither human-made nor natural catastrophes, such as earthquakes, tornadoes, and tidal waves, are among the most prevalent dream themes.

In contrast to the low cost efficiency of simulating illnesses and natural catastrophes, simulating risky activities during hunting and gathering, such as avoiding predators and accidental injuries, would have been highly useful for our ancestors. These types of threatening events were common, and behavioral strategies to avoid such dangers were various and could have been rehearsed in different combinations. Similarly, aggressive encounters in defense of territory or valuable property, both between and within group rivals, probably were regular features in the social environment, and the rehearsal of how to deal with such threats could have led to better reproductive results. When we look at the specific quality of

threat simulations in dreams of modern people, realistic and severe threats simulating accidents, failures, and aggressive encounters are prominent in dreams. These results support the prediction of the TST that threat simulations should realistically portray events that were prominent in the ancestral environment.

Strengths and weaknesses of the TST
The major strength of the TST is that it can account for the systematically observed main dream content features and offer an explanation as to why we dream of current concerns and suffer from posttraumatic nightmares. The TST correctly predicts several dream content features that were not studied in detail before the theory was published, namely that threatening events are more common and severe in dreams than in waking life, that the threats are targeted mainly against the dream self and significant others, that the threat simulations are largely realistic, and that the dream self engages in relevant reactions to avoid the incident, which diminishes the consequences. The prediction of the TST that only personal exposure to ecologically valid threat cues in the environment fully activates the threat simulation mechanism has gained support. Nightmares and recurrent dreams seem to be paradigm cases of extreme threat simulation dreams, as proposed by Revonsuo (2000a). In accordance with the TST, the threat simulations are constructed from episodic memory traces containing the highest negative emotional charge. Furthermore, RBD and other sleep disorders seem to involve an overactivated threat simulation mechanism.

The main weakness of the theory is that there is no direct evidence of the effect of dream rehearsal (or the lack of it) on performance or on survival rates across generations of ancestral humans. The relationship between threat simulation and performance (speed and accuracy) could be investigated in the future by exposing participants to severe threats in a virtual reality environment or immersive video game and studying the dream rehearsal rates and performance in relation to each other.

There are also findings that could have lent stronger support for the TST. Although reactions to the threats are almost always relevant and adequate, not all threat simulation dreams allow the rehearsal of reactions. On average, more than one third of threat

simulations are interrupted by discontinuity or awakening, or for some other reason the dream report lacks a description of a reaction. Recently, we noticed that the interrupted threats are often embedded in an another threatening situation so that the attention of the dreamer is shifted away from the ongoing threatening situation toward another, intervening threat, and then the description of the second threatening situation abruptly ends as the first threat requires more immediate attention (Valli, Suominen, & Revonsuo, 2009). Nevertheless, some threat simulations are incomplete for no obvious reason.

Although the most prominent theme of recurrent dreams and nightmares is that of the dreamer being chased or attacked (Robbins & Houshi, 1983; Zadra, 1996; Zadra & Donderi, 2000) and the most commonly experienced affects are fear and apprehension (Zadra, 1996), in threatening situations the degree of realism is lower in nightmares, and especially in recurrent dreams, than in normative dreams (Desjardins & Zadra, 2004; Zadra et al., 2006). In several respects, recurrent dreams and nightmares seem to be paradigm cases of extreme threat simulation, but many of the threats practiced are based on fantasy or fiction. Nonetheless, rehearsing how to escape from the jaws of a werewolf or a vampire might be just as efficient as running away from a human character or a wild animal. Thus, not all fiction-based threats are necessarily inefficient simulations. The explanation for the high rate of fantasy in nightmares may also be that in the modern world, the input concerning extremely threatening agents comes largely from horror movies and similar fictitious sources, especially for children and adolescents. Thus, creatures from horror movies remain in the threat simulation system with high negative emotional charge, reminiscent of a "traumatic" memory.

