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Changes in the Kinesthetic Content of Dreams Following Somatosensory Stimulation of Leg Muscles During REM Sleep

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The notion that dreaming is isolated from sensory activity is challenged by demonstrations that somatosensory stimuli are frequently incorporated into dream content. To further study such effects, four volunteers were administered pressure stimulation to either the left or the right leg during REM sleep and awakened to report their dreams. These dreams were rated and compared to non-stimulated dreams. Stimulated dreams more frequently contained leg sensations and references to the pressure stimulus than did non-stimulated dreams; dreamed leg activity, but not dreamed arm activity, was also rated as more intense. Incorporations of the stimulus were typically simple, direct kinesthetic sensations of pressure or squeezing but were also sometimes embedded in more extended 'problem-solving' sequences. Stimulation also increased bodily bizarreness. The latter included changes in kinesthetic quality of movement, instabilities of posture and the environment, as well as visual-kinesthetic synthesias. Although micro-arousals may be an explanatory factor, the results suggest that somatosensory stimulation influences 'kinesthetic fantasy', a dimension of dreaming associated with both central and peripheral sources of kinesthetic activity.

KEY WORDS: dream content; dreaming; somatosensory stimulation; REM sleep; kinesthetic fantasy; kinesthesis; proprioception.

INTRODUCTION

Although the role of somatosensory activity in dreaming is not fully understood, there is a history of scientific interest in dreaming's sensitivity to internal and external sources of somatosensory stimulation (e.g., Gendlin, 1986; Hunt, 1989; Koulack, 1969; Lerner, 1967; Levitan, 1984; Nielsen, Kuiken & McGregor, 1989; Nielsen, 1991). The effects of some experimentally administered somatosensory stimuli have been described in clinical anecdotes and in self-observational studies

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since the late 18th century (see Freud, 1900, pp. 82-105, for review). Freud himself attributed a particular importance to somatic determinants of dream content (pp. 314-338), describing them as an imagery source similar in kind to the day residue, a '. . . cheap material always ready to hand, which is employed whenever it is needed . . . (p. 335).'

A number of instances recorded by Freud (1900, pp. 84-86) illustrate how both naturally-occurring and experimentally-produced somatosensory events can influence dream content. In one instance, Meier (1758) reported dreaming that some men stretched him out and drove a stake into the earth between two of his toes. He awoke to find that a straw was stuck between these toes. In a second instance, J. Gregory reportedly dreamed that in climbing Mount Etna he found that the ground had become extremely hot. He had been sleeping with his feet on a hot water bottle. In a third instance, Maury (1878) reported a particularly frightening torture dream in which a mask of pitch was pulled off of his face, ripping his skin in the process. This dream occurred after his lips and nose had been intentionally tickled with a feather. Such accounts illustrate how somatosensory stimuli of different kinds can be amplified, displaced and elaborated into apparent sensory determinants of dream content. Moreover, they illustrate how such determinants are also frequently associated with an especially vivid reality quality during the dream experience (Nielsen, 1991).

Post-Freudian experimental dream research has not yet provided a satisfactory description of these somatosensory transformations in dream content nor an account of how they occur. The discovery of REM sleep and its association with processes of motor and sensory inhibition (e.g., Chase & Morales, 1990; Pompeiano, 1976) provided a ready explanation of why sensory stimuli might *not* be represented in dream imagery, but it did not contribute to a satisfactory explanation of the many intriguing instances in which such incorporations do occur. The transformation of external somatosensory stimuli into the sensory determinants of dream content remains a scientific puzzle.

