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Counterfactual Cognitive Operations in Dreams

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We hypothesized that counterfactual (CF) thought occurs in dreams and that cognitive operations in dreams function to identify a norm violation or novel outcome (recorded in episodic memory) and then to integrate this new content into memory by generating counterfactuals to the violation. In study 1 we compared counterfactual content in 50 dream reports, 50 pain memory reports and 50 pleasant memory reports (equated for word length) and found a significantly greater number of CFs in dream and in pain memory reports relative to pleasant memory reports. In study 2 we used a more liberal method for scoring CF content and analyzed 34 dream reports obtained from elderly individuals engaged in an ongoing study of neuropsychologic, health and religiosity variables. Study 2 also examined neuropsychologic associations to CF content variables. In the elderly sample and with our more liberal scoring procedures we found that norm violations along with counterfactual-like attempts to correct the violations occurred in 97% of reports. In 47% of these cases (roughly half of all reports), attempts to undo the violation obeyed at least one constraint on mutability typically observed in laboratory studies of CF processing. Cognitive operations associated with attempts to undo the norm violation (e.g. transforming focal actors or the most recent causal antecedent of the violation) were significantly correlated with measures of right frontal function. We conclude that dreaming may involve a process of learning from novel outcomes (particularly negative outcomes) by simulating alternative ways of handling these outcomes through counterfactual cognitive processes.

KEY WORDS: dreams; counterfactuals; mental simulations; norm theory; right frontal cortex.

INTRODUCTION

What is the function, if any, of dreaming and how is dreaming consciousness related to waking consciousness? One source of information as to the nature of the dream is the analysis of dream content. If such analyses were to find that dream content was composed, for example, of thoughts and associations centered around "current concerns," then we

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would be justified in exploring the possibility that the function of dreaming had something to do with problem solving around current concerns in waking life. Or if we found that no single type of cognitive activity predominated in dreams and instead that the content of dreams was typically bizarre and random, then dreaming would probably have no important or discernible cognitive function.

Several hypotheses concerning the nature of dream cognition have been proposed. Most of these hypotheses can be read as reflecting the fundamental assumption of *continuity* between dream consciousness and waking consciousness. The continuity assumption states that dream cognition and waking cognition are alike in all fundamental respects except that dream consciousness lacks the reflective or evaluative capacity of waking consciousness. Foulkes (1985), for example, argued that dreams were "credible world analogs" or imaginative simulations of waking life that obeyed fundamental rules of waking cognition but they differed from waking cognition in that they, to a great extent, lacked reflective thought. Rechtschaffen (1978) too, emphasized the single-mindedness quality of the thought that occurs in dreams. He observed that we do not usually entertain two thoughts at once during a dream and we usually naively and unreflectively accept whatever occurs in the dream action as real. Reviewing quantitative studies of dream content across a wide variety of populations, Domhoff (1996) found that dream reports were typically fairly representative of waking thoughts and concerns of the dreamer, except perhaps in such emotion-laden categories as aggression and victimization. These anomalies, however, could also be due to a reduction in reflective thought insofar as it results in a lack of censorship or inhibition. Hartmann (1996) has suggested that dream cognition, like waking cognition, is the product of spreading excitation between semantic nodes in a semantic network. In the case of dreams however the patterns of activation are able to make connections more broadly and more inclusively than does waking cognition-presumably because of the lifting of some waking-associated inhibitory process or the lack of focal attention or censorship. The activation patterns are thought not to be random but to reflect the waking concerns of the dreamer. Finally, Hobson, Pace-Schott, Stickgold, and Kahn (1998) have pointed out that PET studies have repeatedly demonstrated lack of normal activation of dorsolateral prefrontal cortex during REM sleep. The reduced activation of dorsolateral prefrontal cortex may help explain the one consistent difference dream cognition displays relative to waking cognition: lack of reflective or evaluative capacity.