As a final word, we wish to point out that all the predictions of the TST are intended to apply fully only to an ideal model population. The theoretically ideal model population consists of a group of individuals that would mimic a population living in an ancestral environment, with early, lifelong exposure to ecologically valid threat cues. As far as we know, such populations are both extremely rare and difficult to reach for research purposes. Therefore, we have to rely on indirect evidence based on the dreams of available participants who are distant from an ideal sample but whose dream content can nevertheless be used to test the theory. In the available populations, we should expect to find statistical patterns of threat content that are in the direction predicted by the TST, but we should not expect to find a perfectly developed and fully activated threat simulation system outside the ideal model populations.

Conclusion

Overall, the available new evidence and the new direct tests of the predictions of the TST yield strong support for the theory. A mass of evidence indicates that threat simulation is a function of dreaming, an evolved psychological adaptation selected for during the evolutionary history of our species. On current evidence, the strengths of the theory seem to outweigh its weaknesses.

1. Revonsuo and Valli (2000) were not the first to categorize threats in dreams, although at the time they devised their scale, they were not aware of the previous work by Framo et al. (1962). Moreover, Framo et al. also named their coding system the Dream Threat Scale.

2. Subjective threats may be rehearsal for a state of heightened threat detection and vigilance in an environment where there are subtle threat cues but no direct evidence of an upcoming threat. In our most recent studies we omitted subjective threats from threat content analysis because they are rare (accounting for only 1–3% of all threats) and very difficult to code (often unscorable), and it seems they cannot be used to test any predictions derived from the theory.

3. Note that if we look at the mean number of threat simulations per dream, not the proportion of dreams including at least one threat, nontraumatized adults have rates equal to those of severely traumatized children. Therefore, many of adults' dream reports include more than one threatening event, whereas children's dreams focus on simulating single and separate events.

4. Interestingly, Framo et al. (1962; presented also in Hall & Van de Castle, 1966) used very similar threat identification criteria as were later introduced by Revonsuo and Valli (2000). The fact that two research groups independently arrived at almost identical definitions of dream threats adds to the validity of the measure.

REFERENCES

Antrobus, J. (1983). REM and NREM sleep reports: Comparison of word frequencies by cognitive classes. *Psychophysiology, 20,* 562–568.

Barrett, D. (Ed.). (1996). *Trauma and dreams.* Cambridge, MA: Harvard University Press.

Boeve, B. F., Silber, M. H., Ferman, T. J., Kokmen, E., Smith, G. E., Ivnik, R. J., et al. (1998). REM sleep behavior disorder and degenerative dementia: An association likely reflecting Lewy body disease. *Neurology, 51*(2), 363–370.

Claridge, G., Clark, K., & Davis, C. (1997). Nightmares, dreams, and schizotypy. *The British Journal of Clinical Psychology: The British Psychological Society, 36,* 377–386.

Comella, C. L., Nardine, T. M., Diedrich, N. J., & Stebbins, G. T. (1998). Sleep-related violence, injury, and REM sleep behavior disorder in Parkinson's disease. *Neurology, 51,* 526–529.

Decety, J. (1996). Do imagined and executed actions share the same neural substrate? *Cognitive Brain Research, 3,* 87–93.

Desjardins, S., & Zadra, A. (2004, June). Threat simulation in nightmares. Paper presented at 18th annual meeting of Association for Professional Sleep Societies. *Sleep,* 27(Suppl.), A61.

Dobson, A. (1992). People and disease. In S. Jones, R. Martin, & D. Pilbeam (Eds.), *The Cambridge encyclopedia of human evolution* (pp. 411–420). New York: Cambridge University Press.

Domhoff, G. W. (1996). *Finding meaning in dreams: A quantitative approach.* New York: Plenum.

Dyken, M. E., Lin-Dyken, D. C., Seaba, P., & Yamada, T. (1995). Violent sleep-related behavior leading to subdural hemorrhage. *Archives of Neurology, 52,* 318–321.

Fantini, M. L., Corona, A., Clerici, S., & Ferini-Strambi, L. (2005). Aggressive dream content without aggressiveness in REM sleep behavior disorder. *Neurology, 65,* 1010–1015.

Foulkes, D. (1985). *Dreaming: A cognitive-psychological analysis.* Hillsdale, NJ: Erlbaum.