LABORATORY STUDIES OF SENSORY STIMULATION DURING REM SLEEP

A considerable variety of laboratory research has attempted to determine how sensory activity may be incorporated into the dreams of REM sleep (see review in Arkin & Antrobus, 1978). Stimulation administered in most sensory modalities has demonstrated changes in at least some dreams. Such changes have been provoked by olfactory stimulation (Trotter, Dallas, & Verdone, 1988), auditory stimulation (e.g., Berger, 1963; Castaldo & Holzman, 1969; Castaldo & Shevrin, 1970; Hoelscher, Klinger & Barta, 1981; Strauch, 1988), visual stimulation (Dement & Wolpert, 1958; Rechtschaffen & Foulkes, 1965), vestibular stimulation (Woodward, Tauber, Spielman, & Thorpy, 1990), and a variety of somatosensory stimuli. The latter include applications to the skin of water (Dement & Wolpert, 1958; Foulkes & Shepherd, 1972; Foulkes, 1982), of trains of electrical pulses (Koulack, 1969) and of cotton swabs (Foulkes, 1982), passive displacements of trunk (Baldridge,

1966) and limb muscles (Foulkes & Shepherd, 1972; Foulkes, 1982), and thermal stimulation (Baldridge, 1966). Pain stimuli have not been investigated, although we have observed a variety of sensations of discomfort, including mild pain, in pilot trials with the pressure cuff methodology used in the present study (Nielsen, in press). An interesting attempt has also been made to correlate dream content with migraine-induced awakenings (Levitan, 1984). Taste stimuli have not been systematically investigated (but cf. Titchener, 1895).

Some types of somatosensory stimuli are particularly likely to alter dream content. Dement and Wolpert (1958) reported that a spray of water on the skin influenced more dream reports (42%) than either stimulation with tones (9%) or light flashes (23%). Electrical stimulation of the wrist also produced a relatively high percentage of direct or indirect effects (64%), and an even higher percentage (78%) when trials which were accompanied by alpha in the EEG were considered (Koulack, 1969). An early stimulation study (Cubberly, 1922), in which Cubberly himself was the sole subject, reported effects on dream content in 95% of stimulation trials. The effective stimuli in this case were gummed squares of tape which produced constant tensile stimulation of the skin throughout the night. An even earlier experimental manipulation of limb position in sleep (Vold, 1896) produced numerous types of dream content modifications, although descriptions and statistics are not available in English (see summary in Freud, 1900, pp. 101-102). Other interesting somatosensory effects have been reported after subjects' sleep positions were changed by raising or lowering the upper part of the bed (Baldridge, 1966). However, with young participants some of these types of somatosensory stimulation have been found to be much less effective (Foulkes, 1982). In summary, laboratory research suggests that somatosensory stimulation is particularly likely to influence the content of dreams.

The Method of Pressure Cuff Stimulation

The point of departure for the present work was a series of self-observations by the author concerning how naturally-occurring instances of somatic stimulation influence dream content. It was observed in a series of home dreams that when an arm or a leg had inadvertently been left in an uncomfortable or twisted position for an extended period of time, such that sensations of paresthesia (e.g., 'pins and needles') or paralysis were experienced in it upon awakening, there frequently occurred imagery sequences in the preceding dream in which the limb was prominently featured. The affected limb appeared in the dream as either vigorous and forceful or as paralyzed and ineffective.

A review of the physiological literature subsequently revealed that pins and needles sensations are produced by elevated levels of neuronal activity in the afferent muscle pathways consequent upon either brief (up to 5 min) interruptions of the blood supply to that muscle or a sudden re-engagement of the blood supply in an already ischemic limb (Seneviratne & Peiris, 1968). Sensations of ineffectuality are produced when occlusion of the blood supply continues beyond 5 min, whereas feelings of paralysis occur after about 25 min of occlusion (Seneviratne & Peiris, 1968). These findings together led to the development of a methodology for selectively producing kinesthetic hyper- or hypoactivity of the limb muscles during REM sleep, and to tests of the hypothesis that these conditions would produce corresponding dreams of invigorated or ineffective movement.

In preliminary trials with this method, kinesthetic activity in REM sleep was modulated by slowly inflating a blood pressure cuff that was positioned on a participant's limb. Although these trials did not confirm the original hypothesis in all aspects, they did reveal an increased frequency and intensity of movement imagery with cuff pressure (Nielsen, 1985; 1986; Nielsen, Kuiken & Rindlisbacher, 1985). More importantly, they revealed both that the pressure cuff was incorporated into dream content to an unprecedented degree and that it appeared to alter bodily orientation and posture in the dreams. A subsequent study of over 40 experimentally-altered and control dreams reported by two volunteers who slept 15 nights in the laboratory confirmed these impressions; analyses demonstrated a high degree of incorporation of the pressure cuff stimulus (as much as 90% in one participant) as well as alterations of self-participation in the stimulated dreams (Nielsen, 1990). The latter alterations included postural contortions, self-heaviness, self reclining, and balance themes.