Despite the impressive evidence for overall continuity between dream and waking consciousness (minus reflective capacity) there is equally persuasive evidence for a version of a discontinuity hypothesis—i.e. that dreams represent a fundamentally dissimilar form of cognitive processing when compared to waking consciousness. Several authors, including Freud and Jung, have commented on the occurrence of metaphor and the symbolic nature of dreaming (see for example Lakoff, 1993). These investigators believe that dreams prefer a kind of condensed pictorial language to evaluate meanings, particularly emotional meanings. The content-the settings and happenings- of most people's dreams seems to differ in important ways from their waking lives. Strauch and Meier (1996), for example, reported that most dreams contain non-normal or unfamiliar background settings and that half of the dream reports in their sample contained people who were unknown to the dreamer (strangers). Dreaming or its associate REM sleep, also appears to be associated, like other specialized cognitive functions, with activation of a selective set of neural structures—namely those in and around the basal forebrain. Solms' (1997) exhaustive review of the neuropsychologic literature on loss of dreaming after brain damage convincingly demonstrates

that the connections between mediobasal frontal cortex and the dienchephalic and brainstem sites are "centrally implicated" in the activation and maintenance of dreaming. When any key element in the orbitofrontal-diencephalic/brainstem circuit is lesioned, people report loss of dreaming. In waking life the basal forebrain structures support a range of appetitive behaviors such as curiosity, emotional interest, and other goal-driven behaviors. They are also implicated in learning and memory. Damage to cholinergic circuits of the basal forebrain are implicated in various dementing syndromes including Alzheimer's disease. Thus REM sleep apparently relies on specialized neural machinery to accomplish its goals. To the extent that REM sleep and dreaming is associated with brain activation patterns distinct from those typically activated during waking life, it seems unlikely that complete continuity in cognitive processes between dreaming and waking cognition could be sustained.

We take a middle position in the continuity-discontinuity debate. We suggest that dream consciousness is distinct from waking consciousness in that it utilizes various processing procedures of waking life to compute distinct and unique outputs relative to the products of cognitive systems of waking life. In addition the inputs to these procedures are anomalous when compared to experiences of waking life. The dream takes unusual input, applies a specialized computational procedure to this input and then outputs a distinct product. The "computational procedure" is borrowed from waking life but is altered slightly and thus it is guaranteed to produce a distinct product. McNamara (2000) suggested that one such cognitive procedure in dreaming involved the processing of counterfactual simulations generated in response to an anomaly or negative event in a dream narrative. This idea was summarized in the following hypothesis:

> Cognitive operations in dreams function to identify a norm violation recorded in episodic and autobiographical memory and then to re-instate normality in memory by generating counterfactuals to the violation.

By "reinstating normality" in memory we mean that the information content associated with the norm violation has to be integrated into the semantic networks of episodic and autobiographical memory. If the integration does not occur then the person will perhaps be less able to interpret novel experiences, and thus will be less able to effectively learn from them. Counterfactual processing may be crucial for this type of human learning (see papers in Roese and Olson, 1996; and Byrne, 1997; Roese, 1997). Following a given outcome, particularly negative outcomes, we appraise the significance of the outcome by imagining alternatives or what might have happened if things had gone differently. We then cognitively generate simulations or imaginative scenarios that would allow or promote the alternative outcome. We do this typically by changing or mutating various causal antecedents of the outcome. We next compare the simulations of what might have been to what actually happened in an attempt to restore the unwanted outcome to a more normative routine outcome. To the extent that the comparison process reveals that the counterfactual alternatives seem plausible or possible as compared to what actually happened we feel tension, distress or discomfort and are therefore motivated to try to right the situation or to make sense of the situation. In addition, the contrastive reasoning associated with CF processing may help reveal the ways in which unmet goals might be achieved (Roese, Hur and Pennington, 1999). By engaging in these counterfactual simulations we may more easily learn how to avoid negative outcomes in the future or we learn how to strive more effectively for current unmet goals or desired outcomes. It is as if the counterfactual mechanism activates a motivational state in us such that we strive to "make right" what had gone wrong or "unmet" or what had almost happened.

We suggest that we experience these counterfactually-initiated motivational urges or states along with associated imaginative embodiments of these states, in dreams.

In waking life people will tend to accept the causal implications of a counterfactual if the counterfactual is predicated on alterations of a local or specific nature rather than alterations of more general laws or universals. For example, people will more readily accept or allow themselves to learn from the causal implications of a statement like "If he had run a little faster, he would not have missed the bus" rather than from statements like "If he had been able to fly, he would not have missed the bus." Much of recent research on evaluations of counterfactuals has focused on just what kinds of particular or local factors can be manipulated in "acceptable" counterfactuals. Kahneman and Miller (1986) proposed these general rules of mutability:

1. Exceptions are more mutable than routines.
2. Ideals are less mutable than non-ideals. When asked to change the outcome of a card game or tennis match subjects do so by imagining an improvement of the losing game rather than a deterioration of the winning game.
3. Reliable knowledge is less mutable than unreliable knowledge.
4. Causes are less mutable than effects.
5. The actions of the focal or attended actor in a situation are more mutable than those of a background actor.