Framo, J. L., Osterweil, J., & Boszormenyi-Nagy, I. (1962). A relationship between threat in the manifest content of dreams and active–passive behavior in psychotics. *Journal of Abnormal & Social Psychology, 65,* 41–47.

Garfield, P. (2001). *The universal dream key: The 12 most common dream themes around the world.* New York: HarperCollins.

Hall, C. S., & Domhoff, G. W. (1963). Aggression in dreams. *International Journal of Social Psychiatry, 9,* 259–267.

Hall, C. S., & Van de Castle, R. (1966). *The content analysis of dreams.* New York: Appleton-Century-Crofts.

Hamann, S. B., Ely, T. D., Grafton, S. T., & Kilts, C. D. (1999). Amygdala activity related to enhanced memory for pleasant and aversive stimuli. *Nature Neuroscience, 2*(3), 289–293.

Hartmann, E. (1984). *The nightmare: The psychology and biology of terrifying dreams.* New York: Basic Books.

Hartmann, E. (1996). Outline for a theory on the nature and functions of dreaming. *Dreaming, 6,* 147–170.

Hartmann, E. (1998). *Dreams and nightmares: The new theory on the origin and meaning of dreams.* New York: Plenum.

Hartmann, E. (2000). We do not dream of the 3 R's: Implications for the nature of dreaming mentation. *Dreaming, 10,* 103–110.

Jeannerod, M. (1995). Mental imagery in the motor context. *Neuropsychologia, 33,* 1419–1432.

Jouvet, M. (1999). *The paradox of sleep: The story of dreaming.* Cambridge, MA: MIT Press.

Kronholm, E., Härmä, M., Hublin, C., Aro, A. R., & Partonen, T. (2006). Self-reported sleep duration in Finnish general population. *Journal of Sleep Research, 15,* 276–290.

Landers, J. (1992). Reconstructing ancient populations. In S. Jones, R. Martin, & D. Pilbeam (Eds.), *The Cambridge encyclopedia of human evolution* (pp. 402–405). New York: Cambridge University Press.

Lavie, P. (1996). *The enchanted world of sleep.* New Haven, CT: Yale University Press.

Lejune, M., Decker, C., & Sanchez, X. (1994). Mental rehearsal in table tennis performance. *Perceptual and Motor Skills, 79,* 627–641.

Levin, R., & Fireman, G. (2002). Nightmare prevalence, nightmare distress, and self-reported psychological disturbance. *Sleep, 25,* 205–212.

Malcolm-Smith, S., & Solms, M. (2004). Incidence of threat in dreams: A response to Revonsuo's threat simulation theory. *Dreaming, 14,* 220–229.

Maquet, P. (2000). Functional neuroimaging of normal human sleep by positron emission tomography. *Journal of Sleep Research, 9,* 207–231.

Martinez-Gonzalez, D., Obermeyer, W., Fahy, J. L., Riboh, M., Kalin, N. H., & Benca, R. M. (2004). REM sleep deprivation induces changes in coping responses that are not reversed by amphetamine. *Sleep,* 27(4), 609–617.

Meindl, R. S. (1992). Human populations before agriculture. In S. Jones, R. Martin, & D. Pilbeam (Eds.), *The Cambridge encyclopedia of human evolution* (pp. 406–410). New York: Cambridge University Press.

Morrison, A. R. (1983). A window on the sleeping brain. *Scientific American, 248,* 86–94.

Nader, K. (1996). Children's traumatic dreams. In D. Barrett (Ed.), *Trauma and dreams* (pp. 11–24). Cambridge, MA: Harvard University Press.

Nader, K., Pynoos, P., Fairbanks, L., & Frederick, C. (1990). Children's PTSD reactions one year after a sniper attack at their school. *American Journal of Psychiatry, 147,* 1526–1530.