Results from these studies with the pressure cuff methodology formed an interpretable pattern: the incorporated stimulus appeared to disturb the perception-like stability of dream experience in ways which are similar to certain disturbances of waking kinesthetic and orientational perception, such as vibration-induced illusions sense-of-effort (Goodwin, McCloskey, & Matthews, 1972) and of movement (Lackner & Levine, 1979). This similarity between disruption of orientational perception in the dream and the waking state suggests that similar organizational systems may regulate orientational stability in the two states. For the waking state, this system determines normal orientational perception to the terrestrial environment, which is structured by such constraints as gravity, light, and the surrounding atmosphere. For the dreaming state, this system determines 'virtual orientation' to an hallucinatory reproduction of the terrestrial world—with a corresponding sensitivity to the multisensory constraints on its structure. In both cases, the hypothesized organizational system appears to govern how either real or apparent sensory modalities are coordinated to produce a unified perceptual (cf. Gibson, 1966) or perception-like experience of the well-oriented self.

The goal of the present study was to replicate the large pressure-induced incorporation effects observed in prior studies, and to provide further information about changes in the perception-like nature of dream experience relevant to the notion of virtual orientation. The study was also designed to address some of the technical problems besetting the previous studies using the pressure cuff method. Specifically, whereas in the earlier studies relatively high levels of cuff pressure were employed, a substantial number of awakenings were also provoked. In the present study, lower maximum pressure levels were employed and fewer awakenings provoked. Also in the early studies, pressure cuffs were applied to only one leg, thus increasing the likelihood that subjects' anticipations of stimulation in that leg might influence dream content; in the present study, pressure cuffs were applied to both legs and stimulations administered in a randomized order. Finally, control awakenings in the previous studies included those trials during which very short periods of cuff inflation had been administered, a procedure which may have minimized apparent differences between stimulus and control dreams. In the present study, control dreams were collected only after intervals of no cuff inflation.

The phenomenology of kinesthetic and orientational transformations and other alterations of dream imagery related to pressure stimulation are only summarized in the present report; these are elaborated more fully in a separate publication (Nielsen, unpublished).

METHODS

Participants

Four normal volunteers (2 male, 2 female) aged 25-45 years slept for a total of 7 nights in the laboratory. All participants were known to the author, had previously demonstrated an active interest in dreams, and were self-reported high dream recallers. Two males and one female were students in undergraduate university programs; the other female was a student in an adult education course on dream use. Participants were not paid for their involvement in the research.

Procedures

Before sleeping in the laboratory, participants were asked to record their dreams at home for several days. They were asked especially to focus on bodily aspects of their dream experiences in order to habituate them to the task of recalling and describing these features of dream content in the laboratory. In the laboratory, participants slept in a quiet, electrically shielded room containing a single hospital bed. An overhead video camera and microphone ensured that they could be monitored at all times. They were also monitored with a standard sleep staging electrode montage: LOC-A2, ROC-A1, C3-A2, C4-A1, O2-A1, and EMG (Rechtschaffen & Kales, 1968).

To deliver somatosensory stimulation, two velcro-strap blood pressure cuffs 6 inches in width were secured above participants' knees on the left and right legs. The cuffs were connected to separate hand-held sphygmomanometer bulbs by 15-foot, 1/4-inch rubber hoses that led from the bedroom into the adjoining control room. The cuffs were also connected by Y-adaptors to AMG Medical pressure gauges. The bulbs and gauges were situated next to the polygraph in the control room so that stimulation could be administered while REM sleep was simultaneously monitored.