In some dreams one can actually see the dreamer repeatedly generate a counterfactual scenario along with attempts to return to normal routines typically associated with the setting or situation depicted in the dream. This repeated generation of counterfactual alternatives to the dream theme or norm violation involves manipulation of these "constraints" and results in a story line or narrative format wherein the dreamer attempts to right or undo the abnormal situation. Take, for example, the following dream of a 25-year-old on the 4th night of a laboratory study of dreaming. The dream report is from Strauch and Meier, (1996) and occurred in the second phase of REM.

"I am in a major American city where there is a baptism of a rocket for a manned moon capsule. People have come from all over the world and expect something sensational to happen. My sister and Suzanne and I have been invited. Everything took place at a harbor and there was some kind of breakdown at the start and the rocket took off ten or maybe a hundred meters beyond the ramp, and then simply fell back down. And we wondered what might have happened if it had toppled over—just plunged into the water or if it had lifted 200 meters into the air and maybe flipped over and then fallen into the water. If it had gone as high as one kilometer it might have fallen into the city and on top of a skyscraper. And then we fantasized whether the rocket might be propelled by the strength of a statesmen—Giscard Estaing was there too—and thrown upwards like that, which would certainly have caused a debacle. And that was what happened. Several people representing all kinds of nations grabbed the rocket at its bottom, lifted it up and tried to propel it skyward. And the rocket did fly for about one hundred meters, twisted and returned toward the water and everything was tried to save it. And they succeeded once more in putting the rocket into orbit. Finally it did fall into the water. All this time we took photographs from all kinds of perspectives."

The dreamer starts by announcing the situation that will be subjected to counterfactual analysis: there was a breakdown in the takeoff pattern of a rocket about to undergo its maiden voyage. The norm violation in this case is the failed take-off. The subject himself then (counterfactually) states: "And we wondered what might have happened if . . ." and

the generation of counterfactual scenarios begins. As the attempt to undo the failed takeoff proceeds, more stringent, more desperate and more bizarre scenarios are tried or at least imagined in order to undo the negative event. This progressive generation of counterfactual alternatives to an extra-normal or unexpected event may be one source of bizarre imagery in dreams (e.g. Giscard D'Estaing propelling the rocket). In his counterfactual solution to the problem of the failed take-off, the dreamer attempted to obey the rules of mutability. He changed, for example, the effects (falling into the water) rather than the causal (mechanical failure) antecedents of the failed take-off. In addition he attempted to change the activity of the "focal actor"—in this case the crowds of people come to witness the take off. They were recruited to try to propel the rocket off the ground! After a number of scenarios are generated the norm violation is "handled" or undone and counterfactual generation ceases: ". . . they succeeded in putting the rocket into orbit." Now we realize this rather sketchy and facile analysis is much too open and ill-defined to be convincing. We mention it only to show the kinds of items a scoring of counterfactual content could target. We will provide more rigorous interpretive standards below.

In summary, we hypothesized that counterfactual thought is characteristic of dreams and that cognitive operations in dreams function to identify a norm violation recorded in episodic memory and then to reinstate normality in memory by generating counterfactuals to the violation. To test this hypothesis we analyzed (in Study 1) counterfactual-related content in dream reports using memory reports as controls. In Study 2 we studied occurrences of norm violations and probable attempts to "correct" them as markers of counterfactual cognition in dream reports. For Study 1 we predicted significantly greater numbers of counterfactuals in dream reports as compared to memory reports with the greatest difference in CF content occurring between dream reports and pleasant memories. We detail predictions for Study 2 below.