The National Sleep Foundation. (2002). *2002 "Sleep in America" poll.* Retrieved February 1, 2007, from http://www.sleepfoundation.org/site/c.huIXKjM0IxF/b.2417355/k.143E/2002_Sleep_in_America_Poll.htm

Nielsen, T. A. (2000). A review of mentation in REM and NREM sleep: "Covert" REM sleep as possible reconciliation of two opposing models. *Behavioral and Brain Sciences, 23*(6), 851–866.

Nielsen, T. A., Zadra, A. L., Simard, V., Saucier, S., Stenstrom, P., Smith, C., et al. (2003). The typical dreams of Canadian university students. *Dreaming, 13,* 211–235.

Olson, E. J., Boeve, B. F., & Silber, M. H. (2000). Rapid eye movement sleep behavior disorder: Demographic, clinical and laboratory findings in 93 cases. *Brain, 123,* 331–339.

Pagel, J. F. (2003). Non-dreamers. *Sleep Medicine, 4,* 235–241.

Pascual-Leone, A., Dang, N., Cohen, L., Brasil-Neto, J. P., Cammarota, A., & Hallett, M. (1995). Modulation of muscle responses evoked by transcranial magnetic stimulation during the acquisition of new fine motor skills. *Journal of Neurophysiology, 73*(3), 1037–1045.

Peterson, D. J., Henke, P. G., & Hayes, Z. (2002). Limbic system function and dream content in university students. *Journal of Neuropsychiatry and Clinical Neurosciences, 14,* 283–288.

Punamäki, R.-L. (1997). Determinants and mental health effects of dream recall among children living in traumatic conditions. *Dreaming, 7,* 235–263.

Punamäki, R.-L., Ali, K. J., Ismahil, K. H., & Nuutinen, J. (2005). Trauma, dreaming, and psychological distress among Kurdish children. *Dreaming, 15,* 178–194.

Pynoos, P., Frederick, C., Nader, K., Arroyo, W., Steinberg, A., Eth, S., et al. (1987). Life threat and posttraumatic stress in school-aged children. *Archives of General Psychiatry, 44,* 1057–1063.

Pynoos, P., & Nader, N. (1988). Psychological first aid and treatment approach to children exposed to community violence: Research implications. *Journal of Traumatic Stress, 1,* 4–9.

Rechtschaffen, A., & Buchignani, C. (1992). The visual appearance of dreams. In J. Antrobus & M. Bertini (Eds.), *The neuropsychology of sleep and dreaming* (pp. 143–155). Hillsdale, NJ: Erlbaum.

Revonsuo, A. (2000a). Did ancestral humans dream for their lives? *Behavioral and Brain Sciences, 23*(6), 1063–1082.

Revonsuo, A. (2000b). The reinterpretation of dreams: An evolutionary hypothesis of the function of dreaming. *Behavioral and Brain Sciences, 23*(6), 877–901.

Revonsuo, A. (2006). *Inner presence: Consciousness as a biological phenomenon.* Cambridge, MA: MIT Press.

Revonsuo, A., & Valli, K. (2000). Dreaming and consciousness: Testing the threat simulation theory of the function of dreaming. *Psyche, 6.* Retrieved January 1, 2007, from http://psyche.cs.monash.edu.au/v6/psyche-6-08-revonsuo.html

Rizzolatti, C., & Graighero, L. (2004). The mirror-neuron system. *Annual Review of Neuroscience, 27,* 169–192.

Robbins, P., & Houshi, F. (1983). Some observations on recurrent dreams. *Bulletin of the Menninger Clinic, 47,* 262–265.

Roffwarg, H. P., Muzio, J. N., & Dement, W. C. (1966). Ontogenetic development of the human sleep–dream cycle. *Science, 152,* 604–619.

Santamaria, J., Carrasco, E., Kumru, H., Iranzo, A., Pintor, L., De Pablo, J., et al. (2004). Relation between dream content and movement intensity in REM behavior disorder. *Sleep, 27*(Suppl.), A298.

Schacter, D. L. (1996). *Searching for memory: The brain, the mind, and the past.* New York: Basic Books.

Schenck, C. H. (1993). REM sleep behavior disorder. In M. A. Carskadon (Ed.), *Encyclopedia of sleep and dreaming* (pp. 499–505). New York: Macmillan.