Participants were awakened to report their dream experiences from all REM periods except the first. On stimulation trials, inflation of one of the pressure cuffs was initiated according to the following schedule: after at least 5 minutes of REM sleep in the second REM period, 7 minutes in the third REM period, 10 minutes in the fourth REM period, and 15 minutes in the fifth and sixth REM periods. Inflation of the pressure cuff was achieved by slowly pumping (about 6-20 pulses/min) one of the two sphygmomanometer bulbs to a maximum pressure of 120 mmHg for a maximum duration of 12 min. These parameters were based upon experience from previous studies which indicated that higher pressures or faster inflation rates were more likely to produce awakenings. Participants were intentionally awakened by the experimenter earlier than scheduled if a very large body movement occurred late in the stimulation sequence. This was done to minimize the dream forgetting which can accompany such movements. Otherwise, tafter 12 min. the experimenter knocked on the bedroom door, called the participant's name, and entered the bedroom. The pressure cuff was deflated rapidly just prior to awakenings in order to better conceal the stimulation condition. However, on occasion stimulation evoked an awakening and the stimulation could thus not be concealed. On awakening, participants were asked to 1) lie quietly for 30 seconds and remember the preceding dream, 2) report the entire dream, 3) report the dream again while elaborating any details overlooked during the first report, and 4) report any apparent body experiences or awareness of the pressure cuff during the dream. Interviews were recorded on audio tape. Prior to lights out each night, the dream reporting procedures were reviewed with each participant and the pressure cuffs were inflated once to a pressure of 120 mmHg to test their operation and to assure participants of the maximum pressure which would be administered during the stimulation trials.

On control (NOLEG) trials, no inflation of the cuffs was initiated, but participants were awakened according to the same schedule as described for the experimental conditions. The order of administration of the experimental and control conditions was determined by randomly selecting without replacement for each night one of four pre-determined orders: RLNRL, LNRLR, RNLNR and LRNLN, where R = right leg, L = left leg, and N = neither leg. The same experimenter administered stimulation and collected dream reports and was thus not blind to the pre-awakening condition. The pressure cuff methodology was approved by the ethics review committee of the Hôpital du Sacré-Coeur de Montréal, where the research was conducted.

Stimulus Intensity and REM Sleep Measures

Two dichotomous measures of the intensity of the pressure stimulus were calculated based upon the observed distribution of pressure parameters for the stimulus trials: (1) *maximum pressure*: maximum pressure attained during the stimulation trial (1 = less than or equal to 60 mmHg, 2 = greater than 60 mmHg); and (2) *stimulus duration*: total time of inflation of the pressure cuff (1 = less than or equal to 7 min, 2 = greater than 7 min). Mann-Whitney rank sums tests were calculated to determine whether these measures influenced dream content.

Dream Content Scoring

Dream reports were transcribed from cassette tape and all non-content information was removed. The order of the reports was scrambled before they were independently rated by two judges, one of whom was the laboratory experimenter and one of whom was a senior graduate student blind to experimental conditions. The following rating categories were used:

1. BP Cuff. Does the participant refer to the pressure cuff (or similar object) as being on the leg? (y/n) Which leg? (right/left/both/neither)
2. Leg Sensation. Apart from references to the pressure cuff, does the participant refer to any discrete sensations in the foot or leg? (y/n) Which foot or leg? (right/left/both/neither)
3. Leg Activity. Apart from references to the pressure cuff, how intense is activity in the feet or legs? (1 = not at all, 4 = moderate, 7 = extreme)
4. Arm Activity. How intense is activity in the arms or hands? (1 = not at all, 4 = moderate, 7 = extreme)
5. Reality Quality. Does the participant say that any part of the dream seemed real or as if they were awake? (y/n)
6. Gravity Themes. Does the participant refer to a heightened or unusual sense of gravity (e.g., heaviness, floating, flying, spinning, etc.)? (y/n)
7. Bodily Bizarreness. Overall, how unusual or bizarre is the bodily involvement in this dream? (1 = not at all, 4 = moderate, 7 = extreme)
8. Laboratory Incorporation. Does the participant refer to any parts of the sleep laboratory or its equipment, the experimenter or technicians, or the experimental procedures? (y/n)
9. Sexual Activity. To what degree does the dream contain explicitly sexual themes? (1 = not at all, 4 = moderate, 7 = extreme)