STUDY 1

Participants and Procedures

Pain Patients

We used memory reports gathered from 52 pain patients who had participated in another study of neuropsychologic functions in patients with chronic pain. Patients were volunteers recruited consecutively from the Pain Management Group at the Boston Medical Center, Boston, MA. Mean age was 51.2 (SD = 9.9) years. Mean Beck depression inventory score was 13.6 (7.5). Length of pain syndrome ranged from 1 to 50 years with a mean of 9.8 (10.6) years. Respondents rated their general health as average (4.4 (1.5)) on a scale from 1 (very poor health) to 9 (no problems). Severity (as assessed by a combination of patient self-ratings and physician ratings) of the pain syndrome ranged from 4 to 20 with a mean of 8.6 (2.6). Data from two patients was discarded because the length of their memory reports was excessive making it impossible to equate report lengths between memories and dreams. This left an *N* of 50 pain patients producing 2 memories each—a pain memory and a pleasant memory. Patients were asked to recall a pain memory and a pleasant memory. After they wrote down a memory they were asked a series of questions about the memory (data not reported here). Questions were designed to assess encoding and retrieval dynamics

as well as general phenomenology of the memories themselves (another questionnaire—exactly the same in all respects save that the word "physical pain" was changed to "pleasant experience"—was also given to patients). Instructions (for example, the pain memory) were as follows:

Now we would like you to try to remember a personal experience involving *physical pain* that occurred sometime in the past. Choose any memory you like but please describe it in as much detail as you can. Use the back of this sheet to write out your description.

Students

We used 50 randomly selected dream reports (to match the $N = 50$ pain patients) gathered from 300 undergraduate college students who participated in a related study for course credit and whose score on an infrequency scale was less than three—thereby eliminating those (2%) whose response style was unreliable. Mean age of the group was 19 years. Most were female (60%). As part of the study students completed a test battery consisting of a demographic sheet, questions related to sleep and dream behaviors (e.g. dream recall frequency, nightmares, somnambulism, bruxism, night terrors etc.—data not reported here), instructions for reporting a dream. The remainder of the battery was composed of scales that assessed "object relations," including interpersonal dependency and depression. Only counterfactual content data are reported here.

Coding Scheme Counterfactual Thinking (From Roese, 2000)

Mention of a Counterfactual

This variable is the number of mentions of a counterfactual thought in a written passage (the memory or the dream report). A counterfactual is any mention of an alternative to the actual state of affairs. It refers to something that did NOT happen, but could have happened. Coders were instructed to look for grammatical markers such as: "might have," could have, "almost," "should not have," "if only," "if," "what if," "wish that."

Examples:

"If only I were taller, I'd get more dates."
"I should've tried harder."
"I wish that he hadn't done that."
"He almost made it to the track on time."
"He never would have made it without my help."
"It could've been worse."
"You might have tried harder."

Inter-Rater Reliability

A trained research assistant blind to the purpose of the study and the first author independently scored each of the 150 reports for overt counterfactuals. There was perfect 100% agreement for all CFs identified.

Results

Mean word lengths of dream reports (34.3 (29.0)) did not significantly differ from word lengths of memory reports (41.1(52.5); $t < 1$). There were 4 (8%) overt counterfactuals among the pain reports, zero (0%) overt counterfactuals among the pleasant memories and six (12%) among the dream reports (chi square = 259, df = 2, $p = .0001$).

Discussion

As predicted we found significantly greater numbers of counterfactuals in dream reports as compared to memory reports. The difference was especially marked between dream reports and pleasant memories where, consistent with the literature on counterfactual use, no overt counterfactuals were noted. Nevertheless, there were only very few overt counterfactuals in either the dream or memory reports. Thus, while this result is consistent with our overall hypothesis (that dreams result from or reflect CF processing), it certainly does not strongly confirm the hypothesis. In our next study we therefore attempted to use more exact criteria to identify CFs and their processing concomitants. Since counterfactuals typically attempt to mentally "undo" a violation of normal or expected events, we next scored norm violations and attempts to undo them in dreams. We reasoned that if we could identify mental attempts to undo a violation in a dream we would be identifying mental simulations that were initiated to mentally handle a violation, i.e. a counterfactual. Thus, our first prediction for this second study was that at least one norm violation and an associated attempt to undo that violation would occur in each dream report analyzed.

In Study 2 we also intended to examine possible relationships between neuropsychologic variables and CF dream content. Recall that Solms (1997) presented neuropsychologic evidence that demonstrated that the connections between mediobasal frontal cortex and dienchephalic and brainstem sites were crucial for the activation and maintenance of dreaming. Recent evidence (Hooker, et al., 2000) points to the frontal lobes as crucial for CF processing as well. Thus, our second prediction for Study 2 was that we would find a correlation between measures of CF content and measures of frontal lobe performance.