Schenck, C. H., Bundlie, S. R., Ettiger, M. G., & Mahowald, M. W. (1986). Chronic behavioral disorders of human REM sleep: A new category of parasomnia. *Sleep, 9,* 293–308.

Schredl, M., Ciric, P., Götz, S., & Wittmann, L. (2004). Typical dreams: Stability and gender differences. *Journal of Psychology, 138*(6), 485–494.

Schredl, M., & Hofmann, F. (2003). Continuity between waking activities and dream activities. *Consciousness and Cognition, 12,* 298–308.

Schwartz, S., & Maquet, P. (2002). Sleep imaging and the neuropsychological assessment of dreams. *Trends in Cognitive Neuroscience, 6,* 23–30.

Smith, C. (1995). Sleep states and memory processes. *Behavioural Brain Research, 69,* 137–145.

Strauch, I., & Meier, B. (1996). *In search of dreams. Results of experimental dream research.* Albany: State University of New York Press.

Terr, L. (1979). Children of Chowchilla: A study of psychic trauma. *Psychoanalytic Study of the Child, 34,* 547–623.

Terr, L. (1983). Chowchilla revisited: The effects of psychic trauma four years after the school-bus kidnapping. *American Journal of Psychiatry, 140,* 1543–1550.

Tooby, J., & Cosmides, L. (1992). The psychological foundations of culture. In J. H. Barkow, L. Cosmides, & J. Tooby (Eds.), *The adapted mind* (pp. 19–136). New York: Oxford University Press.

Tooby, J., & Cosmides, L. (1995). Mapping the evolved functional organization of mind and brain. In M. S. Gazzaniga (Ed.), *The cognitive neurosciences* (pp. 1185–1197). Cambridge, MA: MIT Press.

Valli, K., Lenasdotter, S., MacGregor, O., & Revonsuo, A. (2007). A test of the threat simulation theory: Replication of results in an independent sample. *Sleep and Hypnosis, 9*(1), 30–46.

Valli, K., Revonsuo, A., Pälkäs, O., Ismail, K. H., Ali, K. J., & Punamäki, R.-L. (2005). The threat simulation theory of the evolutionary function of dreaming: Evidence from dreams of traumatized children. *Consciousness and Cognition, 14,* 188–218.

Valli, K., Revonsuo, A., Pälkäs, O., & Punamäki, R.-L. (2006). The effect of trauma on dream content: A field study of Palestinian children. *Dreaming, 16,* 63–87.

Valli, K., Strandholm, T., Sillanmäki, L., & Revonsuo, A. (2008). Dreams are more negative than real life: Implications for the function of dreaming. *Cognition & Emotion, 22*(5), 833–861.

Valli, K., Suominen, S., & Revonsuo, A. (2009). *The actions of the dream self in threatening situations.* Manuscript in preparation.

Wilmer, H. A. (1996). The healing nightmare: War dreams of Vietnam veterans. In D. Barrett (Ed.), *Trauma and dreams* (pp. 85–99). Cambridge, MA: Harvard University Press.

Yaguez, L., Nagel, D., Hoffman, H., Canavan, A. G., Wist, E., & Homberg, V. (1998). A mental route to motor learning: Improving trajectorial kinematics through imagery training. *Behavioral Brain Research, 90,* 95–106.

Zadra, A. L. (1996). Recurrent dreams and their relation to life events. In D. Barrett (Ed.), *Trauma and dreams* (pp. 231–247). Cambridge, MA: Harvard University Press.

Zadra, A., Desjardins, S., & Marcotte, E. (2006). Evolutionary function of dreams: A test of the threat simulation theory. *Consciousness and Cognition, 15,* 450–463.

Zadra, A. L., & Donderi, D. C. (2000). Nightmares and bad dreams: Their prevalence and relationship to well-being. *Journal of Abnormal Psychology, 109,* 273–281.

Zadra, A. L., & Nielsen, T. A. (1997). Typical dreams: Comparison of 1958 versus 1996 student samples. *Sleep Research, 26,* 280.