RESULTS

Inter-judge reliabilities were assessed with Kappa coefficients. The two judges' scores showed significant inter-judge reliability coefficients for eight of the nine content categories. With the exception of *sexual activity*, coefficients all ranged from .42, to .92, or in the fair-to-strong range according to Fleiss (1981). Ratings for *sexual activity* produced a Kappa of .25 (poor). This category was therefore dropped from further analyses. The most reliably scored variable was the incorporation variable of central interest—*BP cuff*—with a Kappa of .92. The blind judge's scores were used for all subsequent statistical analyses.

Of the 26 awakenings (RLEG = 10, LLEG = 8, NOLEG = 8), 23 (88%) produced dream reports (RLEG = 9, LLEG = 6, NOLEG = 8). Content scores for right leg (RLEG) and left leg (LLEG) stimulation trials were combined into a single group (LEG) for statistical comparisons; differences between LEG and control (NOLEG) trials were evaluated nonparametrically with Mann-Whitney rank sum tests.

There was no difference in the total number of minutes of REM sleep which preceded awakenings in the LEG (12.41 ± 6.4) and NOLEG (12.01 ± 6.0) conditions ($p = .846$). The average duration of all pressure cuff stimulation trials was 6.7 minutes and the average maximum pressure attained during these trials was 59.0

Table 1. Content Ratings for Dreams from Stimulation (LEG) and Control (NOLEG) Trials

	LEG		NOLEG			
Content Category	Mean	*sd*	Mean	*sd*	m-w[c]	*p*
1. BP Cuff[a]	.800	*.41*	.125	*.35*	19.5	*p = .002*
2. Leg Sensation[a]	.867	*.35*	.250	*.46*	23.0	*p = .004*
3. Leg Activity Intensity[b]	3.267	*1.49*	2.000	*1.07*	30.0	*p = .048*
4. Arm Activity Intensity[b]	2.067	*.96*	2.125	*1.64*	52.5	*p = .609*
5. Reality Quality[a]	.733	*.45*	.625	*.52*	53.5	*p = .599*
6. Gravity Themes[b]	2.467	*2.00*	2.000	*1.93*	52.0	*p = .543*
7. Bodily Bizarreness[b]	2.333	*1.80*	1.125	*0.35*	36.5	*p = .074*
8. Lab Incorporation[a]	.800	*.41*	.750	*.46*	66.0	*p = .646*

[a]Dichotomous variable (0/1).
[b]Likert-type variable (1-7).
[c]Mann-Whitney rank sum test.

mmHg. As indicated in Table 1, dream reports following LEG trials were more likely than reports following NOLEG trials to contain explicit references to the blood pressure cuffs (p = .002). Independent of these references, LEG reports also more often included references to leg sensations than did NOLEG reports (p = .004). Furthermore, the latter sensations were rated as more intense in LEG than in the NOLEG reports (p = .048), whereas the intensity of arm activity did not differentiate the two types of report (p = .609). LEG reports were rated as higher (2.3) than NOLEG reports (1.1) on *bodily bizarreness* (p = .074).

However, the two types of reports did not differ on *reality quality, gravity themes*, or *laboratory incorporation*.

There was a correspondence between the stimulated leg (LLEG, RLEG, NOLEG) and the leg appearing in dream content (left, right, neither, both). Specifically, 6/9 (67%) of RLEG, 3/6 (50%) of LLEG, and 6/8 (75%) of NOLEG stimulations were appropriately reflected in dream content as cuff images implicating the right, left, or neither leg, respectively. Further, 5/9 (56%) of RLEG, 2/6 (33%) of LLEG, and 7/8 (88%) of NOLEG stimulations were associated with dream sensations localized in the right, left, or neither leg, respectively. Instances in which the stimulated leg did not correspond with the dreamed-of leg were primarily those in which the pressure cuff incorporation or leg sensation was represented in both legs in the dream. There was only one instance of an incorporation confusion in which a dream featuring the right leg was reported after a LLEG stimulation.