STUDY 2

Participants

Dream reports were gathered from a group of volunteers ($N = 76$) who were serving as participants in study of neuropsychological, health and religiosity measures in community-dwelling middle-aged and elderly persons. Mean age of the participants was 63.5 (12.3). They rated their general health as quite good (7.5 (1.3) on a scale from 1 very poor health to 9 no problems). None of the respondents were depressed according to self-report, or as measured by the depression sub-scale (mean = 4.75 compared to 5.28 in a non-depressed normative sample of persons aged 50–59 reported by Lovibund and Lovibund, 1995-higher score = greater depression) of the Depression, Anxiety and Stress Scale (DASS; Lovibund and Lovibund, 1995). Similarly mean stress scores (DASSS 22.8(7.9)) and mean anxiety scores (DASSA 18.4(5.9)) were within normal limits.

Frontal Tests

Frontal function was assessed with fluency tasks: the Design Fluency task and the verbal alternating Category-letter Fluency task. These are standard, easy to administer frontal measures that index ability to initiate and resist interference (Lezak, 1995; Elfgren and Risberg, 1998). For design fluency, participants are asked to draw as many simple line designs (that do not represent actual objects) as they can within the time allowed (1 minute). The score is the total number of novel designs produced within the minute time limit. For the alternating fluency task participants are instructed to produce as many words as possible for a given letter and then category (in this case animals) and then to alternate between letter and category tasks. If any repetitions of items (perseverations) occur on the second category fluency task they are subtracted from the total score. We used the second category fluency score (after one alternation) as this would have captured the tendency to perseverate. Higher scores indicate less frontal impairment.

Temporal Lobe Activity Test

To examine possible *selective* effects of frontal function we assessed temporal lobe function as well, using a Temporal Lobe signs Inventory (Persinger and Marakec, 1991) that had been developed to work with patients with temporal lobe epilepsy. We used a 30-item version of the inventory where higher scores indicate greater temporal lobe dysfunction. Scores could range between and 30 and 120. Mean TLI score for this sample of persons was 53.0(15.2).

Scoring of Dream Content

Two graduate students were given a 2-hour training on scoring counterfactual-related content. They were instructed to score each dream report in the following way:

First identify descriptions of any norm violation. A norm violation was defined as a surprising, abnormal, or unusual event that seemed to violate the expectations or hopes of the dreamer such that the dreamer or others in the dream attempted to undo or correct the event in question. Rarely more than one norm violation per dream was identified. We randomly selected only one of these to represent the dream. Thus each dream could have only one norm violation for purposes of this analysis. (If there was no identifiable norm violation scorers were to go to step 4 below and continue the scoring).

Next, write down a phrase (preferably taken from the dream) on the data sheet to summarize the violation. Identify the overall emotional tone of the dream, particularly the tone associated with the violation if there is one. Choose from the following list (we chose emotions that we thought would be associated with CFs) the emotion that best captures the emotional tone and record the emotion's associated letter on the data sheet:

regret (something bad happened and didn't have to)
relief (something bad almost happened)
blame (something bad happened and it was someone else's fault)
guilt (dreamer's fault)
surprise (something good happened unexpectedly)

hope (something good may happen)
anxiety (something bad may happen)

If none of the above emotions occur in the dream or in association with the norm violation then write a score of 0 on data sheet for emotion.

Are there identifiable attempts to correct the norm violation? 1 = yes, 0 = no. Are the attempts a counterfactual simulation of an alternative outcome to the violation? 1 = yes, 0 = no.

What is the dreamer modifying (in the norm violation) in order to "reinstate normality"? Choose from among the following mutability variables:

no attempts to correct the situation = 0
focal (vs. secondary) actor mutates/changes/does something differently/acts to correct anomaly (yes = 1; no = 0)
a controllable (vs. non-controllable) factor is manipulated or changed (1 = yes; 0 = no)
the spatial setting is changed (1 = yes; 0 = no)
a previous action (vs. failure to act) is changed
an exceptional event is worked on vs. non-exceptional events (yes = 1; no = 0)
a salient cause (vs. a more subtle cause) is worked on (yes = 1; no = 2)

If an attempt to undo a norm violation was a counterfactual simulation it should a) appear to the scorers as such and they would endorse yes under the appropriate question concerning CF simulations and b) the attempt should obey one or more of the mutability constraints summarized above.