Although scores for most dream content variables were higher for either the stronger pressure (>60 mmHg) or the longer duration (>7 min) stimulation trials than they were for the either the weaker or the shorter trials, only a few of these differences approached statistical significance. *Reality quality* was elevated for both the high *maximum pressure* trials (p = .065) and longer *stimulus duration* trials (p = .065). *Leg activity* was elevated in longer *stimulus duration* trials only (p = .063).

The Nature of Pressure Cuff Stimulation Incorporations

Dream reports from the stimulation trials proved to be remarkable in the frequency, explicitness and creative variety with which they portrayed the pressure cuff stimulation. It was evident that stimulation produced, at one extreme, disguised simple incorporations of somatic sensations and, at the other extreme, multisensory imagery sequences about the stimulation situation. The simple somatic sensations were the most unambiguous incorporation effect; they included feelings of pressure, pulsing, tingling or pulling of the stimulated limb. They were more or less direct incorporations of the sensations that are produced by the pressure cuff during the waking state.

The multisensory imagery sequences produced by the pressure stimulus often involved intentional activities by the dreamer concerning a dreamed stimulation scenario. There were several such sequences exhibiting a type of 'problem-solving' structure and in which the dream ego responded to what were perceived as intrusive and unwanted sensations. In one instance, a dream protagonist found his leg to be paralyzed and unmovable despite his strongest attempts. Leg sensations in this case were intense and uncomfortable. He then dreamed of loosening the velcro strap that secures the cuff to the leg, but the expected feelings of relief which typically follow deflation of the cuff in the waking state did not occur. In a second instance, a participant reported a dream in which bothersome sensations of pressure in her leg prompted her to reach toward the pressure cuff, rip open the velcro, and remove it from her leg. This action did succeed in producing the characteristic sensation of relief. The sensation (and perhaps all of the associated imagery preceding it) was likely evoked by the release of cuff pressure moments prior to awakening. It is also noteworthy that the wish-fulfillment motif of attempting to remove the blood pressure cuff is one which has been observed in many dream reports from pilot stimulation trials and from several different subjects; it has not, however, been observed in any dream from a control trial.

There was also clear evidence in the stimulated dreams of many *bodily bizarreness* themes that had been identified in previous trials (Nielsen, 1986; 1990). These included changes in the general kinesthetic qualities of apparent movement (e.g., increased or decreased sense-of-effort, increased repetitiveness of movement), instabilities of static posture (e.g., leaning, somatic displacement), instabilities of dynamic posture and movement (e.g., loss of balance, flying), instabilities of the environment (e.g., objects floating or falling), and visual-kinesthetic synthesias (e.g., fire, objects exploding). Unexpectedly, these effects were not reflected in the *gravity themes* content category, possibly because the category was too globally defined for the judges to use it effectively to assess these types of themes, or because the control dreams contained more of these effects than expected.

DISCUSSION

Elevated Incorporation Effect

The present results demonstrate that dream content is transformed in systematic and easily identifiable ways by pressure stimulation of the legs. They are consistent with results from our previous studies in which an elevated incorporation effect was demonstrated using more intense levels of the same type of stimulation. Moreover, the proportions of dreams in the present study which contained direct, undisguised references to either the pressure cuff (80%) or to leg sensations (87%) were particularly high when compared with proportions reported for other somatosensory stimuli, such as a water spray stimulus (42%; Wolpert & Dement, 1958) or an electrical stimulus (45%; Koulack, 1969). This remains true even if a more conservative comparison is made between the pressure stimulation incorporations and the total incidence of direct *and* indirect incorporations with electrical stimulation (i.e., 78%; Koulack, 1969).

The relatively lower rates of incorporation reported in previous studies were likely a function of the less intense stimuli that were administered. Dement and Wolpert (1958) used either drops or fine sprays of cold water ejected from a syringe onto the exposed skin of sleeping subjects; awakenings were made one or "a few" minutes after stimulation. The latter durations appear to have been much shorter on average than those used in the present study (i.e., mean duration = 6.7 min). Koulack (1969) used short trains of up to 6 electrical pulses at an intensity which produced muscle twitching of the thumb in the waking state; these stimulations were spaced 2.5 sec apart for a total stimulation duration of 15 seconds. This, too, was much less intense than the stimulation used in the present study. In sum, the elevated incorporation effect in the present study was likely due to the intense nature of the stimulation used.

The effectiveness of pressure stimulation in the present study can be attributed to a number of factors. Higher cuff pressures and longer stimulus durations were associated with only some dream content variables, suggesting that factors other then these were also implicated in the effect. These factors could have been habituation, raising of sensory thresholds, or other physiological and psychological features of REM sleep which interact with gradually intensifying stimulation sequences.

Micro-arousal and the Incorporation of Pressure Stimulation

One possible interpretation of the present incorporation effect is that it originated in micro-arousals or other transient shifts from REM sleep to a wakeful mental state. Presumably, during micro-arousals a blockade of sensory information is briefly lifted and the experimental stimulus is perceived by waking-state perceptual processes. Some investigators have attempted to rule out the influence of micro-arousals by discarding dream reports for which increases in alpha EEG occurred during stimulation (e.g., Koulack, 1969). In fact, we also observed increases in alpha in the EEG power spectrum on some stimulation trials, although these analyses are not reported here.

However, it is not clear that incorporations accompanied by EEG alpha should necessarily be excluded from consideration in interpreting stimulation results. First, it is not clear whether alpha in the EEG is a phenomenon specific either to wakefulness or to sensory incorporations during dreaming. The fact that the alpha occurring normally in REM sleep is insufficient alone to score an arousal state (American Sleep Disorders Association, 1992) supports this point. The additional fact that at least one study (Hoelscher, Klinger & Barta, 1981) has failed to find that alpha in the EEG differentiates REM sleep with auditory incorporations from REM sleep without such incorporations also supports this point. In fact, it is known that subjects are able to produce behavioral responses to stimulus tones that are presented during REM sleep without alpha necessarily appearing in the EEG (Kaartinen, Polo, Sallinen, & Lyytinen, 1992). Thus, alpha in the EEG is not a fail-safe index of waking state activity during dreaming.

It is also not clear to what extent REM sleep should be considered as a state which is totally independent of the waking state, i.e., to what extent REM sleep might not include at least some waking state processes as part of its normal functioning. Research with animals has suggested that REM sleep and alert wakefulness may share at least one sensory subsystem: the orienting response (Morrison, 1983). Some REM sleep abnormalities in humans also demonstrate extreme overlap between sleeping and waking states. These include REM Sleep Behavior Disorder, in which the overt enactment of dreams is typical (e.g., Mahowald & Schenk, 1992), and both hypnagogic hallucinations with paralysis (Hufford, 1982) and lucid dreaming (e.g., Laberge, 1985), in which subjective wakefulness is contemporaneous with hallucinated voices, characters, actions, etcetera. Given this evidence of overlap between REM sleep and wakeful states, one might expect that externally imposed sensory activity could trigger some types of waking state sensory activity without necessarily disrupting the integrity of either REM sleep or dreaming.

Incorporation as Alteration of Kinesthetic Fantasy During Dreaming

An explanation of the present results which is sensitive to the previous considerations is that somatosensory stimulation during REM sleep influences a dreaming process which is also in some sense normally a waking state process. This process may be akin to the 'kinesthetic fantasy' dimension of dreaming which was described by Rorschach (1951) and later elaborated by Lerner (1966, 1967). Kinesthetic fantasy was understood as a type of kinesthesis or bodily awareness during imagery, or '. . . the sense of what it would literally feel like to be in a certain physical position, to take a certain emotional stance, or to engage in a certain activity . . . (Lerner, 1967, p. 88)'. Its function is to maintain the coherence of body image (and thus of the waking ego) by providing opportunities for reintegrating bodily experience into memories which lack an adequate kinesthetic component (Lerner, 1967). Lerner, especially, envisioned a role for kinesthesia during dreaming which was much more fundamental than Freud's 'cheap' somatosensory material, used as needed by the dreamwork processes. It was more like the return to a mode of processing which is rooted in schemata of the sensory-motor stage of development.