Inter-Rater Reliability

Each dream scorer re-scored 10 reports that had been scored by the other. Inter-rater correlations on these dream reports for all major content categories was greater than .80. When disagreements on content occurred these were settled by discussion.

Results

There were 34 dream reports for an overall group recall rate of (34/76 =) 45%. Virtually all dream reports (97.1%) contained at least one norm violation and 44.1% evidenced associated attempts to "undo the norm violation." All of these attempts to undo the violation were scored as "simulations." The most frequently cited emotions that appeared to be related to the norm violation were anxiety and surprise. With regard to mutability factors: 47.1% contained transformations of the focal actor when generating counterfactual attempts to undo the violation. Similarly, 35.1% manipulated controllable factors, 5.9% manipulated the setting, 2.9% manipulated an action, 5.9% manipulated an exceptional event (vs. a routine event) and 46.7% manipulated an effect (vs. a cause.). Virtually all of the norm violations that triggered an attempt to undo the violation (i.e. counterfactuals) were from the point of view of waking cognition, highly unusual. These were things like "encountering a building covered with bird cages," "being surrounded by bears," "pages of a sermon hopelessly mixed-up," "had a different menu from friends," "tiny scissors," "inability to articulate directions to her house," "trying to escape tornadoes" etc.

Measures of right frontal function (design fluency) but not temporal lobe function were correlated with number of attempts to correct the norm violation (rho = .45, $p = .010$), and simulations (rho = .38, $p = .034$). DASS anxiety scale score was correlated with simulations as well (rho = .39, $p = .01$).

Discussion

We tested the hypothesis that counterfactual thought is characteristic of dreams and that cognitive operations in dreams function to identify a norm violation or novel outcome recorded in autobiographical memory and then to integrate this new content into memory by generating counterfactuals to the violation. In study 1 we compared counterfactual content in 50 dream reports, 50 pain memory reports and 50 pleasant memory reports (equated for word length) and found, as predicted, a significantly greater number of CFs in dream and in pain memory reports relative to pleasant memory reports. In study 2 we used a more liberal method for scoring CF content and analyzed 34 dream reports obtained from elderly individuals engaged in an ongoing study of neuropsychologic, health and religiosity variables. In the elderly sample and with our more liberal scoring procedures we found that norm violations along with counterfactual-like attempts to correct the violations occurred in 97% of reports. In 47% of these cases (roughly half of all reports), attempts to undo the violation obeyed at least one constraint on mutability typically observed in laboratory studies of CF processing. Cognitive operations associated with attempts to undo the norm violation (e.g. transforming focal actors or the most recent causal antecedent of the violation) were significantly correlated with measures of right frontal function. We construe these findings as preliminary support for the hypothesis that counterfactual processing occurs in dreams and we suggest that dreaming may involve a process of learning from novel outcomes (particularly negative outcomes) by simulating alternative ways of handling these outcomes through counterfactual cognitive processes.

Role of the Norm Violation

The fact that the dreamer commonly expressed surprise or anxiousness when confronted with these anomalies suggests some reflective capacity or ability to evaluate anomalies within the dream. The input or triggering stimulus for the CF processing in the dream is an extra-normal violation of a routine or some kind of negative event or affect. The dream prefers novel and out of the ordinary input. The operations performed on this input generally involve alterations in a number of mutable and causal antecedents of the norm violation or the negative affect. We speculate that these counterfactual operations on the norm violation function to help the dreamer learn from or cope with novel and negative situations.

CFs and Dreams in Coping With Trauma

Investigators of both dreaming and counterfactual processing have independently suggested that the object of their studies appear to be vitally important tools for coping with trauma. Several reviews have appeared recently that cover the ways in which dreams help persons cope with emotional and physical trauma (Barrett, 2001; Hartmann, 1996).

People who have undergone a traumatic experience often find themselves dreaming about it repeatedly. For severe cases of trauma (as in some cases of post traumatic stress disorder, for example), however, dreams about the original trauma do not seem to work as a "working through" mechanism. Such dreams are experienced as persistent, unwelcome, intrusive and unhelpful. CFs too can become dysfunctional as when people engage in involuntary and obsessional ruminations about what might have been. In perhaps more typical cases, however, people do, in fact, *functionally* use counterfactuals to help cope with traumatic life events. Davis and Lehman (1995) found counterfactual thoughts to be quite prevalent in parents of babies who had died of sudden infant death syndrome and in families of victims of drunken drivers. The bereaved in Davis and Lehman's studies did not gravitate toward a single, highly mutable antecedent when mentally attempting to undo the tragic outcome but rather, like the "typical" dreamer, they generated a variety of counterfactual possibilities in an effort to come to terms with the tragedy.