The previous conception may be supplemented by the proposition that kinesthetic fantasy has a basis in real kinesthetic sensation. Kinesthetic fantasy may draw upon a subset of kinesthetic circuits which form the basis of orientational perception in the waking state but which remain active during REM sleep. In broad terms, these circuits and the corresponding kinesthetic sensations arising from them, are both central and peripheral in origin (Howard & Templeton, 1966). On the central side, they include the 'neurosignature' or global awareness of bodily-self which is thought to originate in a cortico-thalamo-limbic network (Melzack, 1989) and the 'sense-of-effort' which is thought to arise in corollary discharges to motor commands for specific muscle groups (McCloskey, 1978). On the peripheral side, kinesthetic sensations include the 'position sense' or awareness of the relative orientations of the body and limbs (Jones, 1988; Lackner, 1988; Lackner & Levine, 1979), and the 'muscle sense' or sense of movement, both of which are thought to arise in large part from the spindle receptors of muscles and tendons (Sherrington, 1906; McCloskey, 1978; see also review in Boring, 1942). These overlapping, endogenous sensory sources produce kinesthetic awareness of the self in the waking state and, if the present proposition is justified, contribute to some extent to virtual awareness of the self in kinesthetic fantasy during dreaming.

According to this conception, the bizarre bodily experiences of stimulated dreams are produced by disruption of the patterns of proprioceptive and central information which contribute to kinesthetic fantasy during dreaming. It is noteworthy that perturbation of somatosensory pathways by vibratory stimulation during the waking state also produces bizarre bodily experience, including illusory changes in sense-of-effort (Goodwin, McCloskey & Matthews, 1972) and illusory movements of limbs, the entire body, or the visual environment relative to the self (Lackner & Levine, 1979). The latter effects are similar in many respects to the effects observed in the present dreams, especially the altered sense-of-effort and instabilities of posture and the visual environment. Due to the complexity of these phenomenological similarities, a more complete description of the stimulation dreams in relation to waking-state kinesthetic illusions is presented in a separate communication.

It is somewhat problematic that the *reality quality* of stimulated dreams in the present study was not elevated relative to that in control dreams. That is, there was no evidence that accentuation of bodily experiences would also augment the apparent reality of dreaming as suggested earlier (Nielsen, 1991). Nevertheless, in the present results the proportion of dreams with at least one reality episode was very high in both the stimulation (73%) and control (63%) conditions, confirming previous impressions that control dreams may be influenced by the subtler sensations of the uninflated pressure cuffs.[1]

The fact that the *reality quality* category was associated with long stimulus durations ($r = .49$, $p = .05$) is also consistent with this notion; low-level stimulation from uninflated cuffs administered for a sufficiently long period of time might be expected to influence dream content. Thus, *reality quality* should be assessed under more rigorous control conditions before its relationship to somatosensory activity in dream formation is ruled out.

In conclusion, the present findings extend those from previous studies in demonstrating that somatosensory stimuli can markedly influence the content of dream

[1]The incidences of laboratory incorporations in the dreams of both the stimulation (80%) and control (75%) conditions were also very high relative to those reported in previous studies (e.g., 14% in Hall, 1967 and 19.34% in Dement, Kahn & Roffwarg, 1965), findings also consistent with the possibility that control dreams were unwittingly affected by the uninflated pressure cuffs.

experience. The elevated incorporation effect and the changes in bodily bizarreness observed are two effects consistent with a model of dream formation in which kinesthetic fantasy is based upon peripheral and central sources of real kinesthetic sensation. This model implies that there is a level of organization at which dreaming and waking state perception of the bodily self may be functionally equivalent. At this level, disruptive external stimuli may provoke characteristic changes in the perception-like or virtual structure of dream experience. The similarity of kinesthetic illusions provoked by somatosensory stimulation in the waking state to those produced during dreaming provide further evidence that real and virtual experience derive from a common organizational system with roots in kinesthetic activity.

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