Role of Right Frontal Cortex

Given the fact that we used only a paper and pencil test of right frontal function we do not feel comfortable speculating on the role of brain functions in dreaming but some remarks are in order. PET scan studies consistently show activation of limbic and orbitofrontal (OFC, but not dorsolateral) regions of the cortex during REM sleep (Hobson et al., 1998). OFC also appears to regulate emotional and autonomic nervous system functions. The right orbital frontal cortex, particularly Brodmann's posterior medial orbital prefrontal cortical areas 12 and 13 integrates information from hypothalamic and limbic regions. OFC may be a regulatory center for basal forebrain circuits as it has strong connectivity with regions in limbic sites, the hippocampus and the basolateral, central, and extended amygdala regions. Through these connections OFC has access to emotional memory and to ongoing emotional processing. The right OFC also appears to specialize in *negative* affective responses. Davidson (1995) has presented a body of electrophysiologic data that suggests that the left frontal lobe is more likely to mediate positive emotions than the right and the right frontal cortex more typically mediates negative emotions. Davidson's data are consistent with findings from studies of patients with brain injuries. Left frontal damage is far more likely to cause depression than are similar lesions to the right frontal cortex. Conversely lesions in right orbitofrontal cortex are more likely to lead to mania and unconcern than are similar lesions on the left.

Role of Negative Affect and Memory Retrieval

We have seen that both dreams and counterfactuals are preferentially activated by negative affect. We, in fact, found greater numbers of CFs in painful memories and in dreams as compared to pleasant memories. One of the most potent activators of CF processing is negative affect (Roese, 1997). It may be that right frontal activation is associated with negative affect, dreaming and counterfactual processing. In support of this possibility are the recent findings that link right frontal sites with episodic memory retrieval (crucial for both dream and counterfactual processing) and in representations of the "Self." In a review of PET studies on episodic encoding and retrieval processes Wheeler, Stuss and Tulving (1997) conclude that episodic retrieval is associated with an increased blood flow in the

right frontal cortex with no increased blood flow in left frontal cortex; while episodic encoding is associated with the opposite pattern, i.e. increased flow in left-frontal cortex and no increased flow in right frontal cortex. They call this set of findings HERA for hemispheric encoding/retrieval asymmetry. Given the right OFC's involvement in negative affect and in representations of the self it should not be surprising to find that it is also involved in processing negative memories as well. It may be that right frontal sites support counterfactual processing as well given its role in dreams and in negative affect.

Limitations of These Studies

Although results reported herein were in line with our predictions and are consistent with our overall hypothesis (that CF processing occurs in dreams), we wish to emphasize limitations of these studies in hopes that future work can remedy them. First, our scoring procedures for identifying CF-related content are new and used on only 34 available dreams in study 2. These scoring procedures should be used on many more dreams by several different coders before they are adopted as the best method for extracting CF content from dreams. Second, in study 1 we compared dream reports from college students with memory reports obtained from patients with chronic pain. Future work should compare dream vs. memory reports from the same individuals. Finally, because of these limitations and the relatively small number of dream reports we had to work with in study 2, we consider our results as only preliminary support for our overall hypothesis, pending future findings.

In summary, we predicted that an analysis of dream content would yield evidence for counterfactual processing. We confirmed that prediction, thus providing preliminary evidence for a new and distinctive characterization of dream cognition. We analyzed free recall dream reports obtained from elderly individuals and dream reports obtained from younger subjects for evidence of counterfactual simulations to norm violations in memory. We found that norm violations along with counterfactual attempts to correct the violations occurred in a majority of reports. In roughly half of all reports attempts to undo the violation obeyed at least one constraint on mutability typically observed in laboratory studies of CF processing. Cognitive operations associated with attempts to undo the norm violation were significantly correlated with measures of right frontal function. We conclude that dreaming may involve a process of learning from novel outcomes (particularly negative outcomes) by simulating alternative ways of handling these outcomes through counterfactual cognitive processes.

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